DIGITAL DEVELOPMENT PARTNERSHIP

INNOVATIVE BUSINESS MODELS FOR EXPANDING FIBER-OPTIC NETWORKS AND CLOSING THE ACCESS GAPS

December 2018

WORLD BANK GROUP

WITH SUPPORT FROM:

Microsoft

GSMA

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Foreword

It is my pleasure to present this flagship report on *Innovative Business Models for Expanding Fiber-Optic Networks and Closing the Access Gaps*.

For decades, the World Bank Group has been engaging with client governments around the world to improve digital connectivity and access, supporting policy and regulatory reforms and investments for broadband communications infrastructure. In the process, we have personally witnessed the evolution of mobile services and broadband Internet from being a luxury service to becoming an important part of many people's lives, and a key driver of economic and social development.

By creating new business models, products, and services, digital innovation provides unprecedented opportunities for countries to accelerate growth and skip the traditional stages of development. In fact, the digital economy is expected to account for a quarter of the world's GDP within the next decade.

Digital technologies are also bringing entirely new solutions to complex global challenges like gender inequality, climate risk, and unemployment. In addition, new and emerging technologies, such as artificial intelligence (AI), blockchain, and wireless systems are quickly transforming the way we are delivering services, including to poor and marginalized populations.

Of course, none of this is possible without efficient and reliable connectivity. While the UN Sustainable Development Goals (SDGs) aim to achieve affordable and universal Internet access by 2020, we still have a long way to go. Today, approximately 4 billion people live without Internet access, 90 percent of whom live in developing countries. The urban-rural divide remains a challenge, and digital inclusion of women is lagging in developing countries. Further, the high price of Internet services in many countries continues to undermine broadband adoption, particularly for the poor.

After years of rapid expansion, the next stage of broadband development will be more complex. Extending broadband access to rural areas and poorer and marginalized populations will require new business models, creative thinking, and active cooperation between all relevant stakeholders.

This report was prepared as a joint effort between the World Bank and the International Finance Cooperation (IFC), with support from our Digital Development Partnership (DDP) donors. It provides a comprehensive overview of the various business models that have been adopted globally to support high-quality digital infrastructure, and will serve as a reference tool for policy makers to tailor these solutions to their country's circumstances and needs.

The report reviews 70 case studies from across the world, spanning all segments of the broadband value chain—international connectivity, national backbone, middle mile and last mile connectivity—and proposes a framework to analyze how they can be replicated elsewhere. With wireless technology leading the way in connecting individuals, it also analyzes key trends related to spectrum policy and planning.

I am confident this report can become a powerful tool for countries to fulfill their digital potential and build the foundations for vibrant, inclusive digital economies.

Boutheina Guermazi
Director, Digital Development Department
World Bank

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Abbreviations

ACE	African Coast to Europe
ADSL	Asymmetric digital subscriber line
ALOA	Active Layer Open Access
ANATEL	Brazilian Agency of Telecommunications
ANCOM	National Authority for Management and Regulation in Communications in Romania
APT	Asia Pacific Telecommunity
ARPU	Average revenue per user
ASEAN	Association of Southeast Asian Nations
ATA	Analogue Telephony Adapter
AWF	Asia Wireless Forum
BBS	Burundi Broadband System
BDUK	Broadband Delivery United Kingdom
BTC	Botswana Telecommunications Corporation
CAPEX	Capital expenditure
CBRS	Citizen's Broadband Radio Service
CEPT	European Conference of Postal and Telecommunications Administrations
CPE	Customer premises equipment
CSR	Corporate social responsibility
DBO	Design, build, operate
DFI	Development financial institution
DFON	Domestic Fiber Optic Network
DFS	Dynamic frequency selection
DOCSIS	Data Over Cable Service Interface Specification
DSL	Digital subscriber line
DTH	Direct-to-Home
DTTV	Digital terrestrial television
DWDM	Dense Wavelength Division Multiplexing
EC	European Commission
EIG	Europe India Gateway
ENPV	Economic net present value
EPL	Ethernet Private Line
ERDF	European Regional Development Fund
ESIF	European Structural and Investment Funds
EU	European Union
FCC	Federal Communications Commission
FIZ	Free Internet Zones
FOBN	Fiber Optic Backbone Network
FTTC	Fiber to the Cabinet
FTTH	Fiber to the Home
GDP	Gross domestic product
GPON	Gigabit Passive Optical Network
GSM	Global System for Mobile communications
GSMA	GSM Association is an originally-European trade body that represents the interests of mobile network operators worldwide
HTS	High Throughput Satellite
ICT	Information and communication technology
IDA	International Development Association
IEEE	Institute of Electrical and Electronics Engineers
IMT	International Mobile Telecommunications
IOT	Internet of Things
IOX	Indian Ocean Xchange
IP	Internet Protocol telephony
IPO	Initial public offering
IRU	Indefeasible Right of Use
ISP	Internet service provider
ITU	International Telecommunication Union
JADI	Jeddah-Amman-Damascus-Istanbul
LAA	Licensed-Assisted Access
LBT	Listen before talk
LEO	Low Earth Orbit

LLU	Local Loop Unbundling
LSA	Licensed Shared Access
LTE	Long-Term Evolution
MEO	Medium Earth Orbit
MESA	Motorized Earth Station Antennas
MMW	Millimeter wave
MNO	Mobile Network Operator
MSS	Mobile satellite services
MTN	Mobile Telecommunications Network
MVDDS	Multichannel Video Distribution and Data Service
MVNO	Mobile Virtual Network Operator
NBN	National Broadband Network
NETCO	Network Company, referring to a company that operates passive network infrastructure
NGA	Next Generation Access
NGCP	National Grid Corporation of the Philippine's
NGSO	Non-Geostationary Satellite Orbit
NLOS	Non-Line-of-Sight
NOC	Network operations center
OB	Oman Broadband
OECD	Organisation for Economic Cooperation and Development
OLT	Optical Line Termination
ONT	Optical Network Terminal
OPCO	Operating Company, referring to a company that operates active network infrastructure
OPEX	Operating expenditure
ORN	Olleh Rwanda Networks
PLOA	Passive Layer Open Access
PPP	Public private partnership
PSTN	Public switched telephone network
RAIN	Rural areas broadband Internet network
RFID	Radio Frequency Identification
RFS	Radio Frequency Systems
RLAN	Radio LAN
RSP	Retail service provision
RSPP	Radio Spectrum Policy Program
SAFE CABLE	South Africa Far East cable
SCADA	Supervisory control and data acquisition
SDG	Sustainable Development Goal
SDH	Synchronous digital hierarchy
SEA-ME-WE	South East Asia–Middle East–Western Europe
SLLU	Sub local loop unbundling
SMS	Short Message Service
SNP	Satellite network portal
SOE	State-owned enterprise
SPL	Service Provider Link
SPV	Special purpose vehicle
TENET	Tertiary Education and Research Network of South Africa
TVWS	Television white space
UFB	Ultra-Fast Broadband Program
UHF	Ultra-high frequency
UMTS	Universal Mobile Telecommunications System
UNHCR	United Nations High Commissioner for Refugees
VAS	Value-added service
VC	Venture Capital
VDSL	Very high speed digital subscriber line
VHF	Very high frequency
VPN	Virtual Private Network
VSAT	Very small aperture terminal
VULA	Virtual Unbundled Local Access
WACS	West Africa Cable System
WAP	Wireless Access Point
WIOCC	West Indian Ocean Cable Company
WRAN	Wireless Radio Access Network
WRC	World Radiocommunication Conference

All dollar amounts are U.S. dollars unless otherwise indicated.

Executive Summary

The increasing importance of the Internet—not only for tasks related to information search, storage, and sharing, but also for connecting people and business, domestic and international trade, education, entertainment and social interactions—has led governments around the world to include Internet connectivity in their priority policy agendas and infrastructure plans. Today, access to the Internet is no longer a luxury, but is increasingly considered an essential service, as important as building transportation and utility networks. However, more than four billion people, overwhelmingly in developing countries, still lack Internet access.

For the past decade, policy makers have sought ways to best create an enabling environment to direct national resources and engage the private sector to effectively expand access to the Internet. In doing so, policy makers and regulators face a unique combination of priorities, resources, market structures, and geographies that will affect their national plans. Experience shows that no one-size-fits-all approach exists, but past and current experience can be analyzed for common factors contributing to success or failure to support similar endeavors in the future.

This report reviews and provides guidance on innovative business models and approaches to the deployment of high-speed broadband networks and highlights global trends related to terrestrial spectrum resources that can be leveraged to meet expected future demand and close existing Internet access gaps. It is intended to serve as a reference tool to help policy makers and regulators assess alternatives for infrastructure deployment and adopt decisions tailored to their country's circumstances and needs.

New Business Models for Broadband Infrastructure Deployment

Over the past several years, new business models have expanded Internet access and helped to ensure that technology developments are deployed in areas typically not served through traditional approaches to broadband network buildout. Private actors, governments, and international organizations have sought solutions to the challenges confronted to serve communities that are not receiving the full benefits of broadband because the deployments are not financially viable for the private sector to invest in alone. However, the menu of solutions is not static as technological change continually generates new opportunities and undermines traditional business models.

KEY TRENDS IN SPECTRUM POLICY AND PLANNING

Wireless technologies are the most common means of accessing the Internet. As such, regulators and policy makers need to ensure timely and adequate access to spectrum under transparent, reasonable, and flexible use terms and conditions in order to enable the expansion of broadband access and facilitate the deployment of new and innovative applications.

Multiple levers can be adjusted to encourage effective use of spectrum resources and wireless technologies. To this end, chapter 2.1 focuses on wireless infrastructure and global trends in spectrum policy and planning, touching on key technologies that are enabling and expanding terrestrial wireless broadband Internet access. Although not intended as a detailed review of global spectrum considerations, this focused examination of key spectrum issues is crucial to understanding the trends affecting the wireless technologies that currently represent the most common means of accessing the Internet:

- **Spectrum for 5G and the IoT.** Internet access is moving towards a connected society, with smart applications provided by different Internet of Things (IoT) use cases. The deployment of 5G networks will further enable the move toward ubiquitous connectivity. As such, global stakeholders are working to identify spectrum to enable the next wave of wireless broadband growth, and the next tranche of spectrum for mobile services, intended to enable 5G services and facilitate the IoT. This includes existing spectrum identifications below 6 GHz, and new spectrum ranges under study between 24 GHz and 86 GHz.
- **Alternative Models of Authorizing Spectrum Use.** On the licensing side, policy makers continue to issue spectrum licenses for the deployment of large mobile networks and fixed wireless services. In order to address the growth of spectrum demand, alternative authorization and spectrum-use models continue to evolve, such as the use of unlicensed spectrum, commonly considered for short-range, last-mile connectivity, as well as spectrum trading and spectrum sharing.
- **Spectrum Repurposing and Refarming.** Spectrum usage should be monitored to ensure its continuous efficient use. Spectrum available for older generations of mobile broadband can be refarmed to allow its use by newer technologies. Regulators are also revising existing spectrum arrangements and rules, to repurpose the spectrum used by other services and enable the deployment of mobile broadband. A key example is the low-band spectrum newly available for use following technical improvements to television broadcasting (known as the digital dividend) and which is particularly attractive for expanding wireless network coverage.

These trends will inform ongoing global developments that enable both the identification of new spectrum and additional options for enabling the most efficient and innovative uses of existing spectrum resources. It is critical that regulators consider how these developments are already taking shape, and the potential impacts on national ICT sectors and regulation.

SPECTRUM-SPECIFIC PRINCIPLES

In considering how best to leverage spectrum resources, the following core set of spectrum principles were used to develop the recommendations set out in this report:

- **Leverage flexibility to enable the introduction and growth of emerging technologies, notably 5G and IoT.** Although 5G technology has been in development for several years and IoT devices and services are already in use, both technologies are expected to experience considerable further development and growth. Regulators and policy makers should ensure that their actions not only do not constrain such growth but, rather, facilitate and encourage it, building frameworks that maximize flexibility, enable innovation, minimize administrative burdens, and take into account the characteristics that make these technologies different from earlier innovations.

- **Maximize spectrum access for wireless broadband services.** Demand for wireless broadband services has continued to grow unabated, driven in part by the continuing improvement of wireless technologies and their new applications, and the increasing ability to use spectrum flexibly to serve different needs and users. Policy makers and regulators seeking to expand access to broadband should keep in mind that the most important method by which to increase capacity and improve the user experience is to ensure the availability of appropriate spectrum for use by wireless broadband services. In addition, regulatory frameworks should facilitate flexible use, allowing for pooling and sharing, to maximize use and efficiency, while at the same time promoting competition.

- **Implement strategies specifically targeting unserved and underserved populations.** Reaching areas and populations that continue to lack adequate—or any—broadband access will require new, more flexible approaches and reconsideration of the role of government. The advent of new wireless technologies with different characteristics and use cases than existing mobile networks should prompt actions that can strengthen existing successful approaches and leverage new technologies, business models, and spectrum authorization approaches to provide governments and regulators with a flexible set of tools with which to develop new sector strategies.

TECHNOLOGY TRENDS IMPACTING NEW BUSINESS MODELS

A number of technology trends strongly impact existing business models or inspire new ones:

- Technological advancements continuously challenge the notion of what constitutes a financially nonviable service area. As unit costs of service provision fall, areas previously considered uneconomic may become profitable for service providers with fewer government incentives or less intervention.
- Virtuous circles of bandwidth deployments are created. Higher bandwidth international and core network support cheaper and more compelling end-user service offerings. Higher bandwidth access technologies deployed more broadly in rural/suburban areas lead to greater capacity requirements in international, national core network and middle-mile networks.
- Legacy investment may be sunk, but historic deployments still may stand in the way of innovation. In markets in which incumbents have significant copper access infrastructure, rollout of superfast fiber networks may be delayed.

- Wi-Fi as an established relative low-cost wireless technology has inspired a breed of new innovative business models.
- New low-cost satellite deployments are promising to change the relatively limited performance and expensive broadband services delivered via satellite.
- TV white spaces is a low-cost alternative technology for rural coverage that has gained some momentum in recent years due to standardization by the Institute of Electrical and Electronics Engineers (IEEE), but there are no large-scale deployments yet.
- Drones, balloons, and other nonpermanent structures are being developed for middle/last-mile access; however, most are still in concept development.
- Using open-source software applications and out-of-the box small cell solutions rather than traditional cellular technology are providing opportunity for lowering the network costs for extension networks in rural areas.

These technology trends are further explored in chapter 2.2.

BUSINESS MODELS REVIEWED

This report reviews 70 Internet-related infrastructure projects[1] from around the world spanning the entire broadband infrastructure value chain (see appendix): crossborder, national backbone, middle mile, and last mile. These initiatives were categorized in terms of the primary attributes that may contribute to a deployment's relative success and evaluated according to a variety of success measures, as shown in table 0.1.

Table 0.1: Attributes and Success Measures

Primary attributes	Success measures
• The market structure in which the deployment operates; • The economic context (for example, strength of demand); • The regulatory and policy efficacy, that is, how well policy, regulation and enforcement align with objectives of the deployment; • The degree and nature of infrastructure-sharing; and • The business model, which may include one of a number of approaches.	• Geographic reach of network; • Increase in installed bandwidth; • Volume of national traffic; • Utilization of network relative to legacy network(s) replaced; • Prices of network services relative to legacy prices and affordability; • Investment and unit investment (for example, per fiber kilometer); and • Performance to plan.

Source: TMG/Salience Consulting.

1 The term "project" is used generally throughout the study to indicate cases of infrastructure deployment. It may refer to specific deployment activity, initiatives, or companies engaging in infrastructure deployment.

Findings and Recommendations

In determining a best-fit approach for facilitating infrastructure deployment and leveraging spectrum resources to expand Internet access, the following recommendations were developed, based on the assessment of the 70 projects and relevant spectrum trends.

GENERAL RECOMMENDATIONS

There are five key principles that should form the basis of any policy for promoting broadband deployment:

- **Limited, incremental state intervention.** Governments should intervene only in cases of clear market failure and only to the extent necessary to overcome market failure and complement private investment. In such cases, the government should attempt to achieve its objectives through the least disruptive means possible and should only increase the scale or degree of intervention if the market failure proves persistent.

- **Minimize regulatory failure.** Governments can take many actions to encourage infrastructure deployment that do not require any direct intervention in the market. The state should first consider the result of measures to obviate or minimize *regulatory* failure before it concludes that *market* failure exists.

- **Consensus on a coherent vision, political will, and leadership.** Intervention should be based on clear policy objectives for the sector, be conducted with commitment on the part of leadership, and flow through to regulation consistent with the policy objectives.

- **Governments should take a sober view of what activity it can credibly and reliably carry out.** All states will have limits as to the skill sets, finances, and legal authority, among others, available to actively participate in infrastructure deployment. Governments should assess these capabilities and craft their participation accordingly.

- **Promoting competition.** Government intervention should be directed at increasing competition, through service-based competition when infrastructure competition is not viable. When infrastructure competition is not feasible, governments should generally support open access wholesale arrangements.

SPECTRUM-SPECIFIC RECOMMENDATIONS

The following recommendations, built upon the spectrum principles and trends identified above, are intended to assist stakeholders, particularly regulators and policy makers, when considering new technologies and trends in the context of spectrum policy. Comprehensive approaches to ensuring Internet access for all will benefit from early consideration of principles to make effective and efficient use of spectrum resources:

- **Promoting 5G and IoT deployment:** Implement policies that enable stakeholders to innovate and leverage emerging technologies made possible by advances in wireless broadband technologies, such as 5G and the IoT.

- **Supporting expected demand growth:** Enable and encourage wireless broadband networks to supply adequate capacity and coverage to meet expected demand for broadband connectivity.

- **Expanding wireless broadband to unserved and underserved areas:** Enable and promote the efficient and innovative use of spectrum and business models that can strengthen existing and new approaches and wireless broadband deployments.

INFRASTRUCTURE-SPECIFIC DEPLOYMENT RECOMMENDATIONS

The five general recommendations above are relevant to most interventions the government might consider, regardless of sector or objective. The analysis of the 70 broadband infrastructure projects also suggests some specific recommendations for infrastructure deployment, should the state decide it must intervene in ways that go beyond the use of standard tools of regulation. The following five specific recommendations are based on examination of the primary attributes and success criteria of the 70 Internet-related infrastructure projects examined in this study.

- **Private sector participation**. Government intervention in infrastructure deployment should involve the private sector wherever possible. The advantages of private-sector participation include the sharing of costs and risks, building expertise, and adding critical financial insight and caution that might not exist without it. Even where government intervention is indirect, implemented through policies such as taxation, subsidization, or regulatory obligation, the private sector impacts should be taken into consideration. The projects reviewed include numerous public-private partnerships (PPPs) where the initiative was simply not possible without private capital or benefited significantly in terms of rollout and financial viability from having private entities involved in constructing and running the network.

- **In the presence of state-owned incumbents, structural changes should be considered as part of the overall national plan.** If the state-owned incumbent operator is part of the solution, then it is quite likely that some sort of restructuring of the operator will be necessary to better position the incumbent to meet the broadband deployment goals.

- **Utilities collaboration and enabling reuse.** In many cases, the government has existing or planned utility infrastructure that is not factored in or not recognized when planning national broadband. Public utilities have valuable assets for broadband deployment purposes, such as ducts and poles, buildings, land rights, and even fiber networks that could be leveraged for cost-effective deployment of new broadband infrastructure. Particularly with a limited budget, the more infrastructure that is reused, the more homes and businesses could be covered. Also, telecommunications and other utilities' networks could be deployed via a single civil works initiative.

- **Justification should be based on a realistic business case and socioeconomic cost-benefit analysis** with a view to local, national, and regional trends in the future. Governments should intervene with the objective of mimicking risk-adjusted, externality-adjusted market outcomes. In other words, economic net present value (ENPV) should be calculated and the initiative reconsidered or abandoned if not positive.

- **One business model's failure can lead to another's success.** The history of telecommunications infrastructure is filled with examples of overbuild, asset stranding, underutilization, and failed commercial endeavors of all sorts. While in the short run some projects may be wasteful, nevertheless, in the context of increasing long-term demand, long-lived assets can often be repurposed, commercialized, or otherwise brought back into productive use and facilitate new entry for the benefit of all. This notion applies to much of the infrastructure of utilities, government-owned networks and facilities of bankrupt public service providers. Policy makers can act to reduce the time that assets lay idle by (re)commercializing and reducing barriers to cross-sectoral engagement.

Finally, the business models reviewed provides a rich collection of **lessons for policy makers seeking to intervene to deploy in underserved areas**. This report provides a decision-making tool (see figure 0.1) to identify experiences that may be particularly

relevant for policy makers, given the attributes of the particular infrastructure challenge that they may encounter. In particular, the tool suggests various options for business models—segmentation, financing, management, and revenue generation—that can contribute to successful infrastructure deployment.

The decision-making tool considers seven scenarios, as well as a **"null" scenario** where the state should reconsider any proposed intervention. Where there is no demonstrable market or regulatory failure to address, state action is generally not justified. There are at least three examples in the list of reviewed projects where the state may have been unnecessarily ambitious in its objectives—the second phase of Rwanda NBFON (involving the pursuit of a single wholesale mobile network for 4G), Peru RNDOFO, and South Africa's Broadband InfraCo. In the latter two, state investment was made in national backbones in markets in which the private sector was capable of delivering infrastructure on its own.

Scenario 1 results when there is no inherent market failure, but counterproductive regulation, unnecessary legal constraints, or unduly burdensome financial obligations are imposed by the state. In this scenario, the state's role is simply to eliminate or minimize the self-created cause of infrastructure inadequacy. In most cases, this amounts to improving licensing—simply authorizing the entry of new players, ensuring spectrum is available, and so on.

Scenario 2 is the case of market failure primarily arising from dominance in the market. Here more active regulatory intervention may be required. This may take the form of more active encouragement of private sector competitors, for example, the creation of WIOCC in the crossborder market of East Africa, mandated access of dominant player networks, or more radical solutions such as structural separation.

Before addressing other, more interventionist, roles that the state may play in infrastructure development, the state has to answer the question of whether it is capable of taking on such a role to create missing markets or infrastructure. The vast majority of states are in some way capable of playing a constructive role; however, there are states that have severe institutional issues, or an inability to commit to required policy or provide appropriate leadership. In these cases (**Scenario 3**) dealing with fundamental governance weaknesses must be a central part of any development program implemented.

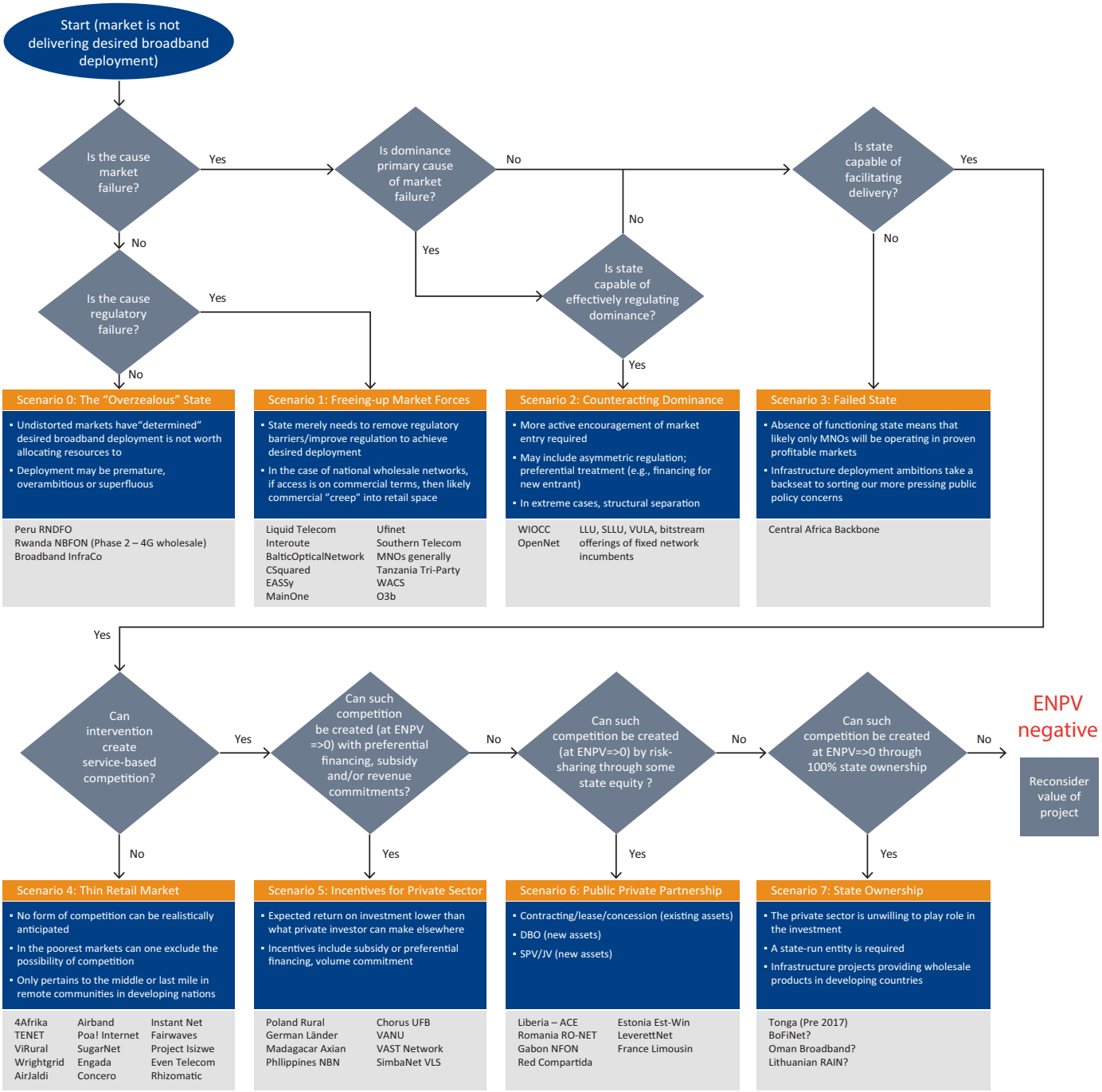
Consistent with the principle of promoting competition, the next question is whether a more active role for the state can be used to create service-based competition. If the market cannot even support service-based competition (**Scenario 4**), then it is probably very thin. These cases tend to be remote local markets. There are a number of innovative technologies and business models discussed in this report that address these particular circumstances.

Scenario 5, 6, and 7 address state action that is progressively more interventionist. In each case, the state's financial commitments should be justified on the basis of a robust cost-benefit analysis. **Scenario 5** is the case where the state can limit its intervention to subsidy, preferential financing, or sales commitments, which offset low or uncertain nonstate revenues. In this case, the state can stay out of the management or ownership of the entity undertaking the project. Ideally, incentives would be competed for through an appropriately structured tender process.

Scenario 6 represents those cases in which the subsidy required to interest the private sector in taking up the opportunity is too high for the state to afford. In these cases, the state must take on more of the project risk in order to attract the private sector.

Scenario 7 is limited to those instances in which the state cannot build a sufficiently attractive offer of financial incentives and risk-sharing to interest the private sector. This would be a very small set of cases indeed. Of all the projects reviewed in this report, arguably, only one may have met this criterion.

Figure 0.1: Decision-Tree for Scenarios for the State's Role in Infrastructure Deployment



Source: TMG/Salience Consulting.

1. Introduction

1.1. Background

Today, the Internet is an essential part of our everyday lives—allowing us to be informed, transact business, and generally communicate. However, too many people still lack access to the Internet. This report seeks to offer guidance on which mechanisms can be used to expand Internet connectivity. These mechanisms include innovative business models and approaches to the deployment of high-speed broadband networks, as well as new trends related to terrestrial spectrum resources that can meet expected future demand and address existing Internet access gaps. This report is intended to serve as a reference tool to help policy makers and regulators assess alternatives for infrastructure deployment and adopt decisions tailored to their country's circumstances and needs.

In the past ten years, we have witnessed a massive increase in the need to deploy and upgrade telecommunications infrastructure to meet the explosive demand for broadband Internet access. This high demand arises from the powerful virtuous circle of proliferation of increasingly data-consumptive devices and applications in everyday life, increasing relevance of content, readiness of the consumer market and falling service, device, and application prices.

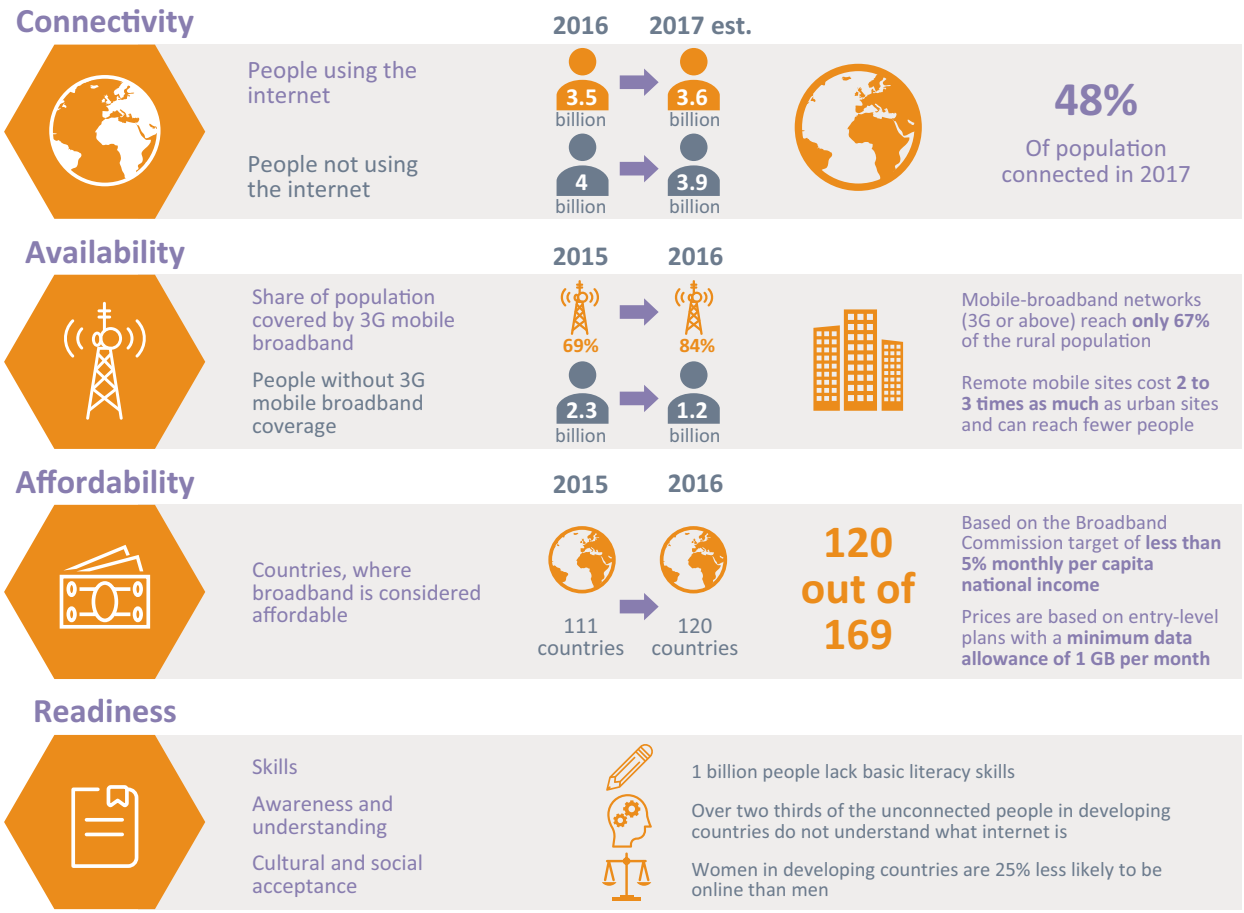
Closing the Digital Divide

Most of the broadband telecommunications investment in the past decade was focused on larger cities with relatively high-density households and businesses. The effect of this investment was to widen the digital divide between cities and nonurban regions, especially rural areas, which are becoming relatively more isolated. This regional, profit-driven pattern occurred on a global scale, with an increasing divergence between more-developed and less-developed nations.

According to a World Economic Forum (2017) report, more than half of the globe's population—about four billion people—are not yet connected to the Internet. As shown in figure 1.1, there are multiple dimensions to the digital divide, including lack of access and availability, lack of affordability, and lack of skills and awareness.

In the current decade, we have seen better coordinated initiatives to bridge this divide. Most governments around the world are now addressing the issue of connectivity to rural and other underserved areas in their priority policy agendas. Successful policies find constructive ways to join the public and private sectors, such as public-private initiatives (PPP); rely on regional initiatives for support (such as European funds for broadband development); and/or exploit new technologies (such as low-cost wireless solutions).

Figure 1.1: Closing the Digital Divide

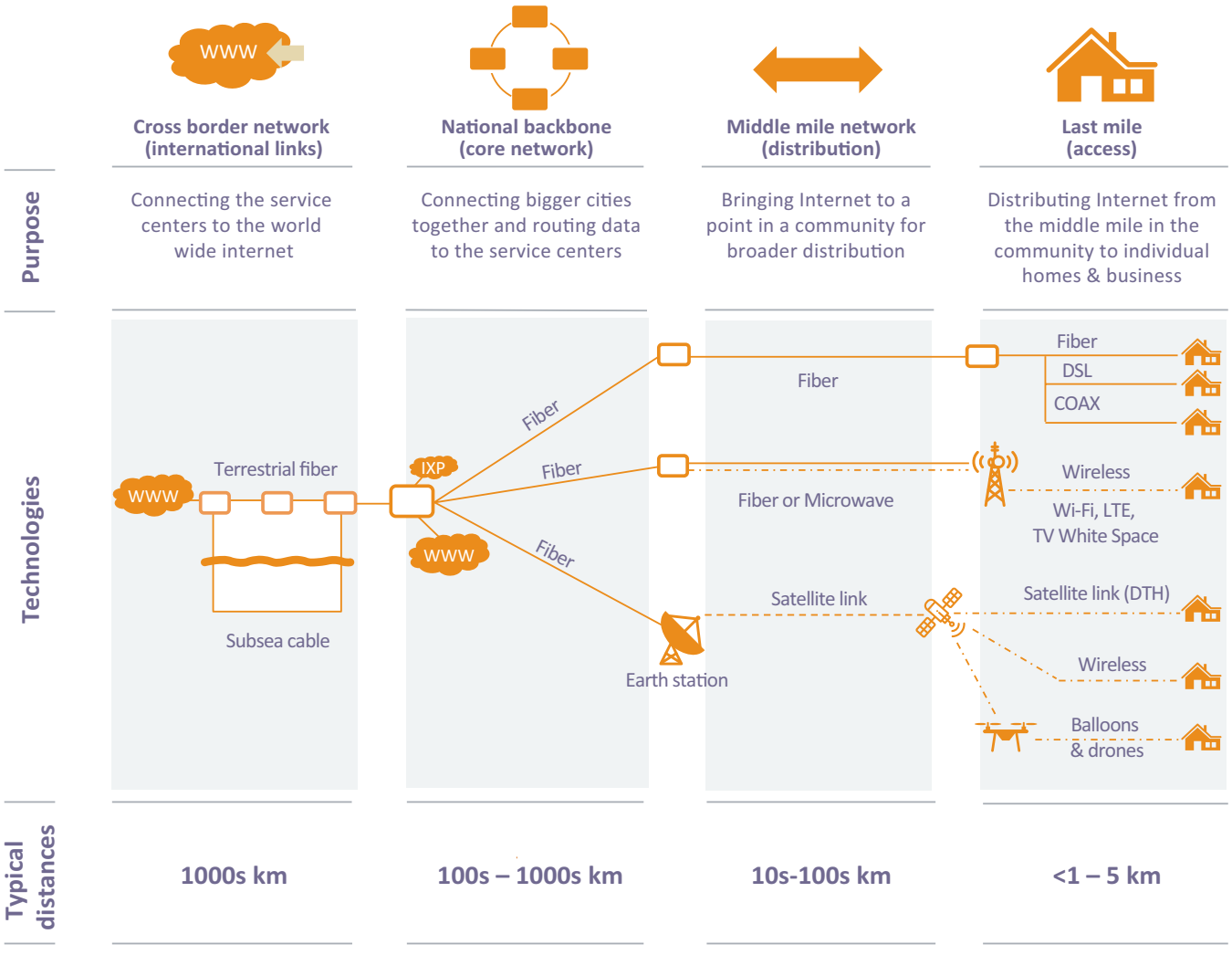


Source: Adapted from infographic in Facebook 2016, with recent ITU data.

Upgrading the Broadband Infrastructure Value Chain

The pressure to expand broadband infrastructure impacts the entire value chain from local access to international connectivity. The benefits of consistent synergistic development can be viewed within the context of the markets of a single region or nation, as well as within the context of uniting fragmented markets across disparate national or regional chains. Each link in the infrastructure chain, shown in figure 1.2, poses its own challenges in the process of installation, expansion, and upgrade. To meet these challenges, service providers, investors, and governments must use a variety of technical, commercial, and business solutions. These challenges and some of the solutions found to address them are discussed in chapter 4 (crossborder and national backbone networks) and chapter 5 (middle-mile networks and last mile).

Figure 1.2: Broadband Infrastructure Value Chain, Technologies, and Reach



Source: TMG/Salience Consulting.

Sustainable Development, Climate Change, and Gender Equality

Digital infrastructure is a key foundational element which facilitates a country's path to the digital economy, as a key enabler for development. A digital infrastructure lowers costs and enables scalable access to services essential for development, thus accelerating the ability to achieve the Sustainable Development Goals (SDGs) by 2030. Unfortunately, digitization is still nascent in most emerging markets and the World Bank Group recognizes that unless swift action is taken by the development community, the development gap is expected to increase multiple times for countries that do not embrace the digital economy.

Digital infrastructure is also essential for tackling global public issues such as climate change and gender disparity. Climate change is considered to be the defining challenge of our generation. Affordable and reliable digital infrastructure enables the implementation of practical and effective climate change adaptation and mitigation measures. In some cases, such as Vanuatu, a small Pacific island state that is highly prone to natural disasters, climate change adaptation plans explicitly note the need for backbone infrastructure investments to facilitate early warning and to coordinate response efforts to natural disasters. The methodology for greenhouse gas (GHG) accounting in the ICT sector is still in its infancy. However, a report by the Global e-Sustainability Initiative (GeSI), an industry group, estimated that greater use of digital technologies could help reduce annual global emissions of carbon dioxide by 20 percent by 2030 (GeSI 2015).

Finally, given that women constitute half of the world's population, it is important to identify at the policy, legislative, and regulatory level, which actions should be taken to ensure equitable access to the Internet and digital technologies. Anecdotal evidence suggests that there is a significant gender gap in the use of digital technologies, particularly in remote areas where women may only be able to access the Internet at public access facilities.[2] The potential to expand opportunities for women across domains is enormous, including access to education, health services, social security transfers, and greater Internet-enabled economic opportunities (for example, online work, digital commerce). Concerted efforts need to be taken to raise awareness, increase institutional capacity and collect actionable gender-disaggregated data in order to fully incorporate gender into national broadband plans, with a particular focus on innovative solutions for last-mile access.

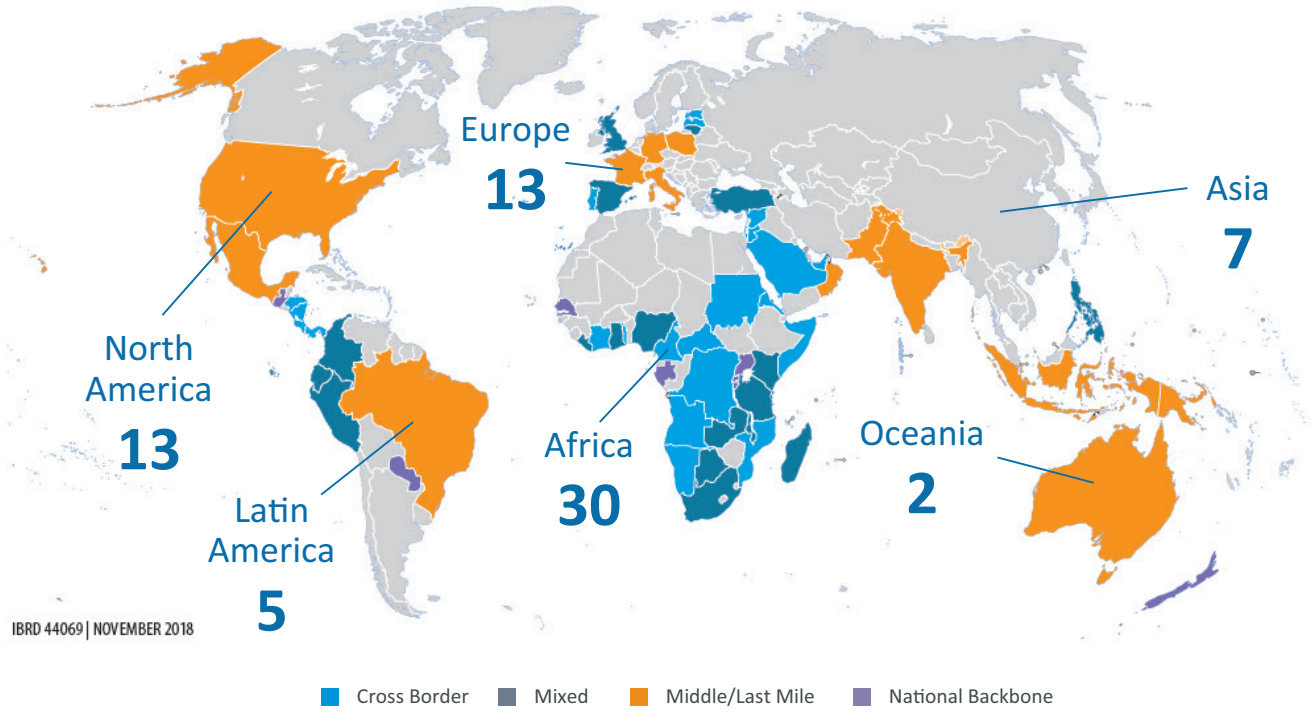
2 Engendering ICT Toolkit, World Bank, 2018.

1.2. The Methodology

This report examines how a wide array of business models have been used in infrastructure deployments around the world to deal with situations where infrastructure deployment proved to be problematic in recent years. The report examines 70 projects from around the world at different links in the infrastructure value chain (see figure 1.3 and appendix).

Figure 1.3: Projects Examined in the Study

70 individual cases were analyzed



12 Cross Border

- Baltic Optical Network
- Central African Backbone
- EASSy
- Interoute
- JADI
- Liberia ACE
- Liquid Telecom
- MainOne
- Tonga Submarine Cable
- Ufinet
- WACS
- WIOCC

13 National Backbone

- BoFiNet
- Broadband InfraCo
- Burundi Backbone System
- Gabon NFON
- Gambia ECOWAN
- Lithuania RAIN
- Madagascar Telma
- Peru RNDFO
- Philippines NBN
- Rwandan NBFON
- Senegal (ADIE)
- SimbaNET VLS
- Southern Telecom

45 Middle/Last Mile Projects

- 4Afrika
- AirJaldi
- Aquila
- Australia NBN
- Avanti ECO
- Burlington Telecom
- Chorus
- Concero
- CSquared
- CyPhy Works
- EE - Helikite
- Endaga
- EstWin
- Even Telecom
- Fairwaves
- France - Limousin
- Germany Länder
- iProvo
- Isizwe
- Kalo
- LeoSAT
- LeverettNet
- Microsoft Airband
- O3b
- Oman
- OneWeb
- OpenNet
- Poa! Internet
- Poland Rural
- Project Loon
- Q.NBN Qatar
- Red Compartida
- Rhizomatica
- RO-NET
- RUNE
- Sugarnet
- Tanzania Tri-party
- TENET
- TOP-IX
- VANU
- VAST
- Village Telco
- ViRural
- Vodafone IN
- Wrightgrid

Assessing these models requires being aware of all of the major attributes that may contribute to a deployment's relative success. In the appendix to this report, projects are summarized based on the following attributes:

- **Market structure** in which the deployment operates;
- **Economic context** (for example, strength of demand);
- **Regulatory and policy efficacy**, that is, how well policy, regulation, and enforcement align with objectives of the deployment;
- Degree and nature of **infrastructure sharing**; and
- **Business model**, which may include one of a number of approaches as discussed in detail in Chapter 3.

The appendix also lists measures of success, depending on the link in the value chain. For crossborder and national networks we examined:

1. **Geographic reach of network,** that is, kilometers achieved and cities/villages connected in absolute terms and relative terms reflecting market size;
2. **Increase in installed bandwidth**, including volume of national traffic;
3. **Utilization of network** relative to legacy network(s) replaced;
4. **Prices of network** services relative to legacy prices;
5. **Investment and unit investment** for example, per fiber kilometer; and
6. **Performance to plan/viability,** that is, success in respect to the specific project plan.

For middle and last-mile projects, we examined:

1. **Cost acceptance/affordability of the solution.** This criterion identifies and benchmarks the cost per premise passed/connected to find examples where the cost is minimized, therefore making the solution more scalable and affordable;
2. **Take-up.** This criterion looks at the actual takeup of the backhaul (middle mile) or end-user connections (last mile). Although related to affordability, takeup is the ultimate criterion for deeming a project successful;
3. **Community involvement.** In many cases, the citizens in the underserved/unserved areas are aware of the benefits of the Internet for the community and the financial obstacles to enabling access. Hence the propensity for voluntary support and involvement is quite high in many communities. If there is an organized way of including the community in the building and/or fundraising processes, the cost of deployment can be lowered and takeup maximized as the community will have a vested interest in the project and will be more motivated to use what they have helped build; and
4. **Performance to plan/viability** (that is, success in respect to the specific project plan), including timescales for planning and execution, number of connections deployed, and so on.

On the basis of this methodology, recommendations and lessons learned are provided, with respect to the effectiveness of business models in different circumstances. The recommendations provide a tool by which policy makers may choose the most appropriate policy approach and business model to address the particular infrastructure challenge they face.

1.3. Structure of the Report

Chapters 2 through 4 discuss the growing global experience of how best to implement infrastructure deployment from a business model perspective. Much has been written about broadband policy planning, the appropriate legal and regulatory framework to support broadband development, and the means to stimulate demand for broadband service. The purpose of these chapters is to examine the factors and attributes that contribute to successful business models, particularly in challenging circumstances where the market cannot be relied upon to deliver economically desirable broadband infrastructure.

- Chapter 2 discusses the facilitation of broadband deployment, including wireless infrastructure, and trends affecting global availability of spectrum—a crucial input for enabling delivery of broadband via wireless technologies. This chapter also addresses technological trends, which strongly influence the practicalities and commercial nature of potential deployments.

- Chapter 3 discusses the dimensions of the business models for infrastructure deployment.

- Chapter 4 examines crossborder (both subsea and terrestrial) and national backbone deployments, as well as the relevant deployment business models and their relative success.

- Chapter 5 examines the experience and relative success of various business models for last-mile and middle-mile deployments.

- Chapter 6 presents observations on the particular cases of cross-sectoral infrastructure sharing.

- Chapter 7 presents conclusions and recommendations, as well as a decision tree to enable policy makers to assess business models for broadband infrastructure deployment and choose components of successful strategies, depending on a country's given circumstances. In addition, it presents specific spectrum-related recommendations focused on meeting expected Internet demand needs, expanding wireless broadband access to unserved and underserved areas, and facilitating 5G and IoT deployment.

The appendix to this report summarizes the 70 case studies that inform the recommendations in this report.

2. Facilitating Broadband Developments

Modern broadband deployment can take many forms—differentiated by reach (that is, wide area and local area networks) and technology (for example, optical fiber, copper wire, mobile cellular, Wi-Fi, satellite, and even drones and balloons). This chapter considers delivery of broadband service via terrestrial wireless services, as well as the evolution from technologies, such as DSL over copper wire to optical fiber, satellite, and other higher-capacity options.

Importantly, this chapter includes a discussion of radiofrequency spectrum, the key input for delivery of wireless broadband services. Wireless technologies enable mobility both within a broad area, such as a village or city, as well as within small areas, such as a home or business. Further, wireless infrastructure can often be less costly to install, enabling new or upgraded broadband connectivity that can serve as a substitute for wired infrastructure. Wireless technologies rely upon one or more spectrum bands—or portions of the radiofrequency spectrum—in order to transmit and receive data without the need for wires. As such, chapter 2.2 focuses on key developments related to spectrum and the delivery of wireless broadband services. This targeted examination of key spectrum issues is not, however, intended as a detailed review of global spectrum considerations.

2.1. Wireless Infrastructure and Global Trends in Spectrum Policy and Planning

Spectrum is a key input to ensure "Internet access for all." Today, the most common way to access the Internet around the world is via mobile broadband networks (3G, 4G/LTE), fixed-wireless networks (TD-LTE, WiMAX) and public or private Wi-Fi networks. Consumers worldwide are using a variety of devices—smartphones, laptops, tablets, and watches—to access the Internet. At the end of 2017, about 5.2 billion people accessed the Internet through a mobile broadband device, an increase of about 15 percent year-on-year (Ericsson 2017).

The overarching trend in wireless broadband connections and traffic is ever-increasing demand for spectrum to fuel the significant and ongoing growth in the number of broadband-connected devices, as well as the increasing rates of wireless data usage arising from both mobile broadband (International Mobile Telecommunications (IMT), commonly known as 3G, 4G, and 5G) and other wireless technologies. As a result, governments must identify the best possible ways to plan, allocate, and assign spectrum in order to meet the future needs of operators and consumers, while assuring efficient use of valuable spectrum resources and fostering competition.

This chapter considers emerging trends related to terrestrial spectrum policy and planning that can assist key stakeholders in designing and developing their national spectrum plans to foster broadband, with input from industry players and civil society. It first addresses the impact of 5G services on spectrum demand and international trends and efforts related to the identification of additional spectrum for expanded and enhanced wireless services. Second, it explores the use of unlicensed spectrum, a key enabler of expanded access to broadband services. Third, it discusses international developments related to assignment of the digital dividend and new approaches to using the spectrum to meet broadband capacity and coverage needs.

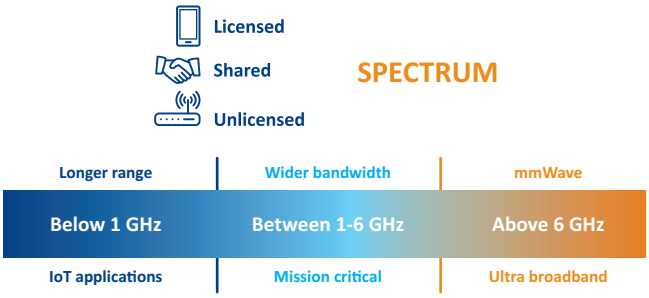
The Emergence of 5G

With the ongoing development and impending launch of 5G networks, governments, regulators, and operators are seeking to identify additional spectrum to enable new and expanded services, including enhanced mobile broadband. These efforts will build on past mobile network operator accomplishments, expanding access, and creating new opportunities for delivery of broadband and broadband-enabled services. 5G will leverage new wireless technologies and additional spectrum bands to enable not only faster mobile broadband, but also massive IoT and mission-critical services. The following subchapters provide information related to trends shaping spectrum identification for 5G services.

5G Spectrum Needs

When considering future spectrum demand of mobile technologies, 5G technologies and their different industry verticals should be considered. The technologies should scale from low spectrum bands for best coverage, to millimeter-wave (mmW) bands—those above 24 GHz—for enhanced performance, and be designed for licensed, unlicensed, and shared licensed spectrum. Using different spectrum bands makes it possible for 5G wireless services to have various levels of reliability, data rates, mobility, and latencies, as required for different use cases. Thus, it is possible to dynamically create services, deployments, or verticals through a configurable connectivity that scales from hotspot deployments to wide area mobile network deployments (see figure 2.1).

Figure 2.1: Spectrum for 5G



Source: TMG/Salience Consulting.

Given the wide range of expected use cases for mobile technologies with the emergence of 5G, as well as the variety of characteristics and strengths of different spectrum bands and spectrum licensing models, a one-size-fits-all approach for 5G spectrum assignment is unlikely. Thus, it will be increasingly important for regulators to offer hybrid spectrum assignment options that allow access to multiple spectrum bands, potentially using a range of assignment and licensing approaches that enable the continued development and growth of wireless broadband technologies and services.

In addition, countries may need to rethink how they calculate their spectrum needs prior to the introduction of 5G—taking advantage of international trends in identification of spectrum for IMT services. 5G will require the use of higher frequency bands with larger channel bandwidths. Unlike 4G and 3G technologies, which use lower frequency channels, calculating frequency reuse for 5G may pose challenges for policy makers because of different needs. Specifically, reuse will be much greater in the higher frequencies that will be used for 5G than in any other band previously used for mobile broadband services, enabling providers to reuse a channel in locations as close as only a few meters in some cases.

The development of 5G will require licensing new spectrum bands, notably mmW spectrum, such as in the 26 GHz and 28 GHz bands. Taking account of particular market conditions, making such spectrum available as soon as possible can position countries as leaders in 5G and development of the Internet of Things (IoT). Conversely, delaying mmW spectrum availability for mobile broadband may result in delayed access to the full benefits of 5G.

As has been true in earlier phases of spectrum planning for mobile services, detailed and transparent spectrum planning for 5G will increase certainty for investors. Investors who are considering commitments of millions—or even billions—of dollars to obtain spectrum licenses and deploy networks rely on clearly defined and stable rules and plans for the allocation and use of spectrum in order to make resource allocation decisions. Therefore, the policies and plans developed by governments and regulators have a direct impact on investor interest in committing resources to the development or expansion of a country's wireless networks.

Bands Under Study for Future IMT Identification

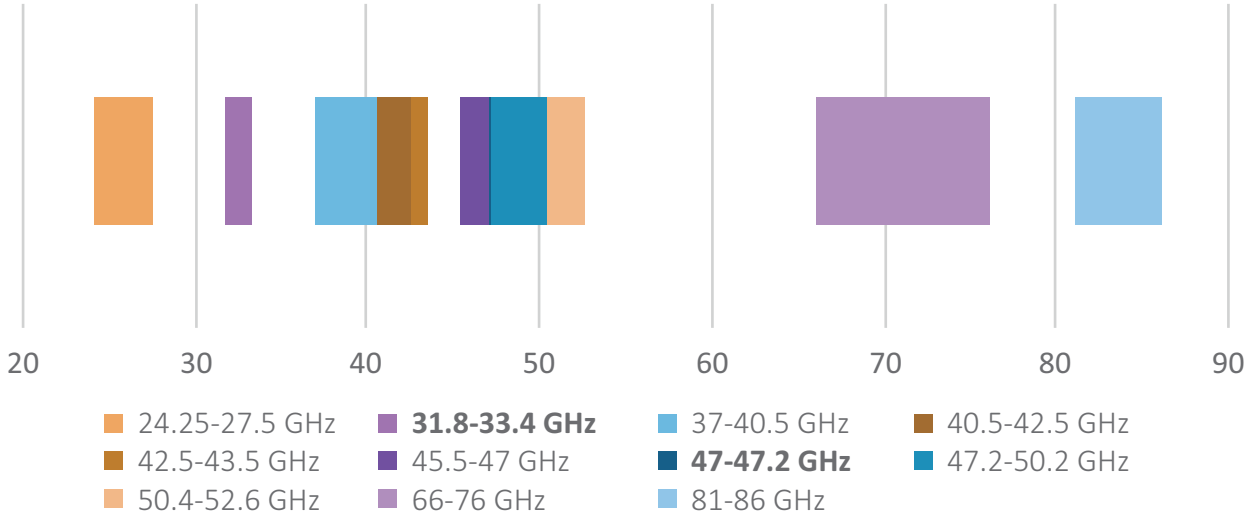
In accordance with decisions made at the 2015 World Radiocommunication Conference (WRC-15), several bands will be analyzed and considered for IMT identification at WRC-19 (see figure 2.2).[3] A band must have a primary allocation for mobile service in order to be identified for IMT, which may be on a national, regional, or worldwide basis.[4]

The International Telecommunication Union's (ITU) vision for 5G and beyond, known as IMT-2020, provides a set of characteristics for the evolution

3 Resolution 238 (Rev.WRC-15), https://www.itu.int/dms_pub/itu-r/oth/0c/0a/R0C0A00000C0014PDFE.pdf.

4 Services with a primary allocation in a band are protected from interference created by services with a secondary allocation in the band.

Figure 2.2: WRC-19 IMT Candidate Bands



Most bands have an existing mobile allocation.
Bold bands may require an additional moblie allocation.

Source: TMG/Salience Consulting, based on ITU-R Resolution 238 (WRC-15).

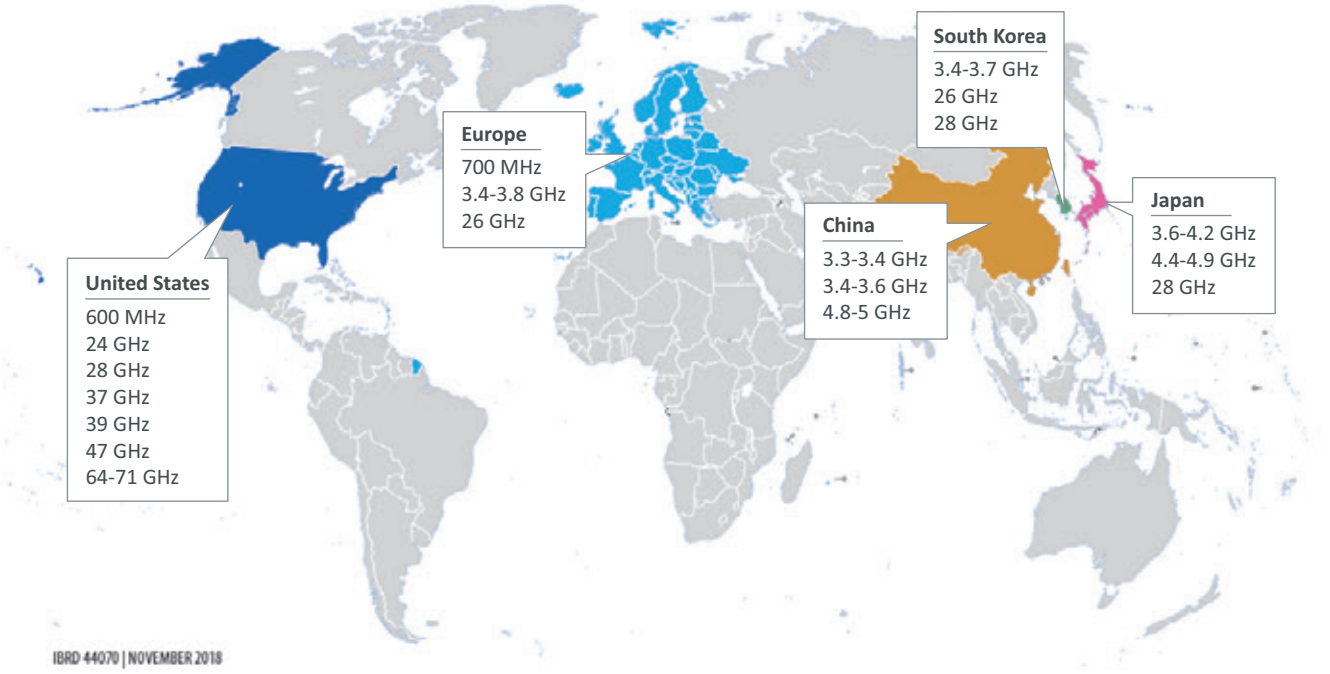
of existing IMT networks.[5] The IMT-2020 concept describes the objective and requirements of the next generation of mobile broadband networks, including beyond 5G. These higher bands, above 24 GHz, are expected to provide capacity enhancements and spectrum reuse needed to achieve the goals described in the recommendation. The ITU notes that IMT-2020 should continue to contribute to efforts including expanding connectivity, evolving the ICT market, bridging the digital divide, creating new forms of education, and promoting energy efficiency. Key IMT-2020 capabilities will include enhanced mobile broadband, ultrareliable and low latency communications, and massive machine type communications.

WRC-19 is expected to take a decision on additional worldwide spectrum identification for IMT services, facilitating harmonization, which is key to achieving global economies of scale. While policy makers may choose to wait for ITU identification of IMT bands, and thus take advantage of the benefits of harmonization, individual countries are also moving forward with IMT identification in order to be at the forefront of the technology development. For example, the United States and the Republic of Korea are considering the use of the 27.25-29.5 GHz range (commonly known as the 28 GHz band) for their first 5G deployments, which is outside the scope of the ITU's current work.[6] Figure 2.3 indicates the bands under consideration for 5G in several jurisdictions, demonstrating the importance of local conditions and the inclusion of low-band spectrum for 5G use.

5 Recommendation ITU-R M.2083, "IMT Vision – 'Framework and overall objectives of the future development of IMT for 2020 and beyond,'" https://www.itu.int/rec/R-REC-M.2083-0-201509-I/en.

6 Canada, Japan, Singapore, and Sweden have also carried out work to promote early 5G implementation in the 28 GHz band. See GSA 2017.

Figure 2.3: Bands under Consideration for 5G, Selected Countries



Source: TMG/Salience Consulting, based on regulator and regional developments.

Spectrum Trading

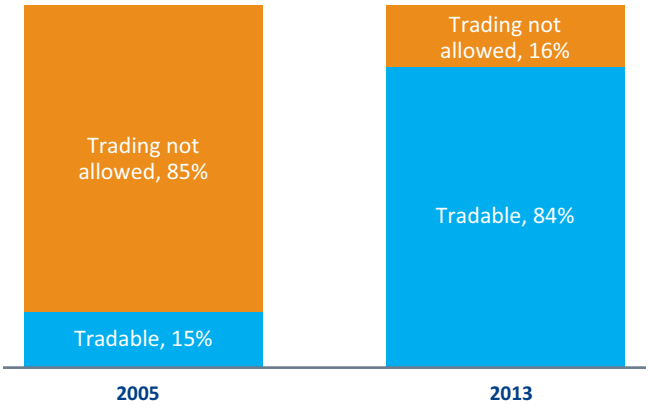
Rather than rely solely on direct licensing of spectrum, policy makers are also increasingly adopting rules to permit spectrum trading through secondary markets. Secondary markets for spectrum—or the ability of licensees to resell or lease their licensed spectrum—are becoming more prevalent. Since spectrum is a valuable and limited resource, governments have a duty to secure its optimal use in the interests of citizens and consumers. By making it easier for spectrum to migrate to those that can generate the greatest value for society, spectrum trading can play a central role in achieving this goal. Secondary markets work by creating economic incentives for licensees to use spectrum efficiently or trade it to others. To enable the market to work effectively, it is important to keep transaction costs low, including those attributable to complying with regulation, as well as reducing the time taken to execute transactions (Ofcom 2011). The regulator's role regarding secondary markets shifts from a hands-on management approach to oversight and possible approval of transactions in order to avoid market imbalances, while continuing to monitor compliance with license terms and addressing disputes.

By allowing interested parties to sell, lease, subdivide, or combine their spectrum use rights with minimal regulatory intervention, regulators improve regulatory flexibility and allow licensees to respond to market developments without the need for a new government-sponsored tender process.

The United Kingdom, for example, has largely adopted rules allowing the total or partial sale and/or leasing of spectrum. Ofcom reported in 2013 that 84 percent of the relevant spectrum was negotiable or tradable, a drastic increase in less than a decade (Ofcom 2013).[7] Figure 2.4 shows the evolution of the proportion of U.K. spectrum tradable in secondary markets between the years 2005 and 2013.

Secondary markets can also come with their own risks and challenges. For example, market players may not take advantage of spectrum trading. Rather than lease or sell spectrum to competitors, a licensee may choose to hoard its spectrum holdings to restrict market entry. Spectrum trading could also harm competition if dominant players buy up spectrum licenses held by smaller operators, leading to high market concentration. However, regulatory frameworks can be structured so as to control for these challenges and allow the secondary spectrum market to function effectively.

Figure 2.4: Evolution of the Proportion of U.K. Spectrum Tradable in Secondary Markets, 2005 versus 2013



Source: Ofcom 2013.

Spectrum Sharing Approaches

Shared spectrum is a newer approach that multiple countries are pursuing as a means to offer additional spectrum for wireless broadband services. Such approaches may be used where licensed spectrum is not available, or feasible in the long term. Spectrum sharing is enabled by technical methods that, in some cases, involve complementary regulatory actions to allow their use. It is reasonable to expect that each of the approaches towards spectrum sharing will receive additional attention as 5G technologies continue to develop.

Spectrum sharing offers new options for expanding the quantity of spectrum available for mobile broadband. Regulators can implement spectrum sharing through various approaches, including license exempt, Licensed Shared Access (LSA), or licensed regulatory frameworks.

- License-exempt approaches have successfully allowed spectrum sharing for applications such as RLANs, Bluetooth, and wireless microphones.
- LSA is a relatively new construct in which currently licensed spectrum can be shared with a limited number of licensed users that conform to predefined conditions that protect the incumbent while enabling additional users access to the same spectrum. LSA is likely to benefit from dynamic approaches to spectrum sharing, in particular.

7 Ofcom's definition excludes uses for which trading is not relevant, namely amateurs and ships, aeronautical, program making and special events (PMSE), police and fire, license exempt, and science and technology.

Overall, sharing permits multiple users to use the same spectrum by leveraging technology that eliminates or minimizes interference. This enables sharing of licensed spectrum through the development of a spectrum commons by mutual agreement. In turn, the users manage their spectrum access, not the government. Thus, the authorization of secondary spectrum use enables opportunistic spectrum access whereby technology permits users to access spectrum based on the characteristics of use at a specific time and location. Rather than focus on power limits to eliminate or minimize harmful interference, secondary spectrum usage focuses on limiting use to particular locations or times.

Some such approaches rely upon the creation or existence of an inventory or database of spectrum usage by band, location, and time. As noted by the Organisation for Economic Cooperation and Development (OECD), spectrum inventories enable assessment of possible spectrum supply to accommodate new applications, the possibilities— in line with overall policy—of shared use in each band (OECD 2014). A spectrum inventory brings the added benefit of providing a useful tool for overall evaluation of spectrum usage, highlighting not only opportunities for sharing, but also for use in determining if spectrum resources are being used efficiently.

In certain instances, regulators are allowing secondary use of spectrum on a shared basis in order to address some market distortions. In these cases, licensed spectrum is made available for use by an entity other than the primary licensee, as long as that entity's operations do not interfere with the primary licensee's services or claim any right to protection from the primary licensee.

In South Africa, for example, the National Integrated ICT Policy proposes the concept of "nationalizing spectrum," if it is assigned under a national license but is not in use (Department of Telecommunications and Postal Services 2014). The proposed goal is to make spectrum available in rural areas. By "nationalizing spectrum," the government intends to allow local governments and communities in certain rural areas to use spectrum previously assigned to mobile operators. The South African government, through this proposal, seeks to address a situation found in certain countries where there are large unserved or underserved rural areas because operators with nationwide licenses do not deploy networks in areas deemed economically unviable. South Africa's proposal is still at an early stage, but the outcome of this process could be a useful reference for those governments facing a similar situation.

The various approaches to spectrum sharing have opened up new opportunities for making the most efficient and effective use of limited spectrum resources while enhancing and expanding broadband capacity.

License-Exempt Spectrum Use

Countries have also introduced regulations to allow unlicensed or "license-exempt" spectrum use to foster innovative applications and services. With lower cost and easier market entry, the license-exempt approach provides opportunities to promote new services and applications and make projects in challenging environments more economically attractive or feasible. A large number of technologies and products typically fall into the license-exempt category, such as Wi-Fi networks, smart devices, radiofrequency identification (RFID), Bluetooth, communications between vehicles, and alarm systems.

The regulatory framework for unlicensed use usually consists of: (i) technical rules to avoid interference; (ii) standards and technical specifications to ensure that quality equipment is being used; and (iii) compliance oversight to ensure that rules are being followed. In certain instances, the regulator may impose some registration requirements, but often this is avoided in order for the regulator to avoid imposing requirements similar to licensing.

Uses of Unlicensed Spectrum

Perhaps most commonly considered in the broadband context as an enabler for in-home or intracampus Wi-Fi networks, spectrum used on an unlicensed basis continues to generate new options for expanding access to Internet service. Below are three approaches countries are taking to promote broadband adoption via unlicensed spectrum.

COMMUNITY NETWORKS

One use case for unlicensed spectrum—usually employing Wi-Fi, but sometimes simple 2G mobile networks—is the development of community networks. These are small networks usually built and operated by community members or entrepreneurs to serve a village or town, meant to complement or fill gaps in commercial mobile networks. These bottom-up networks provide service tailored to the needs of particular communities, enhancing connectivity and promoting both access to and creation of local content and services (Internet Society 2017a; 2017b). However, community networks generally have not been a component of sector policies, and regulations have often not been developed to accommodate them. Policy makers seeking to foster community networks may need to review current policy and legal frameworks in order to identify obstacles to the development of such networks. These could include, for example, allowing secondary use of spectrum on a shared basis by an entity other than the primary licensee, provided that entity's operations do not interfere with the primary licensee's services or claim any right to protection from the primary licensee.

Examples of successful community networks leveraging unlicensed spectrum discussed in chapter 5 include Project Isizwe and Village Telco deployed in South Africa, as well as projects in Nigeria, Colombia, Puerto Rico, Timor Leste, and Brazil. Conversely, lack of flexible rules to allow access to spectrum resources for some community network models such as Endaga, further discussed in chapter 5, has represented a significant barrier to their successful implementation.

TELEVISION WHITE SPACE

Television White Space (TVWS) is also allowed on an unlicensed basis in various countries. This concept allows frequencies unused in a particular geographic area during a specific timeframe to be used for other purposes. Some countries, such as Canada, Colombia, and South Africa have allowed the use of television channels on a secondary basis for backhaul connections in rural areas where television channels are not used.[8]

Usually, TVWS solutions are connected to a Wi-Fi access network to reach the end user. Given the secondary status of such use, no guarantee of protection or availability exists if licensed TV stations decide to use this spectrum to broadcast their programming. However, this secondary use also creates the possibility to use the spectrum for low or no spectrum fees. In this situation, some business cases are being developed for local/community projects using Wi-Fi access frequencies that are unlicensed with an alternative backhaul solution through TVWS.

For example, the 4Afrika initiative launched by Microsoft, further discussed in chapter 5.2, has involved pilots in over 15 African countries, such as Kenya, South Africa, Namibia, Tanzania, and Ghana, leveraging TVWS to deliver low-cost, high-speed, wireless broadband in rural communities. Similarly, beginning in 2016 and funded at least through 2019, a community project in central Colombia is bringing

8 Innovation, Science and Economic Development Canada, "White Space," http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/h_sf10498.html; Agencia Nacional de Espectro (Colombia), "Modificación de la resolución 711 de 2016," https://www.ane.gov.co/index.php/informacion-de-interes/noticias/641-modificacion-de-la-resolucion-711-de-2016; Independent Communications Authority of South Africa, "Notice regarding the Draft Regulations on the Use of Television White Spaces," https://www.gov.za/sites/www.gov.za/files/40772_gen283.pdf.

Internet connectivity enabled by TVWS and Wi-Fi technology to coffee growers and community schools in rural and remote areas.[9]

LTE-U AND LTE LAA

LTE-U in unlicensed bands as a standalone service is designed to operate in bands such as 5 GHz globally, or 3.5 GHz in the United States. It was created to extend the benefits of Long-Term Evolution (LTE) technology used in commercial mobile networks and its ecosystem to Wi-Fi entities that may not own licensed spectrum, such as small Internet service providers using fixed wireless broadband and enterprise or venue owners.

LTE Licensed-Assisted Access (LAA) is designed to enable LTE over short distances in the last mile. It also operates in unlicensed bands but is designed to combine LTE in unlicensed spectrum with LTE in licensed bands, and thus requires both licensed and unlicensed bands to operate. This aggregation of spectrum provides for more bandwidth with faster data rates and a more responsive user experience. LTE-U/LAA is intended to deliver better network performance and an enhanced user experience compared to Wi-Fi offloading, providing mobile operators a solution for making better use of unlicensed spectrum.

While Wi-Fi is one of the best-known uses of unlicensed spectrum, emerging technologies such as LTE-U and LAA are leveraging the experiences and benefits of both licensed and unlicensed spectrum in an effort to create a hybrid approach and expand the reach of wireless broadband services. LTE-U and LAA trials are being conducted in markets in Asia, Europe, and the United States.

RISKS AND CHALLENGES

While unlicensed spectrum does not involve spectrum assignments, either directly or indirectly, such use nonetheless poses risks and challenges, including increased network congestion and the lack of protection against harmful interference. For instance, bands used for Wi-Fi applications are also utilized for a wide variety of applications via wireless phones, Bluetooth, RFID and other short-range devices. With increased use of these kinds of applications, the likelihood of interference also grows. In an effort to mitigate these risks, many users have migrated from the 2.4 GHz band to the 5 GHz band. In addition, unlicensed bands can make it impractical for policy makers to reclaim spectrum for licensed use if national needs or priorities change. Because there is no licensing or registration, equipment operating in an unlicensed band could be hard to locate and/or replace or deactivate in a band-clearing process. This can be exacerbated where large numbers of devices have been purchased and are in use.

The increasing use of unlicensed spectrum for end-user broadband connectivity may also pose a challenge in terms of shifting how a regulator or government approaches its spectrum management role. Because unlicensed spectrum does not generate license revenue and reduces the regulatory management and administration burden, it may be a significant change from past approaches in which regulatory authorities closely controlled spectrum use and imposed license fees to support the related administrative role. To the extent that license fees have been used to generate revenue or cross-subsidize other regulatory or government activities, increased use of unlicensed spectrum may impact such frameworks. As such, the embrace of unlicensed spectrum requires consideration of the impact on the regulator's role in governing spectrum use in the affected bands, as well as the impact on the agency's budget.

9 For further information see: MAKAIA, "Technology Transformation: Life improvement for Coffee Growers," http://makaia.org/en/projects/technology-for-social-change/technology-transformation-improving-the-lives-of-colombian-coffee-growers/.

Potential Future Unlicensed Spectrum Identifications

Wi-Fi networks are seen as an important tool to foster Internet access to end users. Public places, such as restaurants and cafes, and more recently, state-financed projects, are providing free or subsidized Internet access to citizens. Even local operators are beginning to use Wi-Fi networks to provide more affordable Internet connectivity. In addition, Wi-Fi networks are becoming standard in not only communications devices, but in automobiles, electronics, household appliances, medical devices, and other equipment that traditionally has not been connected. The incorporation of Wi-Fi connectivity into noncommunications devices is a key enabler of the IoT, with a growing number of home and business devices sending and receiving Internet traffic.

Wi-Fi uses spectrum on an unlicensed basis in specific bands that are also used by other applications, such as Bluetooth and RFID. The bands most frequently used for such applications are the 2.4 GHz and 5 GHz bands. Radiocommunications services operating in these bands must accept harmful interference; may not claim protection against harmful interference; and are subject to power limits to avoid causing interference to other services.[10] No identification exists for this type of application in the ITU Radio Regulations. Instead, ITU recommendations and reports seek to harmonize spectrum used by RLANs on an unlicensed basis.[11]

WRC-19 will also look at the possibility of modifying existing allocations and technical restrictions in order to make more spectrum available for RLANs.[12] The focus is to expand the 5 GHz band for RLAN applications, and to relax some technical restrictions (for example, power limits) applicable to certain ranges of the band.[13] Any such changes at WRC-19, once implemented at the national level, will expand the spectrum resources available to Wi-Fi-enabled connectivity projects, in line with those detailed in chapter 5.2.

In particular, the current 5 GHz bands for RLANs have a gap between 5350 MHz and 5470 MHz.[14] This gap limits capacity by impeding the creation of larger channels that would allow the transport of more data and strengthen against interference. To continue promoting Internet adoption, policy makers should follow the WRC-19 process and outcomes and plan for additional unlicensed spectrum to facilitate Wi-Fi deployments.

Spectrum Repurposing and Refarming

In an effort to maximize the use of spectrum and thereby better address spectrum demand from relevant stakeholders, regulators are undertaking administrative, financial, and technical measures to recapture spectrum and reassign it for new uses. Spectrum repurposing and refarming is not a new concept, but it is one vehicle that takes on even greater relevance as countries seek to make more spectrum available to meet mobile broadband demand. Such approaches have considered both spectrum used for existing mobile technologies

10 For example, the 5 GHz band was designated for such use by Resolution 229 (WRC-12), https://www.itu.int/oth/R0A06000018/en.

11 ITU-R Recommendation M.1450 (April 2014), Table 2, https://www.itu.int/rec/R-REC-M.1450/en.

12 WRC Resolution 239 (WRC-15), "Studies Concerning Wireless Access Systems Including Radio Local Area Networks in the Frequency Bands Between 5 150 MHz and 5 925 MHz," (https://www.itu.int/dms_pub/itu-r/oth/0c/0a/R0C0A00000C0017PDFE.pdf) invites WRC-19 to take up this issue. It will be addressed under WRC-19 Agenda Item 1.16.

13 In particular, the ITU is studying the frequency bands 5150-5350 MHz (outdoor), 5350-5470 MHz, 5725-5850 MHz and 5850-5925 MHz.

14 See ITU-R Resolution 229 (Rev. WRC-12), "Use of the Bands 5 150-5 250 MHz, 5 250-5 350 MHz and 5 470-5 725 MHz by the Mobile Service for the Implementation of Wireless Access Systems Including Radio Local Area Networks," https://www.itu.int/oth/R0A06000018.

(that is, 2G, 3G, and 4G) and spectrum used by other services. Recent refarming undertakings and consultations have addressed several bands, including the 450 MHz, 900 MHz, and 1800 MHz bands used for earlier mobile technologies and the repurposing of mid-range bands such as the 2.5 GHz and 3.5 GHz bands, as well as the 700 MHz and 800 MHz bands previously used for terrestrial television broadcasting. Refarming will enable operators to pursue the mix of low-, mid-, and high-band spectrum that is most appropriate for their deployment and business models.

One high-profile repurposing target has been driven by the migration of television broadcasting from analog to digital transmission, which enables the provision of improved television services while using less spectrum. The spectrum that can be repurposed from analog broadcasting to other uses—referred to as the digital dividend—has been earmarked by many policy makers for the provision of mobile broadband services. In fact, the creation of the digital dividend has been a major driver of the digital broadcasting migration around the world. The digital television migration and the resulting availability of the digital dividend is critically important for the continued growth and improvement of mobile broadband services around the world.

Digital Dividend—International and Regional Developments

In the European Union, the European Commission (EC), the European Parliament, and the European Conference of Postal and Telecommunications Administrations (CEPT) have developed recommendations and plans for the harmonized implementation of the digital dividend across the continent.[15]

Following the first digital dividend in the 800 MHz band, the EC, European Parliament, and the Council of the European Union agreed in December 2016 on an EU-wide approach for the use of the 470-790 MHz band, including the 700 MHz band (694-790 MHz) (European Commission 2016). Under the agreement, the 700 MHz band is to be assigned to mobile operators and made available for wireless broadband use by the end of June 2020. EU Member States were expected to conclude crossborder coordination agreements by the end of 2017, and to adopt and publish their plans by June 2018.

In addition, several Region 3 countries have identified the 698-790 MHz band for use by IMT, and all of Region 3 has identified 790-960 MHz for IMT.[16] In September 2010, the Asia Pacific Telecommunity (APT) Wireless Forum (AWF) defined the so-called APT700 plan as the most efficient arrangement of the digital dividend for mobile services. In December 2016, the APT approved a recommendation encouraging administrations to adopt a harmonized band plan for IMT in the 698-806 MHz band. However, the APT700 plan had already gained worldwide support by the time that the APT released its recommendation.[17]

Notably, countries in Latin America, Europe, and the Middle East, such as Argentina, Brazil, Chile, Colombia, Ecuador, the Arab Republic of Egypt, France, Germany, Panama, Peru, Mexico, Suriname, and the United Arab Emirates have already awarded spectrum based on the APT700 plan or are preparing to do so, expanding the potential market for compatible equipment beyond the Asia-Pacific region. Recent and upcoming examples of digital dividend refarming are presented in table 2.1.

15 See, for example, Decision 2010/267/EC on Harmonized Technical Conditions of Use in the 790-862 MHz Frequency Band for Terrestrial Systems Capable of Providing Electronic Communications Services in the European Union (May 6, 2010), http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32010D0267.

16 ITU Radio Regulations (WRC-15), Footnotes 5.313A and 5.317A.

17 Asia-Pacific Telecommunity, *APT Report on Harmonised Frequency Arrangements for the Band 698-806 MHz*, No. APT/AWF/REP-14 (September 2010); and Asia-Pacific Telecommunity, "APT Recommendation on 'Frequency Arrangements for the Implementation of IMT in the Band 698-806 MHz," Document APT/AWG/REC-08 (December 2016).

Table 2.1: Recent Digital Dividend Refarming

Country	Band(s)	Date
Argentina	700 MHz	2017
Paraguay	700 MHz	2018
Tanzania	700 MHz	2018

Source: TMG/Salience, based on regulator or government statements.

New Approaches to Digital Dividend Usage

As policy makers and regulators consider how best to make use of the digital dividend, new models are being explored. For example, several countries have pursued the concept of shared network infrastructures. Details vary somewhat, but the underlying concept is to create a nationwide wholesale network operator in the digital dividend band, with that wholesale network providing capacity to the commercial operators that serve end users. Table 2.2 highlights three examples.

Table 2.2: Shared Network Infrastructure Examples in Digital Dividend Bands

Country	Band(s)	Date
Mexico – Red Compartida	• Use 90 MHz to provide wholesale voice and wireless broadband for resale. • Public-private partnership (PPP) under ministry and regulator. • 100 percent foreign direct investment allowed. • Project terms include technology neutrality, nondiscriminatory terms of service provision, and minimum coverage requirements.[a] • To cover 30 percent of the population by March 31, 2018, 70 percent by 2022, and more than 92 percent by 2024.	• January 2017 – Contract awarded to Altán Redes consortium.[b] • March 2018 – Operations launched, first population coverage target met ahead of schedule.[c]

Note:

a. See SCT and IFT 2015, Section 3.2.

b. Altán Redes is comprised of investors from the Netherlands, Mexico, and Canada, as well as participation from the International Finance Corporation and Mexican operators, Axtel and Megacable. See Altán Redes, "Who We Are," http://altanredes.com/en/quienes-somos/; and SCT 2016.

c. See Altán Redes 2018.

Country	Band(s)	Date
Rwanda – Korea Telecom Rwanda Networks (KTRN)	• 4G LTE wholesale broadband provider using digital dividend spectrum included in 2013 broadband policy.[d] • PPP established with Korea Telecom (KT) in 2013. Government equity investment (49 percent) consists of access to national fiber-optic cable, spectrum, and award of wholesale operator license.[e] • To cover 95 percent of population within three years.[f]	• Adoption slower than anticipated. July 2016 population coverage: about 30 percent.[g] • KTRN expected nationwide coverage by end-2017.[h] • January 2018: 95 percent population coverage reportedly achieved.[i]
South Africa – Open access wholesale wireless network	• Open-access wholesale network proposed in 2011.[j] Concept has remained in subsequent plans.[k] • "Public-private sector-owned and managed consortium" (in undefined spectrum) revisited in 2016.[l] • Government incentives may include reduced costs for spectrum and access to public infrastructure, allocation of universal service funds.[m] • Consortium members with appropriate licenses may provide retail services outside of the consortium.[n]	• November 2017: Bill including proposed language regarding licensing of the wireless open access network published for consultation.[o]

Note:
d. See Republic of Rwanda 2013.
e. See Rwanda Development Board 2013.
f. See Smith 2013.
g. See GSMA 2017.
h. See KTRN, "4G LTE Coverage," accessed November 30, 2017, http://ktrn.rw/4g-lte-coverage-map.html.
i. See TeleGeography 2018.
j. See ICASA 2011.
k. See, for example, Department of Communications 2013a; Department of Communications 2013b; Cwele 2014); and ICASA 2014, 75.
m. See Department of Telecommunications and Postal Services 2016, 76.
n. See Department of Telecommunications and Postal Services 2016, 76.
o. See Department of Telecommunications and Postal Services 2017.

Source: TMG/Salience Consulting.

Note that the business models of KTRN and Red Compartida are also discussed in chapters 4.3 and 5.4, respectively. Given the relatively small number of such shared network infrastructure in digital dividend spectrum and the early stages of their development, it is too early to draw conclusions regarding their success or impact.

Spectrum-Specific Principles

Taking into account the trends and observations noted above, and in considering how best to leverage spectrum resources to ensure effective and efficient use that improves and expands Internet access, the following core set of spectrum principles were used to develop the recommendations set forth in chapter 7.

1. **Leverage flexibility to enable the introduction and growth of emerging technologies, notably 5G and the IoT.** Although 5G technology has been in development for several years and IoT devices and services are already in use, both technologies are expected to experience considerable further development and growth. Regulators and policy makers should ensure that their actions not only do not constrain such growth, but rather facilitate and encourage it, building frameworks that maximize flexibility, enable innovation, minimize administrative burdens, and take into account the characteristics that make these technologies different from earlier innovations. These new technologies will both enable novel, flexible uses of spectrum, and also benefit from regulatory flexibility in considering the rules and policies that govern their deployment.

2. **Maximize spectrum access for wireless broadband services.** Demand for wireless broadband services has continued to grow unabated, driven in part by the continuing improvement of wireless technologies and their new applications, and the increasing ability to use spectrum flexibly to serve different needs and users. Policy makers and regulators seeking to expand access to broadband should keep in mind that the most important method by which to increase capacity and improve the user experience is to ensure the availability of appropriate spectrum for use by wireless broadband services, although competition or concentration concerns should be taken into account as well. Increasing the amount of available spectrum is even more important when considering the new connected applications supported by IoT. Identification of bands and transparency regarding the amount and availability of spectrum must be accompanied by appropriate—and sufficiently flexible—licensing and access models that are aligned with the likely use cases of the spectrum under consideration. In addition, regulatory frameworks should facilitate flexible use, allowing for pooling and sharing, to maximize use and efficiency, while at the same time promoting competition.

3. **Implement strategies specifically targeting unserved and underserved populations.** Reaching areas and populations that continue to lack adequate—or any—broadband access will require new, more flexible approaches and reconsideration of the role of government. The advent of new wireless technologies with different characteristics and use cases than existing mobile networks should prompt actions that can strengthen existing successful approaches and leverage new technologies, business models, and spectrum authorization approaches to provide governments and regulators with a flexible set of tools with which to develop new sector strategies.

2.2. Evolution and the Role of New Technology Trends

The Dilemma of Fiber Replacing Copper vs. Upgrading Copper

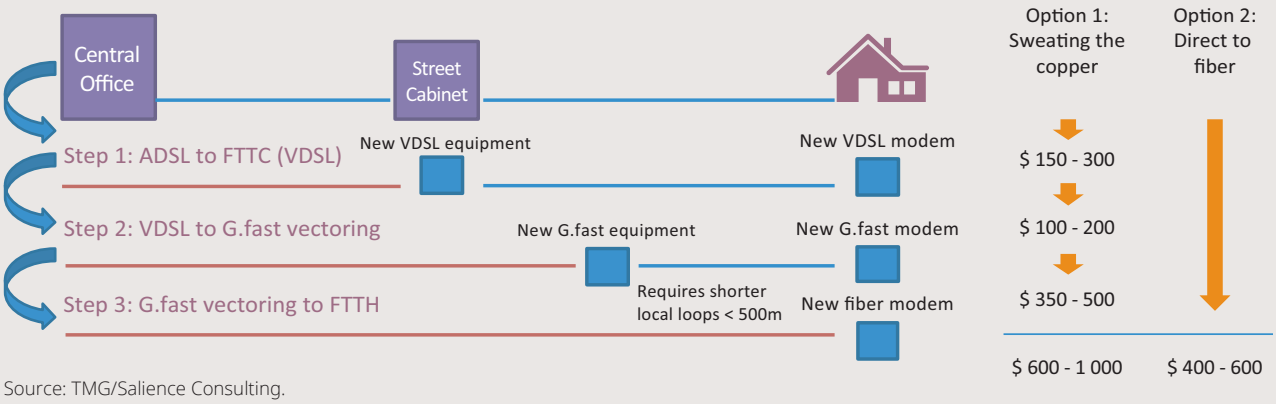
Driven by a mix of competitive forces and public policy initiatives, incumbent operators in many markets came under increasing pressure in the last decade to replace their copper access network with fiber-to-the-home (FTTH) technology. The technology itself was never the main cost issue. Instead, the expensive roll-out of the technology made the pay-off a long-term—and often uncertain—prospect. The presence of existing copper plant was also an enormous disincentive to new infrastructure investment. Hence, many incumbents opted for the short-term fix of upgrading the copper initially to very high speed digital subscriber line (VDSL) technology (or even variants such as G-fast) to delay the heavy investment in all-fiber solutions. In markets where copper infrastructure is limited or practically non-existent, this dilemma is not a key issue. However, in others, this is a central challenge that policy makers have had to contend with either through regulation, incentives, or more active forms of intervention in deployment business models (see box 2.1).

Box 2.1: The 3Ws - Whether, When and Where - to Upgrade from Copper to Fiber

Over the past decade, telecommunications incumbents with significant copper infrastructure (such as BT and Deutsche Telekom) have been wrestling with these questions in the face of the growing conflict between lack of incentive to abandon an existing productive asset and the uncertainty of the additional revenue that could be gained with fiber on the one hand, and the need to slow down the churn to newer, leaner competitors on the other.

The main dilemma for incumbents is whether to upgrade the copper or go directly to fiber. As depicted in the idealized case below, the total cost of upgrading from copper to fiber is more expensive than going straight to fiber. However, in these calculations the factors of better cash flow by delayed investment and risk management are not considered.

Figure B2.1.1: The Case for Upgrading to Fiber



Source: TMG/Salience Consulting.

The case for evolving xDSL networks is instructive for the general case where fixed broadband networks can be upgraded gradually to accommodate higher speed and capacity requirements. Competitive considerations usually drive the need to upgrade while economic considerations from the cost of upgrading and price evolution in the technology ecosystem make some upgrades unattractive. In these circumstances, the operator has a choice to maintain the existing network or transition to fiber.

Table 2.3 below describes likely transitions for the different fixed access technologies:

Table 2.3: Evolution of Fixed Access Technologies

Technology	Perspective	Existing capability	Upgrade option	Long term
Copper/xDSL	Technology	1-20Mbit/s (ADSL)	20-50Mbit/s (VDSL)	>100Mbit/s (G.Fast)
	Business	Under commercial pressure if alternatives available	Valid upgrade with low competition, upgrade to fiber otherwise	Valid upgrade in niche cases only. Upgrade to fiber.
Coaxial cable/ DOCSIS	Technology	30-100Mbit/s (DOCSIS 3.0)	100-250Mbit/s (DOCSIS3.1)	>500Mbit/s
	Business	Under moderate commercial pressure from fiber-based service, if available	Valid upgrade for existing, modern DOCSIS networks, upgrade to fiber otherwise	Valid upgrade for updated DOCSIS networks, upgrade to fiber otherwise
Fiber/GPON	Technology	100-1000Mbit/s (GPON)	100-1000Mbit/s (GPON)	>1000Mbit/s (xxPON)
	Business	Competitive in performance and cost	Competitive in performance and cost	Competitive in performance and cost

Source: TMG/Salience Consulting.

Network technology evolution is subject to many considerations: competitive environment, technology-specific concessions, speed of market evolution, cash-flow implications and investment capacity of operators and state of existing networks.

Transitioning to a fiber solution is associated with:

- **Technology is mature so costs are stable**: Gigabit Passive Optical Network (GPON) equipment costs have evolved and prices have decreased to a stable level, so there is more certainty on the Optical Line Termination (OLT) port and Optical Network Terminal (ONT) costs per user.
- **Last mile distances and network quality**: All networks have differences in the quality of the final infrastructure link to customers in terms of quality and distance or density. While copper

networks critically depend on short distances, fiber networks are much more robust to changes in cable length.

- **Ability to mitigate capital costs**: Any replacement of a coaxial cable/DOCSIS or copper/xDSL network with fiber to the home will require significant installation of new lines with the associated high initial capital cost. This can be mitigated by reuse of existing ducts and fiber network. This cost can be amortized over a long period as no competing fixed network technologies are on the horizon.

- **Higher takeup/high ARPU/high density**: Because the backhaul/middle mile is a shared cost, high-density environments are economically more attractive for upgrades. In many countries, density is also correlated with higher ARPU and higher takeup rates—all positively affecting the case for upgrade.

- **Increased consumption of content and other value-added services**: Even though the impact varies on the revenue side, there is a clear trend of increased consumption of content and value-added services. While many telecommunications operators are benefiting from this trend, there may be cases where operators are not the primary beneficiaries, for example, provision of over-the-top services.

In addition to these choices among access technologies, broadband networks will continue to be impacted by a number of significant general trends:

- **Core network usage increase**: Since most Internet service is provided on the basis of unlimited use, and users are connecting and increasingly using more and more devices, overall usage—and therefore core network costs—is growing. At the same time, revenue remains relatively fixed, which must be offset against higher subscriber numbers, higher ARPU, and lower costs. This is not always achievable.

- **High IP transit prices**: Broadband networks critically depend on international IP connections. Countries may have very high Internet connectivity prices (IPT) that represent a substantial cost in the overall equation, especially in the face of growing usage. This usually affects landlocked countries or those where demand has not justified landing of competitive subsea cables.

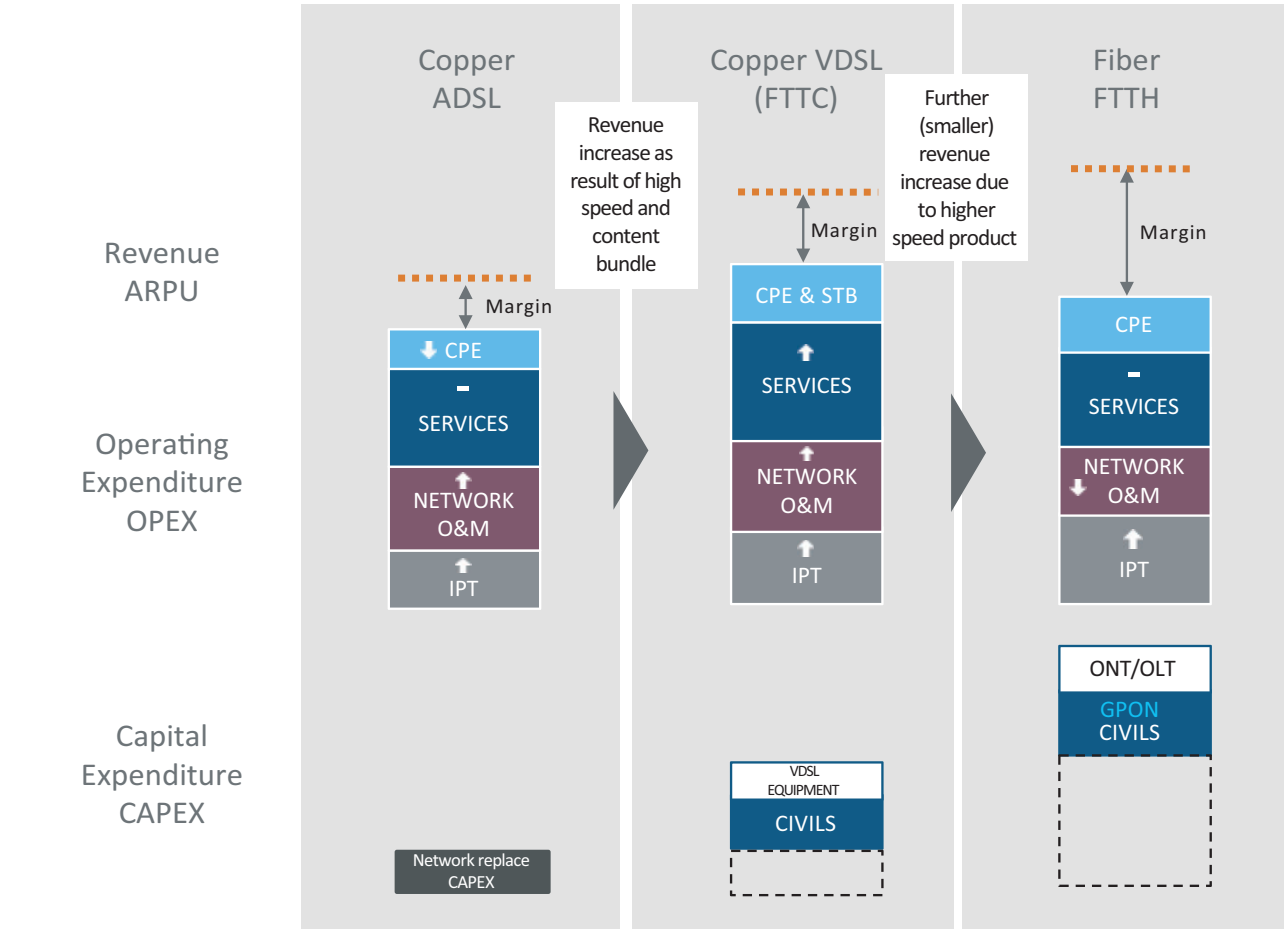
- **Higher churn and competition**: Introducing new technology is often triggered by competition. Higher churn and a highly competitive environment might have a negative effect on the incumbent and challenger business cases.

- **Lower takeup/low ARPU/low density**: Countries with lower affordability generally have lower takeup and pay less on average. Unfortunately, a lot of countries in this category have many remote, low-density areas, which makes the case for fixed broadband networks more difficult. Shared networks, wireless access and regulatory support may help, which is the main topic of this report.

- **Political pressure (local and regional)**: Broadband announcements can be used for political purposes (for example, Australia NBN) and regional pressure relating to concerns about being left behind (for example, the EU's Gigabit Society). These external pressures may not always be supported by a sound economic rationale but may affect decision making.

A more detailed summary of the economics of the upgrade steps in terms of OPEX and CAPEX are also shown in figure 2.5 below. If the CAPEX investment could be absorbed, then upgrades will improve the relative profit margins as both VDSL and fiber will open the door for additional services (content, VAS) and fiber will significantly reduce the network operation costs.

Figure 2.5: Summary of the Economics of Upgrading from Copper to Fiber



Source: TMG/Salience Consulting.

In line with best practice, determining where to upgrade should be conducted via neighborhood-based variations of the general business case and doing phased, but targeted, rollout. Where there is sufficient expected take-up with relatively higher ARPU in the specific area, then upgrading straight to FTTH is recommended. In contrast, if the take-up is uncertain, then a step-by-step upgrade through VDSL and a "sweating the copper" attitude is a more reasonable approach.

The state can also shift the calculations in fiber's favor by undertaking actions to reduce fiber CAPEX. Some of these actions simply involve removing regulatory barriers (as discussed in the Recommendations Section in chapter 7). Others could involve coinvestment or subsidy, if justified, on a cost-benefit basis that takes into consideration incremental economic benefits of fiber over existing copper ADSL or VDSL, or coax/DOCSIS. Some have even advocated for more aggressive fiber switchover policies (Stanislawski and Krauze 2012).

High-Speed Mobile Broadband—Fixed Access Substitute or Complement?

Mobile network operators have played, and continue to play, an important role in increasing Internet connectivity. Since the beginning of 2010, the number of mobile Internet subscribers has increased by 2.3 billion, 75 percent of whom live in low- and middle-income countries and were accessing the Internet for the first time.[18] The planned investment of an additional $900 billion between 2016 and 2020 is expected to bring Internet access to an additional one billion people. In most developing countries and rural areas in the developed countries, mobile is the dominant form of broadband delivery. Even in markets with extensive fixed networks, the advances of mobile broadband technology from 3G to 4G and 5G, along with the increase in the data rates they bring, have presented an opportunity to substitute mobile technology for fixed line access. This is mainly because of the fact that mobile networks tend to be quicker and less costly to deploy and, thus, more profitable for telecommunications operators as compared to upgrading or extending their fixed line networks.

Mobile operators have leveraged widespread deployment together with affordability and ease of use as an opportunity to not only substitute the fixed line but extend the service capability into household broadband, usually delivered via a plug-in dongle containing a SIM card.

Fixed wireless technologies have been present for decades—operators unable to provide efficient and affordable fixed line network access have been delivering a substitute through WiMAX, and more recently LTE fixed wireless technology. From the technology perspective, although WiMAX is near the end of its lifecycle, LTE is expected to last over the long term. For example, ongoing 3GPP standardization efforts that ensure backward compatibility between devices and easy integration are helping to lengthen LTE's lifecycle.

Wi-Fi has also been evolving from a predominantly indoor technology covering homes and businesses to an outdoor technology covering whole cities, such as in Barcelona and Singapore. The solution has received wide acceptance because of the fact that, in many countries, Wi-Fi does not require any specific spectrum license and because Wi-Fi is installed in everyday devices. Wi-Fi is discussed in more detail in chapter 5.3.

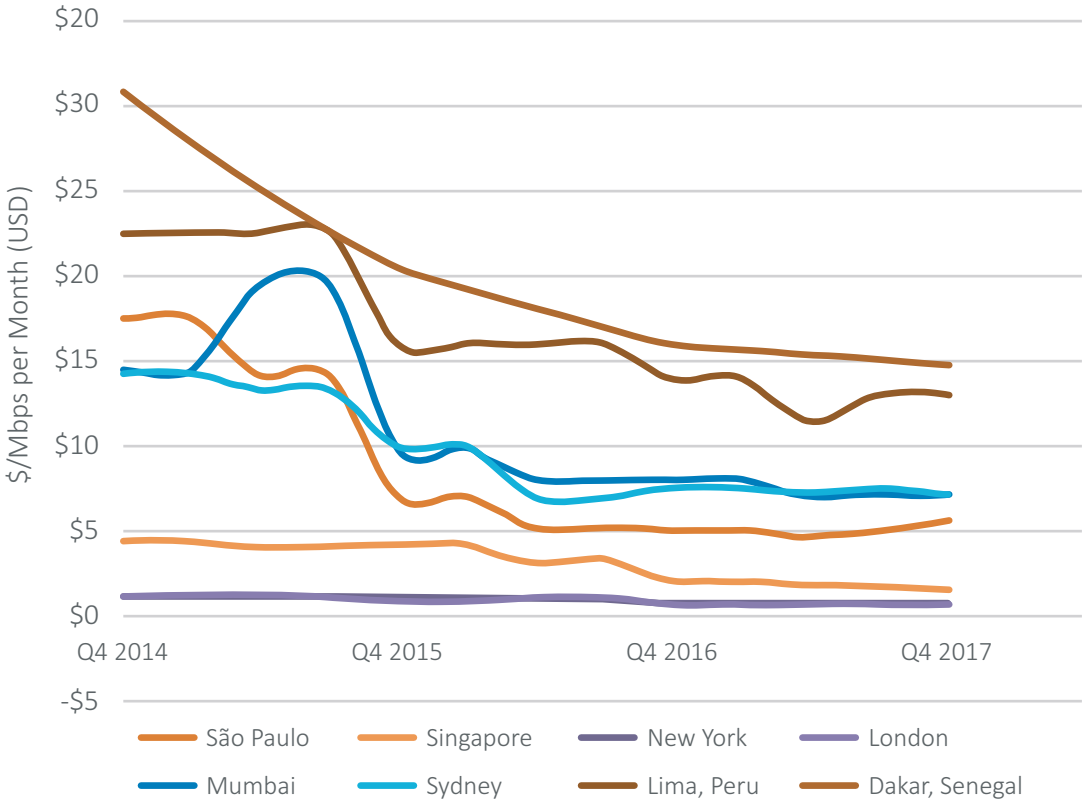
However, mobile broadband technologies have two fundamental issues: 1) their performance is subject to spectrum availability and not comparable with the speed of fiber; and 2) as a common access resource, the cell capacity is shared between a variable number of end users, therefore making service level guarantees of the type available with fiber challenging. For these reasons, mobile broadband continues to be perceived as complementary to fixed line broadband in developed markets, rather than as a substitute.

Growth in Subsea Fiber Deployments

Improvements in fiber and transmission technology has not only impacted terrestrial connectivity but has also enabled exponential growth in subsea cable capacity. The emergence of new subsea cables or upgrades to existing ones in synergy with increased local competition and growing volumes have led to falling prices throughout the world. Figure 2.6 illustrates the drop in international IP transit prices on major global routes over the past few years.

18 Comments received from GSMA (Q1 2018).

Figure 2.6: Median 10GigE IP Transit Prices in Key Cities, 2014-17



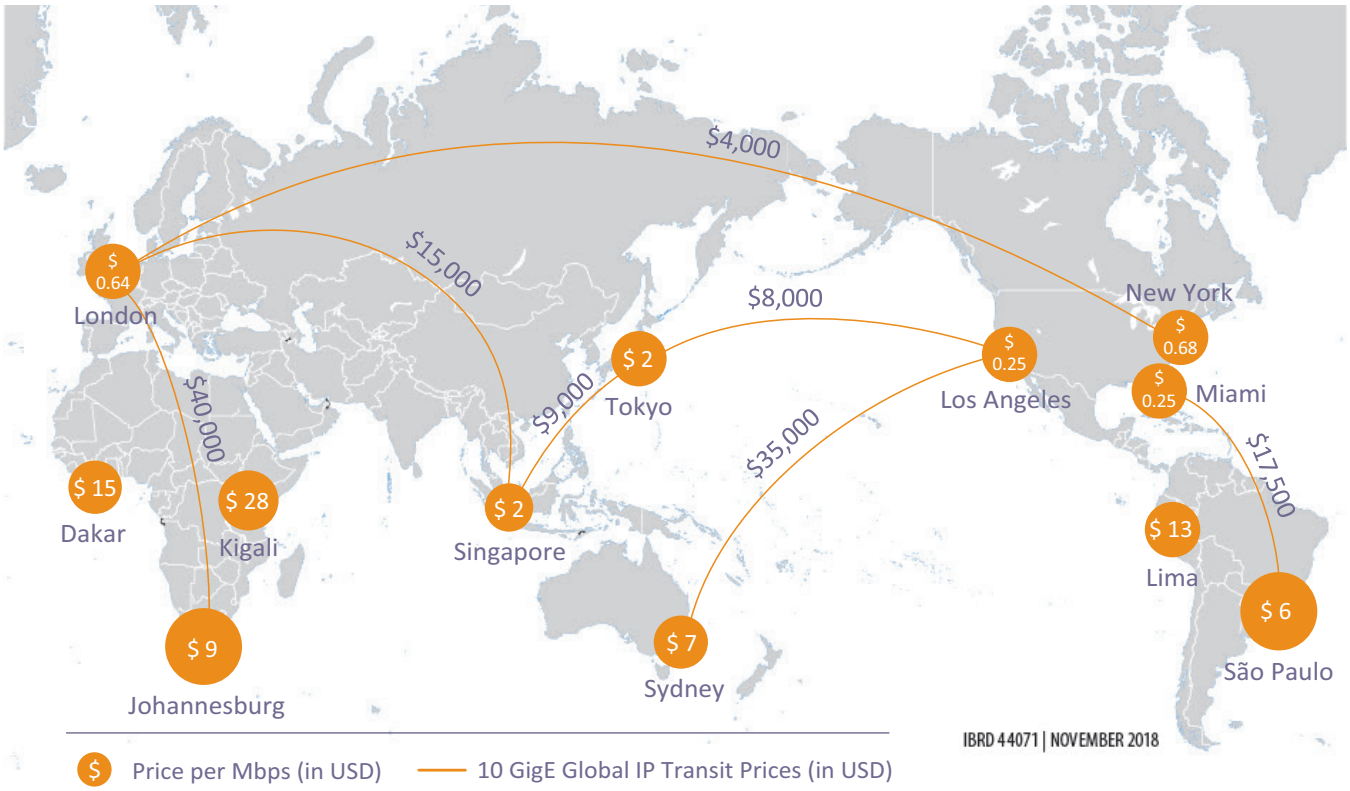
Source: Salience Consulting using TeleGeography data.

Despite the overall drop in prices, the cost of global connectivity still varies widely, with countries in the southern hemisphere paying significantly higher prices (figure 2.7). IP transit costs under $1 per Mbps per month in London, New York, and Los Angeles and about $2 in Singapore and Tokyo. In contrast, IP transit could cost $9 in Johannesburg and more than $15 elsewhere in Africa. Still, the overall picture is one of significantly greater capacity and cheaper prices throughout the world.

In many countries in the developing world, a virtuous circle of higher volumes-lower costs-lower prices-higher volumes has been created by ensuring greater capacity on subsea cables is translated into domestic markets through implementing open access regimes to break the bottlenecks at cable landing stations. Expansion of terrestrial crossborder networks is also relevant, as these networks can further assist in aggregating traffic, driving costs down and volumes up. Indeed, there may be tensions created for specific landing stations in certain smaller countries, which could see national traffic flows drawn to lower-cost landing facilities in larger adjacent nations.

Finally, it is important to note that for landlocked countries, the full benefits provided by subsea cables are only realized when crossborder interconnection is available and reasonably priced. Many of the projects reviewed were initiated by policy makers seeking to address a lack of interconnection or private enterprise seeing the opportunity in the absence of this interconnection.

Figure 2.7: IP Transit Prices per Mbit/s: Northern Versus Southern Hemisphere



Source: Salience Consulting using TeleGeography data.

Future Satellite Constellations and Satellite Broadband – Will They Deliver on the Promise?

With investments from satellite heavyweights, such as Boeing, Qualcomm, Virgin, and SpaceX, the race to cover the globe with new satellite constellations is heating up. The upfront investment in these enterprises is high—in the billions of dollars. However, satellite operators are targeting vast new markets, including the billions of people currently without broadband service and opportunities to expand access limits for current users, for example, from full broadband functionality for air travel to rich niche markets serving high-end business and government customers. This is incentivizing the ambitious rollout.

The new push for satellite broadband is enabled by new technology. Recent and future deployments are quite different to prior satellite systems with high-throughput satellites (HTS) and nongeostationary Low Earth Orbit (LEO) and Medium Earth Orbit (MEO) constellations.

High-throughput satellites exploiting frequency reuse and spot beam technology are providing broadband capabilities unavailable from satellite systems in the past. Broadband satellite service has proven to be a viable business and several new HTS systems have been launched recently, with more planned. Avanti Eco is one example of an initiative to rollout HTS service in rural communities in Africa. Avanti Eco's business model benefits from an initial contribution from the European Space Agency and links communities,

service providers, and private and/or public partners to ensure ongoing affordability through subsidy.

Another new approach is represented by new LEO and MEO technologies, which offer significant improvements over high-orbit, geostationary connectivity in terms of lower latency and higher capacity and performance. Also, the new LEO and MEO satellites being developed by the likes of OneWeb and SpaceX are mass-manufactured at a much lower cost than more traditional satellite technologies. No LEO broadband constellations have been launched yet.

Some relative newcomers who have been applying new technologies over recent years, such as O3b, have achieved notable accomplishments in international connectivity markets, but their lofty ambitions have yet to be realized.

Satellite broadband connectivity based on HTS and O3b's MEO system have proven useful in breaking bottlenecks in wholesale backhaul, as well as providing useful niche carrier wholesale, enterprise, and consumer applications. While broadband traffic carried through satellites is forecast to grow at a similar pace as terrestrial networks, it will remain as a niche segment. Because nonstationary technologies are still nascent, the future will judge their success and whether they will deliver the promise of affordable Internet for the billions of unserved people around the world.

Exploiting the Gaps—TV White Space Providing Broadband Connectivity

As noted above, TVWS refers to wireless technology that utilizes unused television channels, between the active ones, in the VHF and UHF spectrum. These are typically referred to as the "buffer" channels. In the past, these buffers were placed between active TV channels to prevent broadcasting interference. It has since been demonstrated that this unused spectrum can be used to provide broadband Internet access while operating harmoniously with surrounding TV channels. In general, the channels are 8 MHz wide, allowing bandwidths of about 20 Mbps per channel, and typically 12 to 40 channels would be available, depending on the regulatory authority. TVWS solutions are not without some controversy, as they are arguably an anomaly resulting from inefficiently allocated spectrum. It may be that, considering the cost and benefits of narrowing these buffer channels and making more spectrum available, more traditional allocations might offer better solutions for more end-users. See chapters 1 and 5 for more information.

Drones and Balloons Hovering in the Sky

There is currently significant research and development in new connectivity platforms to create alternative, long-term, last-mile and middle-mile coverage solutions. These are based on using large balloons (such as Google's project Loon) or drones (such as the Facebook supported project Aquila) that fly at high altitudes, with each unit covering large areas—from 3,000 to 5,000 square kilometers. Power is generated from solar panels, and light onboard equipment allows for much longer flight times. Both the balloons and the drones are designed to provide coverage over a large area by clustering together with other craft. Only one of the cluster needs wireless ground-based connectivity to provide backhaul connectivity to the rest of the cluster. Individual drones and balloons are designed to come out of circulation about every three months to be replaced by another allowing for continuous coverage over the target zone. Once serviced, they are then returned to the cluster. Just as with the latest ambitious LEOs and MEOs, these technologies are still at a stage where their commercial viability and appropriate market niche are still to be revealed. See chapter 5 for further details.

Technology Summary for Last-Mile Technologies

Table 2.4 compares different technologies in the context of rural access network deployment while figure 2.8 reviews the relative costs for providing access by technology.

Table 2.4: Last-Mile Technological Solutions

Technology head to head comparison

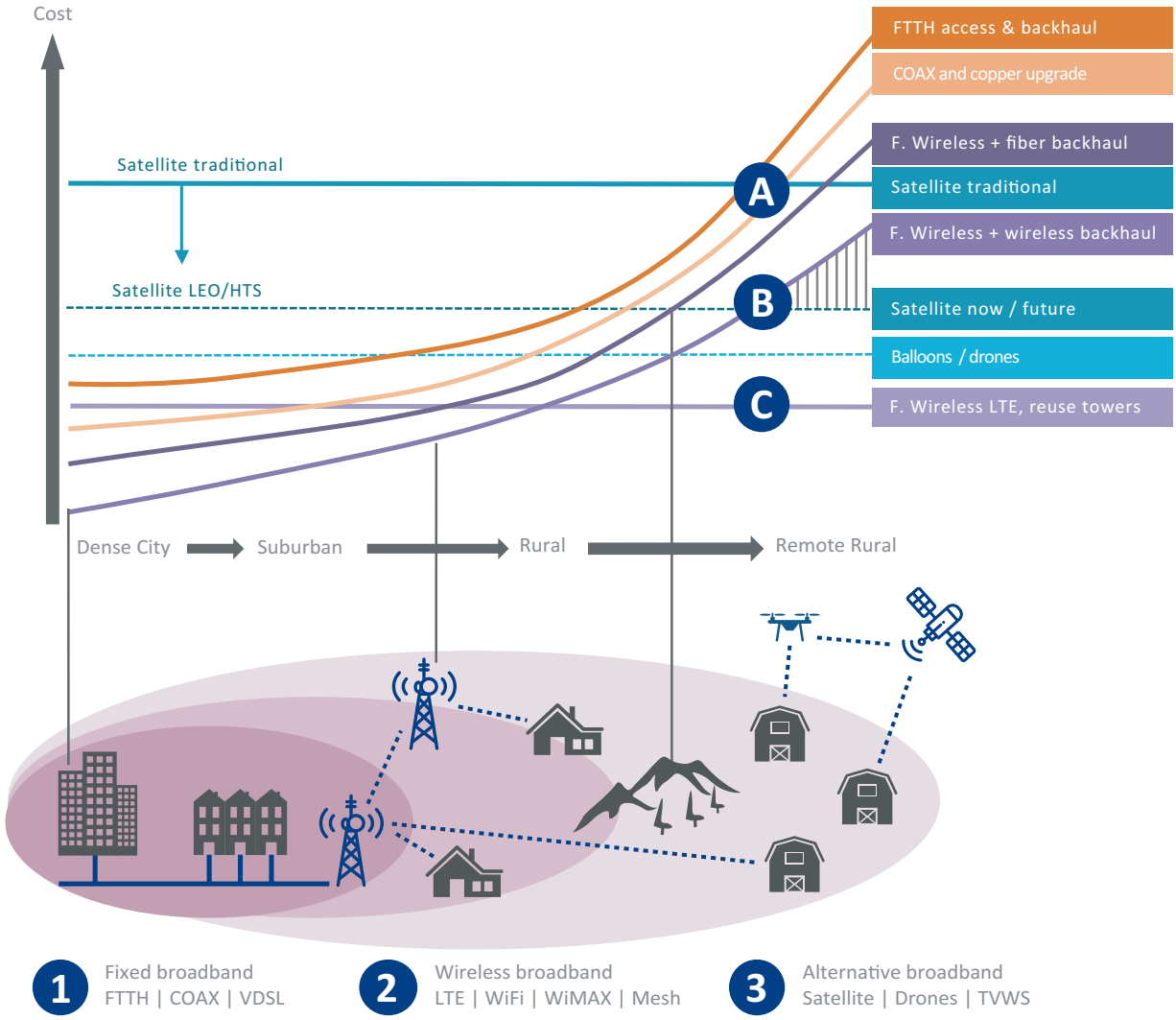
Candidate technologies for bridging the broadband divide

	1 Fixed network			2 Wireless network		3 Alternative wireless network		
Technology	**Fiber to the home FTTH**	**Cable network COAX**	**Copper based network xDSL**	**Mobile Broadband xG**	**Fixed Wireless Wi-Fi/WiMAX**	**Satellite LEO/HTS**	**Balloons / Drones**	**TV White Space**
Passive layer	Fiber optic cable overhead and trenched	Coaxial cable	Copper and mix of fiber and copper	Cellular Towers	Towers or Wireless Mesh	Satellite dish	Balloon/drone	Towers
Active layer	GPON or Active Ethernet	DOCSIS	ADSL 2/VDSL /G.Fast	3G/4G/5G With option for dedicating frequency for households	Wi-Fi / WiMAX	Proprietary satellite technology	Proprietary technology	Wireless 802.11 af
Realistic Speed & Performance	100-1000+ Mbps	30-100 Mbps	30-50 Mbps	10-50Mbps	5-50 Mbps	<30 Mbps	<30 Mbps	<30 Mbps
Future Proof? Can deliver fast broadband access*	Long term	Short/Medium term	Short term	Short/Medium term	Short/Medium term	Short/Medium term	Short/Medium term	Short term
Deployment speed	Slow	Slow	Medium	Fast	Fast	Fast	Fast	Fast
Cost to Deploy	500-1000 USD per household for urban, 1000-5000 USD for rural	400-800 USD per household for urban, 800-4000 USD for rural	300-500 USD per household for upgrade from ADSL	Dependent on the village/ catchment size, recent US FCC fund provided 400 USD per HH	Dependent on the size of the village and technology	Not avail, but advertised as affordable internet	Not avail, but advertised as affordable internet	Lower cost because of UHF spectrum and lower masts
Cost to Operate	Low	Medium	High	Medium/ High	Medium	Low /Medium	Medium	Medium
Suitability for rural deployment?	Only in the case of availability of fiber reach - usually helped by other utility fibers nearby or availability of ducts/poles to reach the village	Only in the case of availability of fiber reach - usually helped by other utility fibers nearby or availability of ducts/poles to reach the village	Only in the case of availability of fiber reach - usually helped by other utility fibers nearby or availability of ducts/poles to reach the village	Yes, but with speed limitations.Gaining popularity due to known technology and synergies	Yes, but with speed limitations. More suitable for operators that don't have access to dedicated spectrum	Yes, but with speed and latency limitations. Newer technologies are promising to resolve this problem	Yes, but with speed limitations	Yes, but with speed limitations. Useful in difficult terrains since non-line of sight

* EU currently defines fast internet connections under the term Next Generation Access (NGA) with current definition of connections >30 Mbps

Source: TMG/Salience Consulting.

Figure 2.8: Relative Costs for Providing Access by Technology



Source: TMG/Salience Consulting

3. Business Models for Infrastructure Deployment

3.1. Introduction

Technological progress and innovation tend to flourish in markets where infrastructure investors and operators can make the economic case for it. This generally means that wealthier nations and larger cities with relatively high-density households were the first recipients of the technological breakthroughs that have made broadband access possible.

Over the past several years, new business models have ensured that these technology achievements are captured for those areas that would not be served through more traditional approaches. Private actors, governments, and international organizations have been finding solutions to the challenges posed by communities who find themselves on the wrong side of the digital divide.

The central purpose of this discussion of business models is to assist policy makers in understanding the wide variety of means available to implement infrastructure deployment. It is important to keep in mind the context in which these business models emerge. Of particular significance is when and how the state participates in these initiatives. The various roles that the state plays may have both beneficial and detrimental effects. As has been discussed in other publications (for example, Kelly and Rossotto 2012), there are key steps that the state can take to focus attention, align priorities, and define its role in a positive manner within a national ICT/broadband policy. The first is to ensure that the regulatory framework facilitates deployment. Encouraging entry and competition through liberal and technology-neutral licensing, sensible spectrum policy, and open access principles where appropriate are key aspects of that framework. Lowering the cost of entry by reducing bureaucratic obstacles is another aspect of good governance that can also promote infrastructure deployment without directly intervening in the business of infrastructure deployment. These actions alone can go far towards achieving infrastructure objectives by creating the right opportunities for the private sector to marshal resources and apply expertise to make sustainable businesses out of what might be otherwise perceived as market failures.[19]

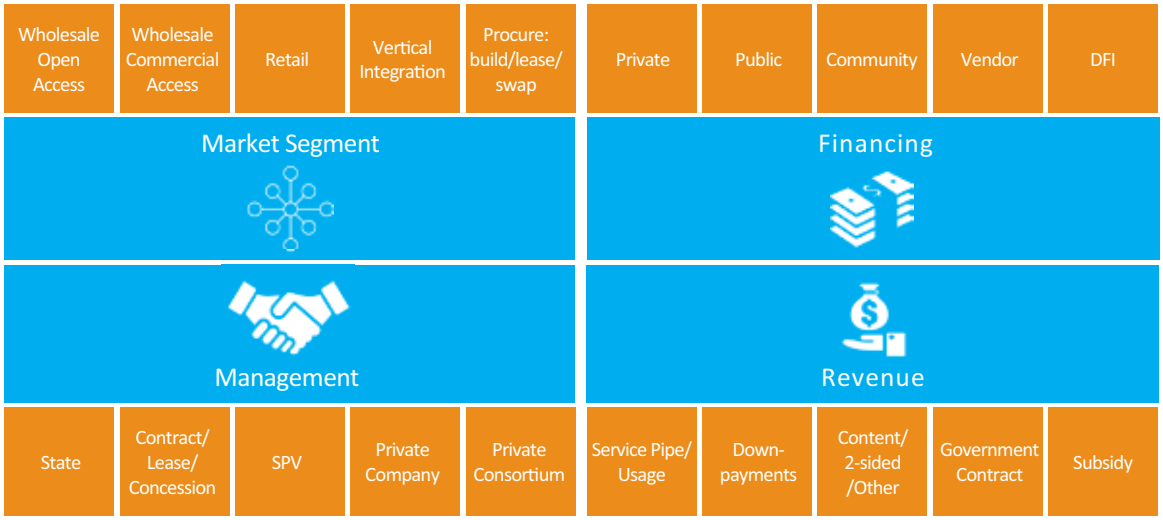
For the purpose of this report, business model means:

*The combination of **market segmentation**, **managerial**, **financing**, and **revenue generation** approaches that define the overall commercial approach to the infrastructure deployment.*[20] (see figure 3.1)

19 Market failure is a situation in which the free market is not delivering services in the quantities they are desired or otherwise inefficiently. There are two main types of market failure in broadband infrastructure deployment: abuse of dominance; and missing markets because of scarcity of capital, excessive uncertainty and/or undervaluation of benefits.

20 Some elements that are part of the traditional business model paradigm have not been included, such as value proposition and competition strategy, as these are treated as givens of the deployment objectives for each initiative and project reviewed. Furthermore, as the focus of this report is infrastructure deployment, the business model analysis will not include such areas as sales and distribution. Clearly, such considerations will be significant for a broader study of telecommunications service deployment. See, for example, the case studies of Dialog Telekom, Idea Cellular, Millicom, and Roshan in IFC 2012, IFC 2014a, and IFC 2014b as well as USAID 2017 and SSG Advisors 2016.

Figure 3.1: Four Elements of the Business Model



Source: TMG/Salience Consulting.

3.2. Market Segment

Segment Options

In terms of business segmentation for infrastructure deployment, five relevant options are identified: wholesale open access; commercial access; passive and network active equipment purchased on a wholesale basis; a fully vertically integrated approach; and segmentation based on how the infrastructure is procured.

Wholesale open access refers to a scenario in which network layers and network services are provided on an open access basis. Open access means that the terms and conditions of infrastructure service provision are offered on a fair, nondiscriminatory, transparent, and reasonable basis.[21] Open access can be applied to the physical infrastructure alone, referred to as passive layer open access (PLOA). Or it can be provided in conjunction with services requiring active equipment, referred to as active layer open access (ALOA).

In contrast to open access, "commercial access" refers to differential treatment of customers. This differential treatment may be simple profit-seeking, such as exploiting different price elasticities of customer demand, or may be conducted with anticompetitive intent. Wholesale network operators offering passive and active infrastructure services and conducting an opportunistic commercial strategy are quite common.

Another segmentation approach for an operator is to make use of passive and network active equipment purchased on a wholesale basis and limit its own infrastructure deployment to that required for retail service provision (RSP).

Wholesale and retail segments are often provided together by a single operator. A fully vertically integrated approach would combine wholesale commercial access and the retail. In concentrated markets, this increases the potential for abuse of market power. However, combining such segments may not pose competitive issues in a multiplayer market or an effectively regulated one. Many public policy driven initiatives in developing countries have supported

21 In this context, it is assumed that open access can either be imposed by regulation or adopted voluntarily.

the creation of state-controlled wholesale-only open access entities in an effort to create service-based competition without heavy regulation. This report examines a number of these.

A final dimension to market segmentation is how the infrastructure is procured. Wholesale, retail, and vertically integrated may build, lease, or acquire-by-swap their capacities.

The choice of which segmentation an enterprise pursues may be driven by market opportunity (such as the terms on which any existing segment is available) or legal restriction (such as a monopoly granted to a single passive access infrastructure provider).

Relationship to Market Structure

The relative merits or possibilities for segmentation will depend on market structure. Figure 3.2 illustrates how different segmentation approaches may appear within the context of different market structures. While not an exhaustive representation of the various market structures, figure 3.2 indicates the diversity of relationships that may develop as a result of market and regulatory circumstances:

- **Market structure 1** depicts a standard infrastructure-based competition scenario with vertically integrated competing incumbent and new entrants. The terms of network access are irrelevant in this case as operators self-supply. This scenario is often found in the early stages of liberalization, and in mature stages as well in developing countries.

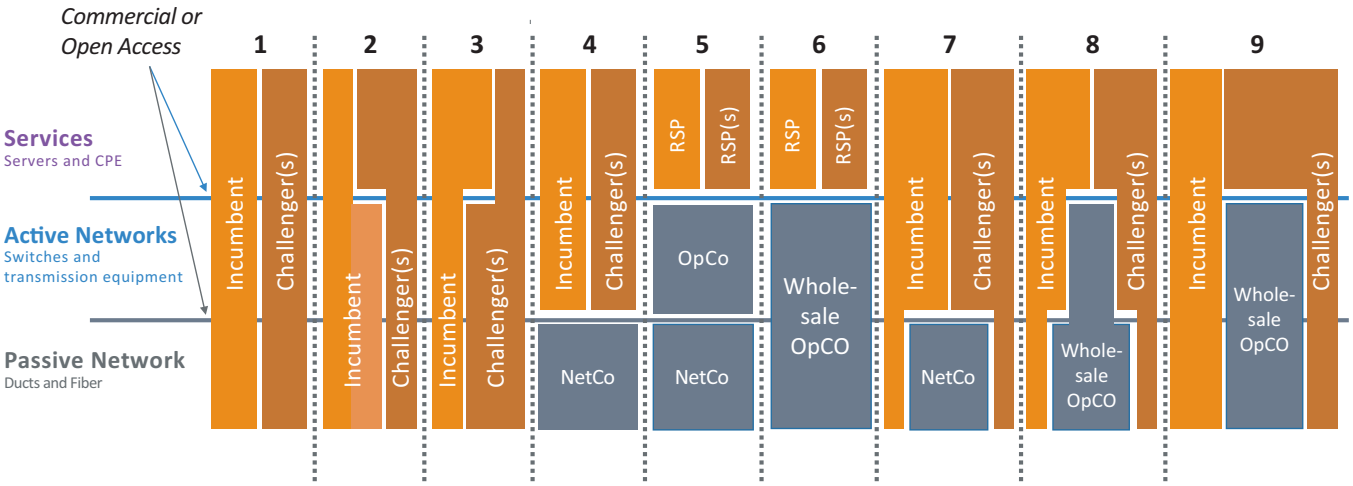
- **Market structure 2** shows a relationship in which the new entrant(s) relies on the incumbent for some network services. These services may be geographically defined (the new entrant using incumbent services in certain areas where the former does not have network) and/or network hierarchy defined (using a self-supplying core network but leasing access network from the incumbent). Where network facilities of the incumbent are a bottleneck, regulators may attempt to impose open access-type conditions to create a level playing field for new entrants.

- **Market structure 3** is found in markets in which new entrants have successfully built out their network more extensively than incumbents and can offer incumbents network services. This scenario has been seen throughout the history of successful liberalization policy with examples such as Level 3 in the United States and Interoute in Europe. In markets where state-owned incumbents are weak, this market structure may develop quite rapidly.

- **Market structures 4, 5, and 6** depict scenarios in which a single passive network operator (NetCo), a single NetCo and a single active layer network operator (OpCo), or unified single wholesale network service provider (Wholesale OpCo) supply retail service providers. These market structures develop where government creates a de jure monopoly (for example, Singapore effectively creating a Market 5 scenario), or where supply and demand conditions ("white or grey areas" in EU parlance) create a de facto monopoly environment. Given the monopoly nature of these market structures, regulators will typically insist on some form of open access conditions.

- **Market structures 7, 8, and 9** demonstrate scenarios in which the wholesale network operators are supplying the market on a nonexclusive basis. Service providers make use of the wholesale network operators' infrastructure where necessary, but also may have their own network infrastructure. As long as the government does not legally restrict entry, then market structures 4, 5, and 6 will often evolve into corresponding 7, 8, and 9 scenarios as the virtuous circle of infrastructure deployment and demand mutate market conditions and expand opportunities.

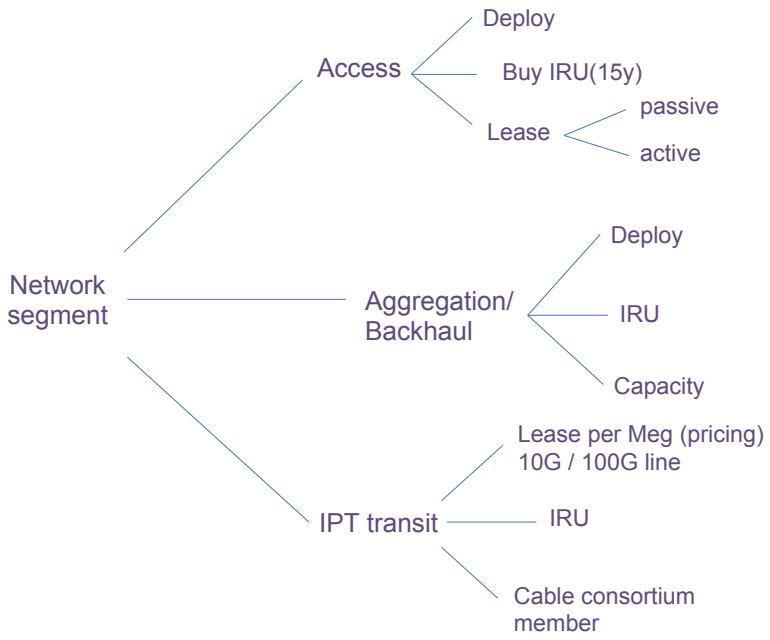
Figure 3.2: Market Segmentation and Structure



Source: TMG/Salience Consulting.

Underlying any of the structures depicted above and the myriad of multiple variants thereof are the market conditions or legal or regulatory possibilities leading to the choice to lease, share, or build across the value chain, as suggested in figure 3.3.

Figure 3.3: Varying Means of Acquiring Network Infrastructure Segments



Notes
Lease is OPEX driven vs deploy/IRU which are CAPEX (long term) solutions. Mixed approach also viable including IBC cabling.

Notes
Operator with less funding & service focus might choose capacity & aggregate service. e.g. How BT Reach offers options.

Source: TMG/Salience Consulting.

Lessons Learned

By themselves, none of these options for market segmentation is a guarantee of success. Instead, they are heavily dependent on the current and evolving conditions shaping market structure. However, on the basis of the initiatives or project reviewed in this report, some observations can be made.

The standard model for telecommunications service provision is vertical integration. Vertically integrated entities are responsible for the rollout of the overwhelming majority of broadband infrastructure in the world. Vertically integrated mobile network operators (MNOs) can be credited with the recent transformation of the ICT environment in developing countries. However, they function best in markets where robust infrastructure competition eliminates upstream dominance and the market distortions that such dominance can produce. Thus, vertical integration may not be the answer for thin markets and in nations where regulatory authorities cannot safeguard against anticompetitive behavior.

Wholesale-only plays, whether implemented on an open or commercial access basis, may or may not be a success from a commercial or public policy point of view. For example, wholesale open access fixed networks that are limited to passive infrastructure appear more prevalent where the commercial limitation to nonactive facilities can be offset by de facto or de jure dominance. In these cases, they are not generally commercially viable for a competitive infrastructure market, nor desirable when market conditions can support effective competition.

Passive infrastructure plays in the mobile sector, for example, TowerCos, have enjoyed much success as they tend to be low cost and have benefited from the evolving MNO model in which operators seek to outsource more network functionality in an effort to reduce cost and focus on retail activities.

All other things constant, wholesale OpCos offering both active and passive products enjoy a better business case than their passive only kin. There have been numerous examples of wholesale OpCos operating sustainably at the core network level in even very underdeveloped markets. Fixed access networks in rural areas typically require outside assistance to remain solvent.

In thin markets where only one open access network may be sustained, dynamic efficiency of the entity can be encouraged by requiring unbundling of active and passive products. Giving service providers the opportunity to self-provide active elements can pressure the wholesale OpCo to keep prices low and innovate as the market requires.

National wholesale mobile infrastructure can be established by the state to provide a shared 4G spectrum platform to increase broadband service competition and extend network to un- or underserved areas. Some instances, such as Mexico's Red Compartida and the second "phase" of the Rwanda NFON, have been controversial. Given the lower cost of mobile infrastructure deployment, the state should be sure to demonstrate market failure before intervening with an initiative that could crowd out private sector activity.

While recent discussion of wholesale-only models has centered around open access networks, a commercial access approach has been the standard for private sector-led wholesale plays. In these cases, even if "carrier neutral," the operator will be pricing to reflect market conditions. This approach has been highly successful in the rollout of core and backhaul networks. Successful private sector wholesale operators tend to begin to creep into profitable retail markets over time. This can cast doubt on whether they can maintain a nondiscriminatory commercial position in relation to competitors in the retail space. Finally, there are a number of successful examples in developing markets where operators selectively choose how to procure wholesale network elements

to serve retail customers. Liquid Telecom, for example, has demonstrated a strategy of minimizing network duplication in its markets by opportunistically leasing existing infrastructure, swapping capacity, and acquisitions.

The options for market segmentation, examples, and these lessons learned are summarized in table 3.1.

Table 3.1: Summary of Lessons Learned from Market Segmentation

Options		Examples	Lessons Learned
Wholesale Open Access	Passive	Oman Broadband Company, OpenNet, Even Telecom, Q.NBN, Est-Win Passive Mobile: TowerCos	Successful business cases benefit from aggregating demand of competing customers as much as possible which compensates for narrow focus on passive infrastructure However, granting exclusive rights leads to worsening performance
	Active + Passive	Chorus, Simbanet, Australia NBN, Burundi Backbone System, BoFiNet, Senegal ADIE, Gabon NFON, Lithuanian RAIN, RO-NET, Peru, European PPP fibre networks, Central African Backbone Active and Passive Mobile: Red Compartida	Significant number of successful cases when focus is the core fixed network. Failed national-level fixed network cases were examples of overinvestment, lack of political consensus or serious flaws in other aspects of the business model Cases restricted to access fixed networks in rural areas typically require additional financial support Allowing customers to purchase passive facilities (duct, fiber) as well as active products (bitstream, VULA) leads to longer run benefit to the market National wholesale mobile infrastructure (4G) have met with considerable more criticism – justification of underlying market failure may be flawed
Wholesale Commercial Access		Liquid Telecom, CSquared, Even Telecom, Baltic Optical Network, JADI	As these are private initiatives, most promising markets are selected; therefore increasing likelihood of success Entities tend to move downstream seeking new opportunities putting sustainability of "carrier neutral" mission in doubt
Retail		N/A	N/A
Vertically Integrated		Most telecoms companies, Gambian ECOWAN, Philippine NBNs, Madagascar Axian	Vertically integrated new entrant MNOs were the mechanism that brought radical change to telecommunications markets around the world at the end of last millennium and beginning of this Creating or reinforcing dominant vertically integrated entities in thin markets is ill advised
Mixed Build/Lease/Swap		CSquared, Liquid Telecom	Avoids duplicating network, increases investment efficiency

Source: TMG/Salience Consulting.

3.3. Financing

Financing Options

In terms of financing, a business model usually involves a combination of approaches. Funding telecommunications infrastructure through private equity or debt is overwhelmingly the most typical case in well-functioning markets. However, where the business cases are built on a narrower basis of profit opportunity, private funding may be problematic. In these cases, the government and communities, which tend to have different assessments of risk and required return than private investors, may have a role to play. State funding of investment in terms of equity or debt is found in the majority of the projects that are reviewed in this report. Community funding from local residents, businesses, and municipalities can play a significant role in filling gaps in the deployment of rural access networks. Vendor financing may be key where more favorable terms are offered with the capital equipment purchase itself. Finally, development financial institution (DFI) funding can be key in markets where capital of any type—private or public—is scarce.

A taxonomy of financing solutions is presented in table 3.2. Again, for any given undertaking, multiple financing tools are usually at play.

Table 3.2: Taxonomy of Financing Solutions

Private	Public	Community	Vendor	DFI
• Project bonds • Direct loans • Syndicated loans • Corporate bonds • Subordinated bonds • Listed equity capital • Unlisted equity capital • Corporate social responsibility (CSR) grants	• Equity capital • Debt capital • Subordinated loans • Minimum guarantees • Offtake agreements • Tax increment financing • Infrastructure bonds • PPP project finance	• Asset transfer (rights of way) • Community bonds • Community • Subscriber equity • Subscriber finance	• Terms finance • Lease option finance • Bank guaranteed loan • Documentary credits	• Investment project financing • Trust funds and grants • Development policy financing • Loans and equity capital to private sector • Syndications • Blending concessional finance

Source: TMG/Salience Consulting.

Lessons Learned

As with the other elements of the business models, the form of financing alone will not generally determine the success or failure of the enterprise. Nonetheless, private financing tends to be associated with faster rollouts. Private equity and debt arrangements can generally be developed in a project-specific manner to address diverse needs of potential investors, for example, strategic versus institutional.

Involvement of public financing can impose additional restrictions on return whereby conditions of state aid effectively act as a form of rate regulation. Successful cases involving significant public and/or DFI financing tend to be associated with strong private sector involvement. Separating financing and ownership among public and private entities requires care to avoid inconsistent incentives.

Community financing naturally is small scale and limited to small community projects.

Vendor financing is often found in combination with other forms of financing. Vendor only cases tend to be found either where a) the risk profile is too high for private financing and/or b) the vendor is keen to demonstrate the feasibility of new technology and will therefore assume additional risk.

A summary of lessons learned on sources of financing is shown in table 3.3.

Table 3.3: Summary of Lessons Learned on Sources of Financing

Options	Examples	Lessons Learned
Private	Liquid Telecom, CSquared, Even Telecom, Baltic Optical Network, Subsea cables, Madagascar Axian, Philippines NBN; TOP-IX; RUNE	Associated with faster rollouts; more profitable enterprise Financing can be shaped to fit the type of role and risk/return profile investor is interested in Diverse combinations deployable under PPP regimes
Public	BoFiNet, Rwanda NBFON, Senegal ADIE, Gabon NFON, Lithuania RAIN, RO-NET, OpenNet/Netlink, Chorus	More success associated with public-private financing combinations or DBO May involve conditionality (on pricing or profiitability) that limits return to investors Separating financing and ownership requires care to avoid inconsistent incentives among public and private actors
Community	LeverettNet, iProvo, Endaga, Rhizomatica, Isizwe	Limited, though often crucial, source for last mile initiatives
Vendor	Senegal ADIE, Village Telco, Kalo	Vendor finance best used as part of broader financing picture. Vendor-only cases tended to be restricted to "proof-of-concept" projects
DFI	Gambia ECOWAN, Central African Backbone	Combining DFI with private sector financing can significantly improved likelihood of success

Source: TMG/Salience Consulting.

3.4. Management and Operation

Management Options

There is a range of options with respect to management and operation. In buoyant markets, it is the private sector that generally designs, builds, operates, and owns the infrastructure. In large-scale deployments covering multiple markets, a private consortium is often established. Privately owned infrastructure may be run in a number of ways, for example, the buildout and the operation may be carried out by different commercial entities.

In thinner markets, there may be cause for some form public involvement. One form is for the government to run the management of the infrastructure as a public service although, absent the profit incentive, this often leads to poor financial performance. The state management approach (public DBO) represents an extreme case of government intervention. There are some instances in which private-sector capital and technical capabilities are so scarce that there is little or no choice but to rely on heavy government involvement.

Another option is joint management with the private sector, which is effectively supervised via a contract, lease, concession, or special purpose vehicle (SPV) with state ownership:[22]

- **Contracting, lease, or concession models** are approaches in which the state cedes (increasing degrees of) management control to a private contractor. In a service or operate and maintain contract the state pays the contractor to run an existing infrastructure (or a defined service within the overall operation of the infrastructure). Under a lease, the state funds the buildout of the entire network, which is then provided on a set-term lease basis and operated by a private contractor. The operating expenses are borne by the contractor, which also collects the wholesale revenues. In return, the contractor pays the leasing fees of the network to the public sector, which remains the owner of the assets. Under a concession, the private contractor may fund the infrastructure build itself.

- The **special purpose vehicle (SPV)** model is a truly integrated cooperation between various public and private stakeholders that have created the new joint venture. Governance, along with the ownership and funding, is shared among public and private entities.

The roles of the public and private sector may change over time as well with, for example, the government playing an initial role to design, construct, and operate until such time as the market opportunity clarifies and then commercializing the entity. Conversely, the private sector may initially build and operate the network before transferring to the public sector. The Tonga submarine cable initiative is one example in which the public sector initiated and supervised the construction of the cable and ran the company for the first few years until privatizing in 2017.

Lessons Learned

Private sector management and operation generally proves the most efficient: rollouts tend to be faster and profitability higher. State management is always accompanied by public financing and public ownership, as the private sector and even DFI tend to shy away from state-managed entities. Because the public sector finances, manages, and owns the

22 For more detailed discussion see, for example, the typology in the World Bank's PPP Reference Guide at https://pppknowledgelab.org/guide/sections/6-ppp-contract-types-and-terminology.

network, all of the financial, operational, and commercial risks are borne by the government. There is a long list of public DBOs that have experienced serious implementation problems, including Gambia ECOWAN, Senegal ADIE, Q.NBN in Qatar, and the Australian NBN.

For the state management model to be a success on a national scale, an unusual amount of political cohesion, intragovernment coordination and leveraging synergies may be required (for example, other public utilities to support the creation of the new utility) to facilitate and lower the cost of deployment, such as in the case of Oman Broadband Company. In Lithuania, the RAIN project benefited from a high level of technical competence within the sector ministry, an attribute that is not found in many governments in those developing nations with scarce human capital of this nature. Oman and Lithuania may indeed be "the exceptions that prove the rule" in favor of private sector management for infrastructure deployment in developing countries.

Where public participation is required in the management of deployment and operation of infrastructure, initiatives have benefited from the expertise and resources of the private sector through leasing, concessions, or a PPP SPV arrangement. A summary of lessons learned on management options is shown in table 3.4.

Table 3.4: Summary of Lessons Learned on Management Options

Options	Examples	Lessons Learned
Private Company	Philippines NBN, Ufinet, Interoute, Liquid Telecom	Associated with faster rollouts; more profitable enterprise
Private Consortium	Subsea Cables (except MainOne), WIOCC, Baltic Optic Network, JADI	Particularly useful in the context of multiple-country cross-border cases where leveraging international partners important
State	Gambia ECOWAN, Senegal ADIE, Rwandan NBFON, Q.NBN, Oman Broadband Company (OBC), Lithuanian RAIN, Australian NBN, Tonga Submarine	Majority of cases have not lived up to expectations
Lease/ Concession	Red Compartida, Simbanet VLS, Peru National Backbone, Gabon NFON, Lithuanian RAIN, Chorus UFB, RO-NET	Private sector tends to operate and manage commercial network better
SPV	Liberia ACE, Central African Backbone, Burundi Backbone System	Mixed ownership and operation proven successful in capital scarce environments

Source: TMG/Salience Consulting.

3.5. Revenue Generation

Sources of Revenue

The approach to revenue generation forms a fourth element to the business model. If the market is buoyant enough, standard service pricing on a capacity or usage basis may be adequate to achieve business case objectives. However, telecommunications service pricing has long exhibited schemes designed to attract low-usage or high-cost consumers "on-net." Two-part tariffing (subsidized access pricing, combined with profit-making usage) is a traditional market solution to the problem. Regulation in the sector as well has often required price averaging.

For larger scale infrastructure deployments or where service takeup might be protracted, further revenue innovation may be required. Down payments are a standard feature of subsea cables, for example. Where government services will be provided, government volume commitments or down payments may be another solution or part of a menu of the solutions.

At some point, however, higher cost and/or less-affluent demand render internal revenue solutions inadequate. Revenue subsidies are a typical response in these cases. Revenue subsidies can simply be recurring grants or payment waivers (for example, tax holidays) provided to the service provider or can be directed at stimulating demand through vouchers to consumers.

Finally, in some community contexts in developing markets, there are less-traditional approaches:

- Service providers require minimum purchase of specific content;
- Two-sided market solutions in which, for example, the end-user is subjected to advertising while using the service, thus advertising assists in the funding of the infrastructure rollout; or
- private actors, pursuing a "double-bottom line," effectively subsidize operations without the intention of recouping losses in service profitability (even in the long run). Instead, they expect value being created in brand or unrelated markets.

Lessons Learned

Virtually all infrastructure deployments have a traditional "pipe and usage" offering as a major component of their revenues. Down payments provide initial cash flow and reduce startup risk for major infrastructure projects. Advance government payments have proved key to a number of national backbone projects, but their significance is limited to the degree that government will utilize the network.

Service provider subsidies are best implemented in the context of a tender to select the least-cost provider. Subsidies should be limited in nature or can lead to inefficiencies associated with soft-budget constraints.

Economists have argued that subsidies are better provided to the end-user to allow demand to drive the allocation of resources. Consumer subsidies are also more appropriate in competitive environments where there is the opportunity to select among service providers.

Finally, with regard to community networks involving low deployment cost, a wide range of revenue possibilities open up. This in turn leads to more opportunities to supply needed infrastructure to low-income locations.

Table 3.5: Summary of Lessons Learned on Revenue Generation

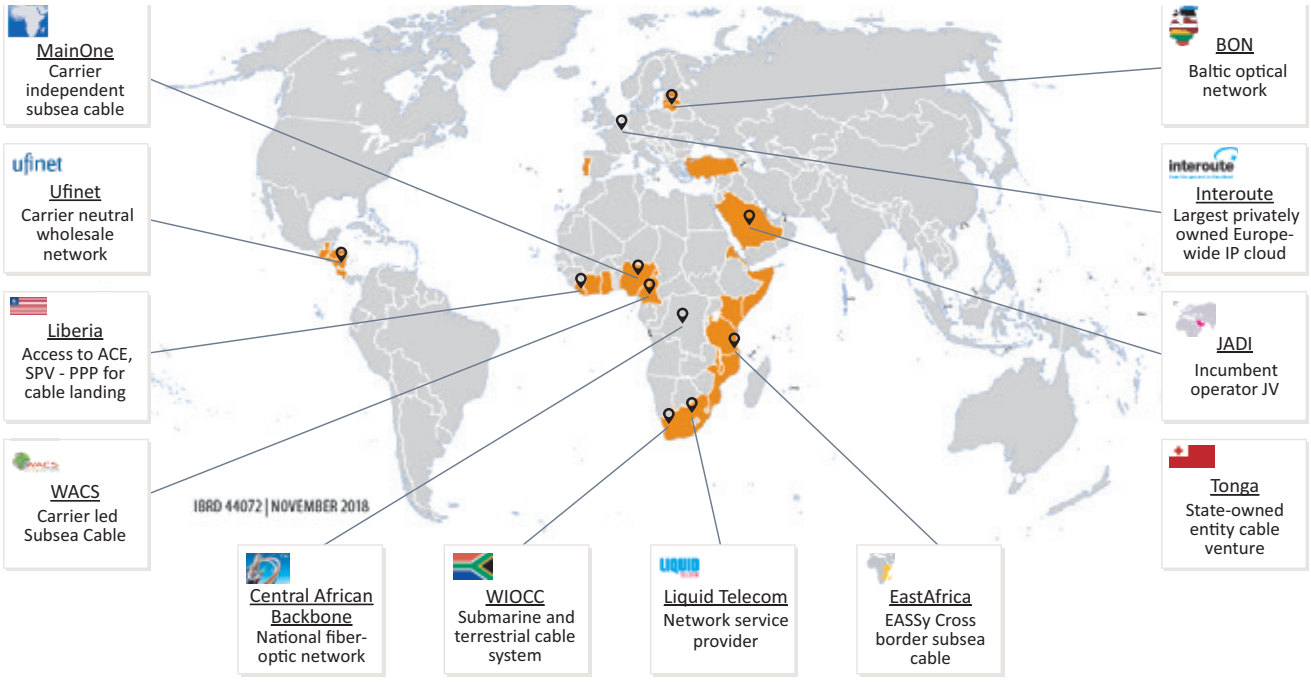
Options	Examples	Lessons Learned
Pipe / Usage	Subsea cables, Baltic Optic Network, Liquid Telecom, Interoute, JADI, RCN, Ufinet, WIOCC, Gambia ECOWAN	Standard pricing for infrastructure services
Down Payments	Liberia ACE, Subsea cables in general	Substitutable for a capex grant, reduces startup risk
Government Contract	Simbanet, BoFiNet	Can derisk revenue streams, but limited to what services government can benefit from or specific government budget
Subsidy	To service providers: Germany Länder, Chorus UFB, Rhizomatica To consumers: Airband, Sugarnet	Most effectively administered through competitive tender or as fixed figure. Ongoing subsidy may incentivize suboptimal behavior Demand side subsidies, for example, vouchers may be a more economically efficient and competitively neutral approach to subsidy
Content/2-sided/2-Bottom line/ Other	4Afrika, Concero, Vodafone Instant Network	Not widespread and tends to be found in last-mile projects, where specific end-user benefits more obvious

Source: TMG/Salience Consulting.

4. Crossborder and National Fiber-Optic Network Business Models

Crossborder infrastructure can be defined as the connectivity established between the national networks of two or more countries. This chapter addresses subsea and terrestrial fiber-optic cables. Traditional satellite and crossborder microwave technologies are not addressed here as these low-capacity connectivity options are not considered effective substitutes for fiber-optic cables and are currently second-best options for broadband service deployment. New satellite technologies in the context of the last mile are explored in chapter 5. Figure 4.1 summarizes the projects reviewed for this report.

Figure 4.1: Crossborder Projects



Source: TMG/Salience Consulting.

4.1. Subsea Crossborder Projects

Submarine projects can be thought of as a substitute for terrestrial connections made attractive by lower cost of covering very long distances. Consider, by way of example, the recently launched SEA-ME-WE-5 project shown in figure 4.2.

Figure 4.2: SEA-ME-WE 5 Route

Source: SEA-ME-WE.

A terrestrial equivalent linking Melaka, Malaysia, to Toulon, France, would have to cross over 20 countries, confronting high civil works' costs and diverse local market constraints in each jurisdiction. By contrast, a submarine connection can stretch from Malaysia to France almost exclusively in international waters (with the Egypt crossing the only exception). As a result, terrestrial cable laying proves substantially more expensive than the subsea equivalent to provide similar capacity.

Once the route is defined, the initiator(s) will generally endeavor to enroll representatives of countries along the way, with several objectives in mind:

- maximizing the number of landing points and, therefore, increasing business opportunities;
- creating redundancies on multiple routes;
- reducing the cost of ownership; and
- facilitating crossing of unavoidable territorial waters.

Except for a small number of private "narrow" ownership projects, for example, MainOne, submarine cables are usually financed, rolled out, and managed by large consortia. Historically, this type of arrangement has been established to help incumbent national telecommunications networks contribute to a shared platform to provide lower-cost, higher-quality international voice and data communication services. More recently, new private operators and groups have also joined existing consortia, with a view to either acquiring international broadband capacity for their own operations (for example, MTN in the West African Cable System, WACS), or to be able to offer competitive wholesale solutions to others (for example, TTCL in the Eastern Africa Submarine System (EASSy) (see box 4.1).

Capital costs in these ventures are entirely borne by the consortium members, in accordance with their ownership agreement, usually referred to as a Construction and Maintenance Agreement (C&MA). Each member is allocated a given unit of capacity, Minimum Investment Units (MIUs) or Minimum Assignable Unit (MAUs), according to their investment participation.

In some cases, each consortium member is classified as Tier A, B, C, D, or E and given an agreed-upon discount. Table 4.1 gives an example of how discounts can be structured, in order to incentivize a bigger group to maximize their contribution, and therefore their involvement.

Table 4.1: Example Consortium Tier Structure

Tier	Initial Investments ($ millions)	Price Ratio	Cost per STM1 End-to-End ($ thousands)
Tier A	> 50	1.0	214
Tier B	40 to 50	1.2	256
Tier C	30 to 40	1.4	299
Tier D	15 to 30	1.7	363
Tier E	< 15	2.0	428

Source: TMG/Salience Consulting.

As shown in table 4.1, the capacity unit cost for a Tier C member would be 1.4 times higher than what a Tier A member would pay. This principle can also encourage smaller parties to collaborate so as to present a single high tier member, therefore gaining access to cheaper capacity.

For a typical consortium, in addition to the initial investment, each operator contributes to the operating and maintenance (O&M) expenses at cost, according to its personal share of the cable.

Each operator can activate its allocated MIUs/MAUs upon request to the consortium central office. Doing so inevitably involves the use of some services provided at landing stations, leading to additional rental charges, which are preagreed within the C&MA.

These landing stations are generally not included within the total cable investment. Landing partners (typically, but not always, consortium members) incur the cost of building and operating landing stations. These costs are then compensated by the consortium, either in one payment on the Ready-For-Service (RFS) date, or over the lifetime of the cable. In the latter case, each connected operator is charged with a monthly contribution towards the landing station it uses.

The consortium will generally create a specific internal committee or unit in charge of the finance side of the cable deployment and put in place a complex mechanism to ensure total investment recovery from the landing partners.

Finally, a consortium rarely has a financing role to play, and the consortium itself generally cannot incur any debt. Thus, consortium members must seek financing separately if necessary.

There are four primary channels of finance that are characteristic of subsea cable projects:

- project financing provided by DFIs, government export credit agencies, or conventional banks;
- vendor financing in the form of short-term favorable payment terms on long-term loans backed by the vendor's financial institution;
- documentary credits, which are debts provided by a bank or a financial institution for the sole purpose of the acquisition of a specific good—with payments from the bank directly to the vendor; and
- down payments from the pre-RFS and Indefeasible Rights of Use (IRU) sales which reduce the need for other financing.

A counter-example to the typical consortium approach to subsea cable projects is MainOne, which provides connectivity between West Africa and Europe. MainOne began as a comparatively small operation providing connectivity for service providers in Ghana and Nigeria. It has compensated for this small scale by implementing a number of prudent business model attributes. For example, it has largely outsourced significant parts of its deployment to specialized partners and found preferential funding

through the Pan-African Infrastructure Development Fund. Furthermore, it has gained scale through pursuing a different segment strategy: providing metro fiber in Nigeria and Ghana as well as datacenter, cloud, and managed-security services.

A key contributor to the overall value of a subsea cable to national economies is how the cable landing bottleneck is implemented. There have been numerous cases where the achievement of the subsea cable deployment has not been fully realized because of the fact that the cable landing was monopolized by a vertically integrated national incumbent. One of the significant innovations that was implemented along the ACE cable (for example, in Liberia, São Tomé and Príncipe, The Gambia, and so on) is that SPVs were created with financial contributions from the private and public sectors with the mission of providing access to subsea cable capacity to all service providers on an open access basis. Public sector participation was often assisted by World Bank financing on favorable terms. These SPVs generally have little incentive to behave anticompetitively and have led to a fuller flow through of subsea cable benefits to domestic markets.

Similar to these SPV landing station initiatives are recent projects in the Pacific, such as in Tonga, where public-private arrangements are operating links to bigger subsea cable systems, for example, Southern Crossing. Again, these subsea cable companies provide domestic service providers open access to international networks at reasonable rates. DFI involvement has been critical for these projects given the high startup costs and uncertain demand.

Box 4.1: EASSy – Eastern Africa Crossborder Subsea Cable

Conceived in 2003, the Eastern Africa Submarine System (EASSy), is a submarine cable system linking Sudan to South Africa, via Eastern African countries including: Sudan, Djibouti, Somalia, Kenya, Tanzania, the Comoros, Mozambique, Madagascar, and South Africa.

From inception, EASSy was structured as a consortium of public and private operators, though mostly ruled by private institutions.

The supply contract, which represents the beginning of the two-year deployment, came into force in May 2008. The Ready-for-Service date was celebrated in September 2010.

During the following year, the consortium members agreed on two consecutive upgrades, raising the overall capacity of the cable to 4.7 Tbps.

Designed by Alcatel-Lucent, the system comprises two fiber pairs configured as a flat ring for higher resilience that run over 10,000 kilometers and land at nine different stations. Like most subsea cables, EASSy uses DWDM technology, transmitting SDH frames. The flat ring architecture, also referred to as a collapse ring, enables full protection of the system in case of rupture of one branch or any termination card or equipment at the landing station.

EASSy's consortium members are all operators of terrestrial cables, and/or members of other subsea

consortium, providing EASSy with extensive onward connectivity around and throughout Africa, and towards Europe and the Middle East.

With no direct involvement of any governmental bodies, except for five incumbents, EASSy cannot be considered as a flagship PPP endeavor. However, WIOCC, the consortium member with the highest share of the project (28 percent)—well ahead of the second highest MTN with 15 percent—is itself comprised of 14 smaller telecommunications players (see figure 4.3). These include the Lesotho Communications Authority, which seeks to contribute to the development of its telecommunications sector in a country with one of the lowest broadband penetration rates worldwide.

For more details, see appendix, page 136.

Figure 4.3: WIOCC Shareholding with EASSy Consortium

WIOCC Shareholders
Botswana Telecom
Dalkom Somalia
Djibouti Telecom
Gilat Satcom
Lesotho Communications Authority
LPTIC Libya
Onatel Burundi
Seychelles Cable System Company
TDM Mozambique
Telkom Kenya Orange
TelOne Zimbabwe
UCOM Burundi
Uganda Telecom
Zantel

EASSy Consortium Members	
WIOOCC (28%)	British Telecom
Neotel	Saudi Telecom
MTN Group	Etisalat
Bharti Airtel	Telma
TSA - Vodacom	Zamtel
Comores Telecom	Mauritius Telecom
Botswana Telecom	Sudatel
France Telecom	TTCL

Source: WIOCC; TMG/Salience Consulting.

WIOCC's initial mission was to open the most remote part of Africa to affordable communications. This is well summarized in WIOCC's current vision: "To make an enduring contribution to Africa's communications." It has indeed itself invested or indirectly led to further investments in adjacent markets in the region.

One of the key success factors behind EASSy was the scarcity of alternate solutions for international connectivity from Eastern African countries, as well as the growing rate of many of these economies. For most of the member countries, accessing European traffic meant being routed to other countries via terrestrial cable, transiting to India via SAFE or IOX and eventually completing the journey on one of the numerous subsea cables linking India to Europe. EASSy generated an immense opportunity for affordable and reliable international connectivity to the western world, essential to the growth of these countries.

Challenges to the immediate success of the project did arise. EASSy suffered from setup issues typical in a large consortium. Addressing the concerns of each consortium member was difficult both because of differences in each member's objectives and because the members were also partners, client-providers, and competitors outside of the cable project. Such a complex set of relationships can make it challenging to reach agreed resolutions.

4.2. Terrestrial Crossborder Projects

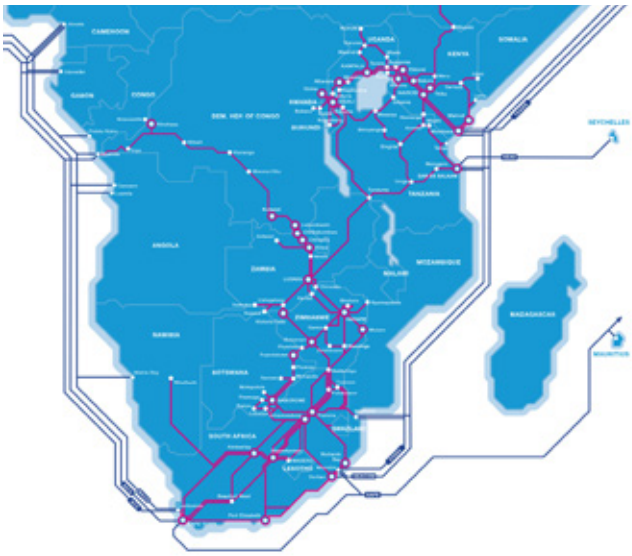
While submarine projects are intended to resolve long-distance crossborder cost issues through cheaper rollout, terrestrial crossborder projects tend to follow a different conceptual path. These projects often appear as a series of bilateral interconnection endeavors. In particular, initiatives have been based on:

1. the organic growth of one small player extending internationally (for example, Liquid Telecom, Interoute, and Ufinet);
2. the interconnection of various independent networks across multiple countries (for example, Baltic Optical Network, JADI, RCN, crossborder WIOCC); or
3. the product of large development funds projects with regional reach (for example, Central Africa Backbone).

In the case of a small player extension, the private operator may start either from a national network initiative (for example, Liquid Telecom in Africa) or a crossborder intention from inception (for example, Interoute in Europe).

Liquid Telecom, started in Zimbabwe, and remained a national network for its first 10 years. Once it had reached a certain level of maturity and financial stability, Liquid (called Econet at the time) searched for growth in neighboring countries and initiated international expansion through acquisition with the goal of increasing value, capitalizing on growing foundation and experience, and reaching out to new territories (see box 4.2). Interoute's early history was challenging, having been born as market liberalization was sweeping across Europe. It fell victim to the burst of the telecommunications bubble and capacity overbuild in the early 2000s, but kept its ambition to link all the major business centers in Europe with a carrier-neutral crossborder wholesale and enterprise play. This type of international growth generally materializes through acquisition of operators in other countries, or through a series of greenfield license acquisitions. Consequently, these types of large crossborder terrestrial operators tend to be characterized by sophisticated financial strategies and tax-optimized structures.

Figure 4.4: Liquid Telecom and Interoute Network Maps



Source: Liquid Telecom and Interoute.

Ufinet followed a similar expansion as Liquid Telecom and Interoute but has been based primarily around telecommunications assets associated with gas and power utilities. Ufinet was born of the commercialization of telecommunications assets of Spanish natural gas utility Union Fensosa. It then expanded into central America through acquisition and new fiber investments. The company has positioned itself as a carrier neutral core and crossborder network service provider and successfully benefited from market liberalization.

Large crossborder networks can often be formed by connecting various existing national networks. Two initiatives in the Middle East—the Jeddah-Amman-Damascus-Istanbul (JADI) cable and the Regional Cable Network (linking UAE, Saudi Arabia, Syria, Jordan and Turkey)—were born of efforts to reduce existing crossborder bottlenecks in the region. The Baltic Fiber Network is the linkage of the telecommunications networks of power utilities in the three Baltic states of Estonia, Latvia, and Lithuania. The network is an alliance rather than a commercial entity. They have found a market opportunity to offer services to customers across borders to better compete against traditional telecommunications players.

WIOCC represents a clear example of finding regional synergy and scale through consortium. As mentioned above, these 14 small operators, private and public, created a consortium capable of taking the bigger shares of EASSy, WACS, and Europe India Gateway (EIG). Their cooperation lead to terrestrial expansion, and WIOCC now runs a core network running from South Africa to Kenya.

The third type of crossborder terrestrial network tends to be initiated and financed by DFIs. Generally, these types of cable projects have particularly unattractive economics and are feasible only through DFI initiative. This type of project naturally bears a high financing risk and has little attractiveness to typical investors. As such, these projects must be seen in the context of an attempt to capture broader economic benefit rather than as market-based endeavors. The Central Africa Backbone represents an example of this type of venture, where the World Bank has attempted to bring fiber connection to the poorest countries in the world. The backbone runs from Chad to the Democratic Republic of Congo and, once finalized in 2019, will have taken more than 10 years to complete, mainly because of financing complications.

Large development fund projects tend to be built entirely from scratch. Association with an equipment manufacturer is not uncommon, as it serves the role of a flagship project for the vendor, while enabling attractive vendor financing, therefore reducing the risk taken on by the initiating DFI.

Table 4.2 summarizes the high-level attributes of the business models of these crossborder initiatives. Although there is variation as discussed above, there is a great deal of uniformity among the business models at this top point of the infrastructure value chain. As we descend to the last mile, the challenges become more difficult and the business models become more diverse and innovative.

Table 4.2: Business Models in Surveyed Crossborder Networks

Case	Segmentation	Financing	Management	Revenue Generation
EASSy	Wholesale commercial access subsea cable	Consortium, DFI	Consortium	Traditional, volume commitment
MainOne	Wholesale commercial access, carrier neutral subsea cable	Private and Public	Private	Traditional, volume commitment
WACS	Wholesale commercial access subsea cable	Consortium	Consortium	Traditional, volume commitment
Liberia ACE landing	Wholesale open access landing station	Private, Public, DFI	SPV	Traditional volume commitment
Tonga Subsea Cable	Wholesale open access sub-sea cable and landing station	Public, DFI	Initially State, now Private	Traditional
Liquid Telecom	Wholesale commercial access carrier neutral terrestrial crossborder	Private	Private	Traditional
WIOCC	Wholesale commercial access terrestrial crossborder	Private	Private	Traditional
Interoute	Wholesale commercial access carrier neutral terrestrial crossborder	Private	Private	Traditional
Central Africa Backbone	Wholesale open access	DFI, Public	PPP	Traditional, subsidy
JADI	Wholesale commercial access terrestrial crossborder alliance	Private	Private	Traditional, volume commitment
BON	Wholesale commercial access carrier neutral terrestrial cross border alliance	Private	Private	Traditional
Ufinet	Wholesale commercial access carrier neutral terrestrial	Private	Private	Traditional

Source: TMG/Salience Consulting.

Box 4.2: Liquid Telecom: African Crossborder Terrestrial Cable

Created in 1997 and initially known as Econet Satellite (Zimbabwe), the company became Liquid Telecom in 2004, establishing its first large crossborder African terrestrial network in 2009. Privately financed in its entirety, Liquid Telecom has rapidly become an essential broadband infrastructure provider in eastern, central and southern Africa.

With over 50,000 kilometers of fiber across 15 countries, Liquid is the first regional fiber ring of the continent.

Liquid Telecom has increased its footprint by combination of network expansions and large acquisition, mainly financed through debt raised at group level.

Liquid extended most of its reach through acquisition (Zimbabwe, Kenya (KDN), Zambia, Rwanda (Rwandatel), Uganda, and so on) but also creates joint ventures with utility companies, especially those reaching the lucrative mining industry (the Copperbelt Energy Corporation in Zambia, the Botswana Power Company, the Kenya Electricity Transmission Company, and Société Nationale d'Électricité (SNEL) in the Democratic Republic of the Congo). However, once in a country, Liquid works to improve networks with a fair share of deployment.

Finally, with a large variety of such partnerships, Liquid Telecom's strategy also led to diversifying its portfolio of services. The company now offers not only broadband connectivity, but also products as varied as IP transit, EPL, datacenters, leased lines, VSAT broadband, enterprise IP VPN, ethernet VPN, hosting, and even some retail services. Originally more or less a carrier neutral wholesale play, this diversification enables a comprehensive product offering, but may raise questions about its ability to provide nondiscriminatory wholesale services in the future.

For more details, see appendix, page 140.

4.3. National Backbone Network Projects

A national backbone is the collection of high-capacity links and nodes connecting dispersed regional and local networks throughout a country. These links function to aggregate and route traffic among regional and local networks as well as to and from international markets.

Given adequate volume levels and competition, there may be more than one backbone network extending to large and small cities. In these markets, the volumes of traffic are adequately high to justify parallel and extensive backbone investments and competing operators with access networks will generally have their own core or backbone network.

In less developed countries, it is common to find only one national backbone, often with limited reach. Just as investing in access networks gives rise to additional backbone capacity requirements, building backbone facilities can promote the deployment of access networks. In the past two decades, policy makers in developing countries have often facilitated the construction of national backbone networks to relieve access network providers of the additional cost associated with linking diverse local networks. This additional cost may take the form of: a) having to pay an incumbent for existing backbone facilities at prices that may not be cost based; or b) building one's own facilities to carry what may be a small share of total national backbone traffic.

This chapter examines the business models that have been used to deploy such backbones in cases in which the dominant provider has not provided reasonable terms for access or in which adequate infrastructure is simply absent.

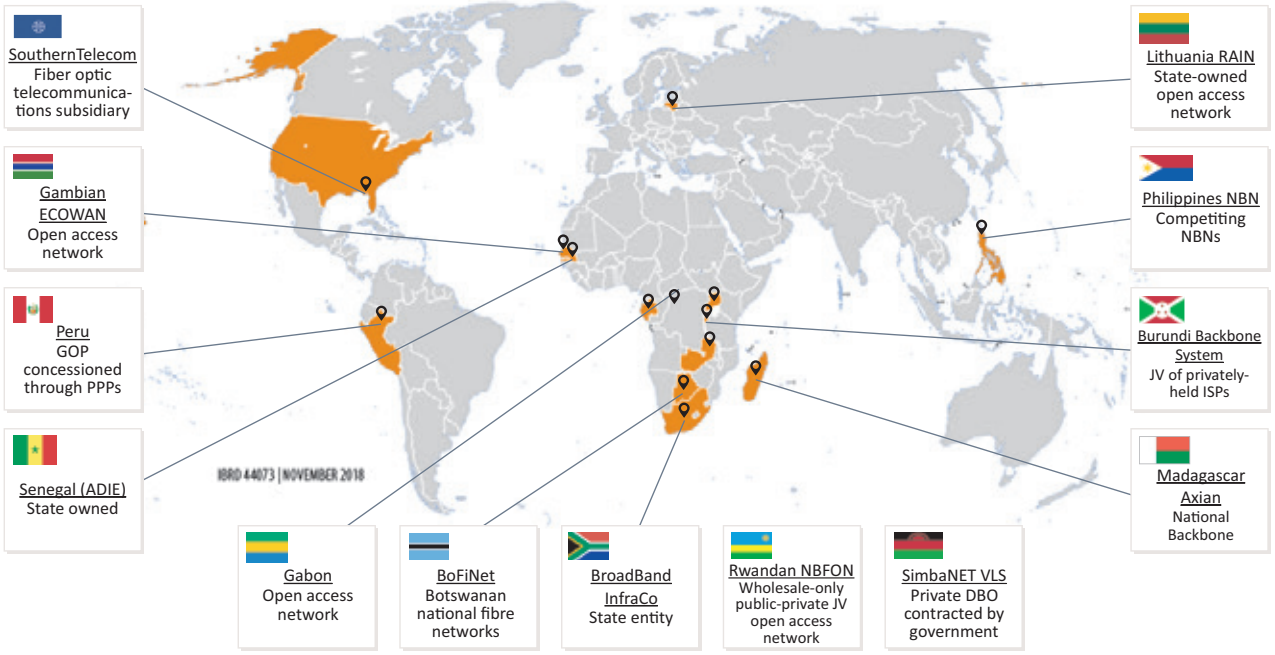
In terms of technology, although alternatives to fiber optics exist—in particular microwave and satellite—these have not proved realistic for broadband transmission. Traditional satellite transmission is slow and can be vulnerable to climatological conditions. New satellite technologies in the context of the last mile are examined in chapter 5. Microwave, while often having a role to play in thin routes, is generally not appropriate for high-speed backbone requirements.

As one moves down the infrastructure supply chain from crossborder connectivity to national backbones, the economics of network deployment can become more problematic. In the developing world, there are likely to be regions that do not generate the volumes of traffic, even if aggregated, to convince private actors to invest. It is therefore not surprising that a wider range of business models are beginning to emerge in this space as actors seek more creative means to make an investment case (see figure 4.5).

In **Botswana**, the effort to expand and upgrade the national backbone network began with a restructuring of the incumbent state-owned company, Botswana Telecommunications Corporation (BTC), in advance of its privatization. In doing so, the government had two objectives: 1) retaining what was perceived as a national strategic asset in state hands; and 2) reducing the market power of the incumbent associated with its vertical monopoly in the sector. Thus, the international connectivity capacity in EASSy and the WACS subsea cables and national backbone assets of BTC were transferred to BoFiNet in advance of the former going public. Its creation was a compromise between the desire to privatize the incumbent (BTC) and the government's wish to keep certain strategic assets under state control. BoFiNet operates on an open-access basis.

Gabon chose a different route: finding an international firm to build and operate the Gabon National Fiber Optic Network. The government spent some $60 million to construct the network, with the assets fully in state ownership. The state hired the French firm, Axione, as the management partner.

Figure 4.5: Selected National Backbone Projects



Source: TMG/Salience Consulting.

Significantly, this is not a long-term concession, but rather a medium term operating contract of seven years. Support is ongoing, and the government of Gabon continues its involvement in the financing by covering CAPEX, while the network operator covers only OPEX. As of 2017, the operation of the landing station is successful, but the backbone linking over 20 cities and villages is still in test phase. Services offered will include backbone transport, dark fiber leases, colocation, and transit services to mobile operators and Internet service providers (ISPs), provided on an open-access basis.

Yet another successful PPP approach found in Africa is SimbaNET in Malawi. Advised by the World Bank Group, the government of **Malawi** ran a competitive tender for a 10-year contract to design, build, and operate a national backbone. SimbaNET deployed 900 kilometers of fiber and a "virtual landing station" within the landlocked nation. This virtual landing station includes the meet-me and network operations center (NOC) facilities one would expect at a subsea cable landing station but is located in Malawi. SimbaNET contracts for connectivity to the actual cable landing stations for the TEAMS, EASSy, SEACOM, and WACS subsea cables via Tanzania and Zambia. To improve the business case, the government offers an offtake arrangement guaranteeing a critical level of sales to the new entity. SimbaNET is required to offer services on an open-access basis.

The **Lithuania** RAIN initiative is similar to BoFiNet in the sense that the state has retained both ownership and management of the company. The Ministry of Transport and Communications exercises the state's ownership function. A state company "Placiajuostis internetas" manages the network. It does, however, outsource the operational maintenance of the network to private contractors. Also, similar to the other national backbones discussed above, RAIN facilities and services are provided on a nondiscriminatory basis. There is also a subsidy involved that arises from the fact that prices are set at a level that ensures that retail broadband services in the targeted

areas can be provided at a price similar to retail levels in urban areas. State assistance comes in the form of European Regional Development Fund (ERDF) funding and the Lithuanian national budget.

Another notable case is that of **Madagascar**. The national fixed line incumbent, Telma, was privatized in 2004 through acquisition by a local, horizontally diversified company, Axian. Axian has interests in the financial services, real-estate and energy sectors as well as telecommunications. In the past few years, Axian has built out 8,800 kilometers of fiber-optic cables nationwide in addition to rolling out fiber and mobile access networks as well as operations in Reunion-Mayotte and Comoros. In addition to Telma, Axian operates TowerCo of Madagascar (ToM). Axian's Telma and ToM are two of four recipients of subsidies to buildout 65 telecommunication towers in remote areas, a deployment that promises to provide service to more than two million new subscribers. With this subsidy, Telma, ToM, Camusat, and Orange, are responsible for building, owning, and operating shareable infrastructure under open-access conditions, with nondiscriminatory and low-cost pricing.

An interesting case from the **United States** is Southern Telecom. Southern Telecom is a vertically integrated (generation, transmission, and distribution) power company operating in Mississippi, Alabama, Georgia, and Florida. The company took advantage of new rights given to utilities under the 1996 Telecommunications Act to provide capacity to multiple public telecommunications service providers. In addition to expanding its wholesale network, Southern Telecom has expanded into private mobile network service provision for public and private sector clients requiring coverage to remote locations in the southeastern states.

Finally, it is worth mentioning the **Philippines**. The Philippines is one of the few developing countries in the world with competing national fiber-backbone infrastructure: PLDT's Domestic Fiber Optic Network (DFON) and Globe Telecom's Fiber Optic Backbone Network (FOBN) and the National Grid Corporation of the Philippine's (NGCP) national private telecommunication network. The government's priority is therefore focused at the middle- and last-mile level.

However, it is considering how to best facilitate these backbone networks to support programs to rollout middle- and last-mile networks in unserved and underserved areas. This includes: 1) identifying areas yet to be served by the domestic backbone routes but that will eventually serve as the primary nodes for reaching underserved areas; and 2) linking the national backbones to avoid the need to duplicate network rollout to these challenging areas.
However, alongside these positive stories of success, innovation, and prudent choices for public intervention, there are cautionary examples where the benefits of the project were not fully realized.

In **The Gambia**, for example, the fully state-owned fixed-line incumbent, Gamtel, constructed a national backbone comprised of 817 kilometers of fiber-optic links. The network was financed by a loan from the Islamic Development Bank and was intended to be a low-cost open-access network available to all service providers. After completion of the network construction, the operation of the network remained in Gamtel's hands. Beyond its deteriorating financial health, Gamtel has found it organizationally challenging to fulfil the sector leadership tasks assigned to it by the government, among which are providing low-cost, reliable, and nondiscriminatory backbone transmission services. Owing to high prices and low service quality, some operators are continuing to rely on, or even moving back to usage of their microwave networks instead of the ECOWAN. The ECOWAN, which should bring the capacity from ACE submarine landing station across the country, is therefore highly underutilized.

A similar story can be found in **Senegal**, where the government launched a vendor-financed national fiber-optic project to connect government buildings, ministries, and facilities. The network had aspirations to be an open-access backbone service as well, but it is operated and maintained by the government's own

ICT agency, which is arguably inadequately resourced to fulfill that mission. The network has been poorly maintained, underutilized, and required excessive subsidy to keep afloat. The government is now seeking ways to introduce private sector expertise and possible private sector investment to transform the network into a financially sustainable, open-access initiative.

Burundi, a landlocked neighbor, followed a different path. Faced with similar challenges, in what has been termed a "cooperative" model, a consortium of Burundian telecommunications operators was created with assistance from the Burundian government and World Bank. The resulting Burundi Broadband System (BBS) involved the creation of a 1,250-kilometer fiber-optic backbone connecting all 17 provinces. Network connection points at the borders with Rwanda and Tanzania provide the landlocked country with access to the landing points of international submarine cables in Mombasa and Dar es Salaam. Like BoFiNet, BBS was an open access wholesale service provider. The Burundi government does not hold an ownership stake in BBS directly, but a major shareholder, Onatel, is a state-owned enterprise (SOE). The state also supported the project financially through a prepaid subsidy. The subsidy was significant, totaling somewhat more that the total equity contributed by the consortium members. Ultimately, BBS's financial basis proved too weak. Some of the private operators failed to contribute the funds they had promised and others, like Africell, effectively exited the market. Onatel faced bankruptcy following a failed privatization process. It also faces severe competitive pressure with the market entry of Lumitel in 2014. In January 2017, the government revoked BBS's PPP status and took it into government ownership.

A large part of the problem with these projects could be ascribed to limited participation of the private sector, financial frailty, and soft budget constraints, but there are also cases where lack of a robust business case has also lead to poor performance. In 2014, the government of Peru issued a number of concessions to design, build, and operate a north-to-south national backbone (RNDFO). As with most of the other projects, the backbone was to offer wholesale open-access services to mobile operators and ISPs. However, at the same time, the mobile operators were building out their own networks, as might be expected in a vibrant Latin American market such as Peru. As a result, prices for network services crashed and the network became highly underutilized.

The **Rwandan** government was one of the first African nations to confront its backbone issue with direct intervention. As part of its National Information Communication Infrastructure plan for 2005-10, it set out to deploy a high-capacity national fiber-optic backbone throughout the country. It did so by contracting Korea Telecom to supply a network comprising 2,300 kilometers of fiber to link 317 institutions (97 in Kigali and 220 outside the capital) across all 30 districts of the country, as well as connecting at all nine of Rwanda's borders. Most of the network is underground, but Rwanda NBFON has relied on the power utility infrastructure for laying above-ground fiber.

The Rwandan government originally contracted Broadband Systems Corporation to manage the backbone, but it has since transferred operations to Olleh Rwanda Networks (ORN), which is majority owned (51 percent) by Korea Telecom, with the Government of Rwanda holding a 49 percent stake. The company has been renamed KT Rwanda Networks. The construction of the fiber-optic network was completed in 2011 with a capacity of 10 Gbps and is meant to sell dark and active fiber on an open-access basis. KT Rwanda Networks was also granted a monopoly on 4G LTE wholesale in the country and has been increasing its presence in retail markets. Not surprisingly there have been complaints that such a 4G monopoly is incompatible with intended models of a carrier neutral entity. Indeed, local Rwandan mobile operators are favoring the upgrade of their own networks rather than using KT's monopoly 4G network.

A final cautionary tale comes from **South Africa**, which has numerous public and private sector backbones. There are two primary public-sector

backbones used primarily for public telecommunications: one belonging to the incumbent, Telkom SA, the other, Broadband InfraCo, owned and operated by the national power utility and the national rail operator. There are several private backbones of various sizes. Of interest here is Broadband InfraCo, which ostensibly enjoyed the advantages of an existing infrastructure base before commercializing the telecommunications assets in 2009. However, because of politicization that often comes with state ownership, the company was first obligated to sell its capacity to Neotel to fulfill government aspirations for the second national fixed line operator. It has since had numerous troubles delivering under competitive conditions in South Africa (Macmillan Keck and the Columbia Center on Sustainable Investment 2017, 173-79).

Table 4.3: Business Models in Surveyed National Backbone Networks

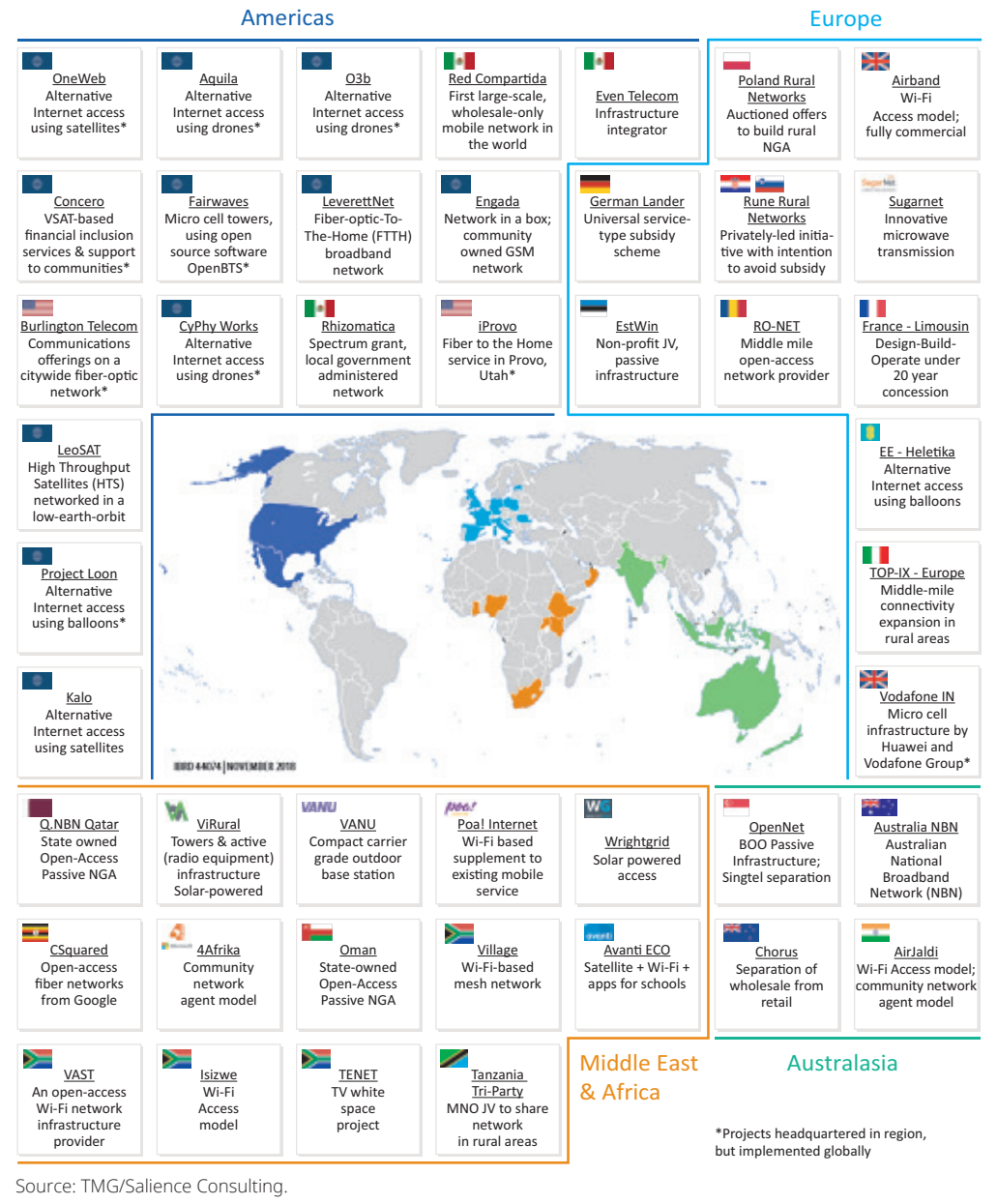
Case	Segmentation	Financing	Management	Revenue Generation
Botswana BoFiNet	PLOA/ALOA	State	State	Traditional, volume commitment
Gabon NFON	PLOA/ALOA	State	Private contractor	Traditional, volume commitment, subsidy
SimbaNET Malawi	PLOA/ALOA	Private, Offtake agreement	Private DBO	Traditional, volume commitment
Lithuania RAIN	PLOA/ALOA	State	State/Private contractor	Traditional, volume commitment, subsidy
Madagascar Axian	Vertically Integrated	Private	Private	Traditional
Southern Telecom	PLOA/ALOA, niche retail mobile	Private equity	Private	Traditional
Philippines NBN	Vertically Integrated	Private	Private	Traditional
Gambia ECOWAN	Vertically integrated	State	State	Traditional, subsidy
KT Rwanda Networks	PLOA/ALOA, but increasingly vertically integrated; monopoly on 4G	Private, Public sharing	State/Private	Traditional, volume commitment
Senegal ADIE	PLOA/ALOA	State; vendor	State	Traditional, subsidy
Burundi Backbone System	PLOA/ALOA	Private	Private	Traditional, volume commitment, subsidy
Peru National Backbone	PLOA/ALOA	Private, Public sharing	Private	Traditional
Broadband InfraCo	PLOA/ALOA	Public	Public	Traditional

Source: TMG/Salience Consulting.

5. Business Models and Technologies for the Middle and Last Mile

This chapter focuses on infrastructure deployment for those noneconomically viable locations that require a different approach as compared to traditional market-driven investment. It looks at business models and/or unique technologies that could bring down, or otherwise offset, the relatively high cost of connections. Figure 5.1 displays the different middle-mile or last-mile projects analyzed as part of this study.

Figure 5.1: Selected Middle or Last Mile Projects



Source: TMG/Salience Consulting.

5.1. Fixed Access Networks

Fixed Broadband Access Technologies

Serving rural areas with broadband technology has always been a challenge, especially in the early phases of broadband deployment where costs are a major concern. In general, rural areas have a more scattered distribution of housing that increases the costs of deployment on a per home passed basis.

The two main cost drivers for fixed broadband access deployment are: average house frontage (the frontage distance on or from the main road) and takeup.[23]

Typically, in a rural area the frontage is much bigger than in an urban area, and takeup may be lower because of less affluent demand – significantly increasing unit costs. This applies to all fixed wired technologies, such as fiber, coaxial or even copper, although copper may have the advantage if it has already been installed for public switched telephone network (PSTN) services.

However, fiber-to-the-premises is still considered the "future-proof" solution in terms of bandwidth, and with an ultimate capacity of petabits per second (Pbit/s), it arguably will not be superseded by any other known technologies, including 5G.

Rural FTTH

Greenfield fiber-to-the-home (FTTH) deployment in rural areas has not been common until now because of these cost considerations. As mentioned above, frontage distances are higher in rural areas, which results in higher costs on a per home basis, both for trenching and cable. Of course, in rural areas it is generally more acceptable to deploy fiber on poles, as overhead cable, rather than to require underground fiber installation, and this can significantly reduce costs, especially if poles can be shared with other utilities, such as electricity providers. Furthermore, it is important to note that settlement densities can vary widely, and many rural villages can have a fairly dense cluster of housing, with small frontages. In these cases, the costs for access may be comparable to urban areas. Of course, last-mile fiber may only be suitable where middle-mile access is also brought through fiber (or through another technology that can provide comparable performance), so it may be the high middle-mile and backbone costs that would represent the bigger obstacle.

Rural Coaxial/DOCSIS

Coaxial cable, using Data Over Cable Service Interface Specification (DOCSIS) standards, is frequently used by cable operators to deploy cable television and broadband services. It is generally installed as a tree and branch network, with fiber taken to the last amplifier, feeding the coaxial cable. In general, if used in rural areas in a greenfield scenario, its costs will be similar to the FTTH case. In some cases, coaxial cable can have some cost advantage over FTTH. For example, coaxial cable is arguably better suited to distribution on poles.

However, although coaxial cable can be used to deliver bandwidths of greater than 1 Gbit/s, higher frequencies exhibit higher loss, and the technology starts to approach its fundamental limits. It is not as robust as FTTH. The only case where coaxial deployment is economically justified would be in an existing network requiring upgrade to provide better performance—in this case upgrade cost will be lower than new fiber build.

23 The degree to which infrastructure can be shared at the access level may be another cost driver. In addition to lower cost, infrastructure sharing reduces some competition risk, which is generally beneficial to a service provider's business case.

VDSL/FTTC

Very high speed digital subscriber line (VDSL) is the preferred technology for incumbent operators that have already deployed copper cable extensively for PSTN services. VDSL line cards are installed in existing street cabinets, connected to the copper pairs in the distribution cable, and fiber is taken to the street cabinet (fiber-to-the-cabinet (FTTC)), serving the VDSL line cards.

For greenfield situations, with new copper, cabinets and fiber, the costs would be higher than FTTH, and therefore the greenfield VDSL is rarely an option. VDSL really comes into its own in brownfield situations, where copper is already present and the local loops are relative short (as VDSL performance is best below 1 km).[24] The copper pair is reused in the distribution network, and overall costs are much lower. A further point is that the systems can be rolled out in a much shorter timescale since much of the work has already been done.

Bandwidths available from VDSL typically are about 40 Mbit/s, but lately the technology has been improving. For example, technologies such as G.fast allow higher bandwidth, but at the expense of shorter usable distances, perhaps just a few hundred meters. This means that costs escalate significantly, since fiber is taken further into the network, such as perhaps the distribution point.

VDSL has also been used in rural areas, although often supported with government subsidization. For example, the Broadband Delivery UK (BDUK) initiative was focused on broadband in rural areas, and most contracts were awarded for VDSL deployment.

VDSL in rural areas is a useful alternative, and a significant improvement on available services in rural areas, but it is still a temporary situation pending a full FTTH deployment, and even under those circumstances, it will face stiff competition from 5G services.

Fixed Broadband Access Business Models

Twelve fixed broadband networks were examined as part of this study (see table 5.1).

These cases show a consistent story of the private sector outperforming state ownership and management models. The Australia NBN, Burlington Telecom, iProvo, and Q.NBN are all cautionary tales for state management of broadband infrastructure management. Oman Broadband Company (OBC) (see box 5.3) is exceptional to date, but it has benefited from consensus on its role in the market. Under truly competitive conditions, it is quite possible that OBC would not have survived.

In the case of Burlington Telecom and iProvo, sustainability was achieved through privatization of state assets. LeverettNet and France Limousin demonstrate that state ownership can benefit from proper concessioning and outsourcing of operations.

Singapore's National Broadband Network (NBN) is an example of a privately run network subsidized by government (see box 5.1).

Rural network examples (France Limousin, Poland's Rural networks, Germany's Länder program and RUNE) have generally required subsidy to close financing gaps (see box 5.2). RUNE seeks to be an exception to this by, among other things, targeting more densely populated villages.

24 In case of longer distances where equipment needs to move from central offices to new build street furniture (roadside boxes) the costs might be prohibitive.

Table 5.1: Business Models in Surveyed Fixed Access Networks

Case	Segmentation	Financing	Management	Revenue Generation
Australia NBN	Wholesale open access	State equity and debt funded	Public	Traditional
Burlington Telecom	Vertically integrated	City-owned, until bought by private company in 2017	Public until 2017, now private	Traditional
Chorus	Wholesale open access	Private equity and debt	Private	Traditional
CSquared	Wholesale commercial access	Private and DFI equity	Private	Traditional
France Limousin	Wholesale open access	State and regional funding	Private through DBO concession from regional authority	Traditional, subsidy
German Länder	Vertically integrated and wholesale open access	Private equity	Private	Traditional, subsidy from federal government
iProvo	Wholesale open access	Municipal funded until bought by Google	Public until 2014, now private	Traditional
LeverettNet	Vertically integrated	State funded	Concessions and leases to private companies for network operation and services	Traditional
Oman Broadband Company	Wholesale open access	Funded by state grant	State	Traditional, initial subsidy
OpenNet/ Netlink	Wholesale open access	Private equity and debt	Private	Traditional, initial subsidy
Poland Rural	Wholesale open access	Private equity and debt	Private	Traditional, subsidy
Q.NBN	Wholesale open access	State equity	State	Traditional, initial subsidy
RUNE	Wholesale open access	Private equity	Private	Traditional

Source: TMG/Salience Consulting.

Box 5.1: OpenNet/NetLink Trust Singapore: Privately Run Network Utility Subsidized by Government

Singapore's National Broadband Network (NBN) was a pioneering initiative, as it was one of the first networks to involve mandated complete separation of the infrastructure assets belonging to the incumbent operator

In 2005, Singapore published its 10-year ICT plan under Intelligent Nation 2015 (IN2015) which, among other things, called for the establishment of a single national fiber infrastructure. Among the first implementation tasks given to the regulator was conducting an open selection of the NetCo license for passive infrastructure and OpCo license for active infrastructure operation under a three-tier framework that included retail service providers (RSPs) as a top layer providing much of the service innovation. Initially, the award of the licenses was to be completed within a 1.5-year period; however, various political and consortium issues resulted in the process taking twice as long.

Eventually a handful of bidders reached the final round with OpenNet, a Singtel-led consortium, winning the NetCo license in September 2008 and Nucleus Connect, the StartHub-led consortium, winning the OpCo license. The OpenNet consortium consisted of Axia NetMedia (30 percent), Singapore Telecommunications/SingTel (30 percent), Singapore Press Holdings (25 percent) and Singapore Power Telemedia (15 percent). The OpenNet consortium received $500 million as a government grant as part of the process, and the OpCo license holder also received a $170 million government grant.

Implementation of the new regime was not without its challenges. Numerous operators have complained about the inadequate space provisions in the exchanges and the preference given to the incumbent, Singtel. Throughout the years, the telecommunications regulator has also had to penalize OpenNet repeatedly for failings in fulfilling its service obligations especially in respect to time to connect to customers.

In 2011 NetLink Trust was established and the passive nonfiber infrastructure assets that were required as part of the rollout of next generation fiber network, comprising underground ducts, manholes and central offices, were transferred to NetLink Trust from Singtel. NetLink then acquired OpenNet in 2013 as part of a consolidation process to acquire the fiber network – effectively Singtel buying out its four partners for a combined amount of $95 million. The International Development Association (IDA) approved the transaction with certain caveats relating to the monitoring of the operations, the role of Singtel as main subcontractor and mandating SingTel to divest the majority of its ownership in NetLink by 2018. In line with the agreement, Singtel sold 75 percent of its shares through an initial public offering (IPO) in July 2017 with a value of $1.7 billion, thus completing its divestment move.

In 2013 Netlink reached full nationwide fiber coverage in terms of residential homes and nonresidential premises passed. As of 30 September 2017, the company reported 1.5 million homes passed and 1.1 million homes connected across Singapore, confirming the strong business case fundamentals of the NetCo business.

For more details, see appendix, page 185.

Box 5.2: PPP Limousin France: Regional Concession to Create and Operate Rural Broadband Network

The Limousin is a rural region of France, where the search for adequate broadband connectivity began as early as 1996. Not content with the options available from the incumbent or new entrants, regional authorities ultimately formed a public consortium called DORSAL to secure the appropriate financing, defining the scale and scope of the deployment and overall project management for their own broadband network.

In a first phase, after securing €204 million in financing, a 24-year concession was awarded by competitive tender to a local ICT company called Axione Limousin in 2005. Through this concession, Axione was mandated to design, build, and operate a broadband core and middle-mile wholesale network, available to all French service providers on a nondiscriminatory basis. This deployment was referred to as the first-generation network.

In parallel, another consortium, SPL Aquitaine, was created and given the mandate to design and build public fiber access networks, which were then transferred through concession to Axione to commercialize and operate. This was then referred to as the second-generation network. One key success factor of the project was the harmonization between the first and second-generation networks.

The region has also encouraged private investment and allows service providers to deploy their own infrastructure in the most populated areas of the region.

For more details, see appendix, page 174.

Box 5.3: Oman Broadband: Public NBN Utility Incubated from Utility Assets

In the early stages, the Omani government saw the opportunity of utilizing existing utility works to deploy an access fiber network. That is why, in 2008, when the wastewater utility, Haya Water, was given the mandate to deploy a sewage pipes network in the city of Muscat, the operation was extended to the deployment of an additional FTTH access network alongside.

In 2013 Oman Broadband (OB) was created as a nationwide utility with the objective to fulfill the government mandate of efficiently deploying a national broadband network. As part of this mandate, OB took over Haya Water's telecommunications operations.

The formation of Oman Broadband was a key part of the national broadband strategy, which aimed to overcome the comparatively low levels of fixed broadband penetration within Oman, limited competition between the operators, and the high cost of expanding broadband services to rural areas.

After its formation, Oman Broadband expanded its infrastructure sharing with other utilities, such as water and power companies, for access network installation and sharing the already existing long-haul routes for supervisory control and data acquisition (SCADA) applications and the other ministries' national private networks. The initiative harmonizes infrastructure rollout and allows a national backbone network to be provided quickly and relatively cheaply.

Since the network is offered on an equal access basis to different service providers, with little existing competition for infrastructure, the takeup rate for service is high, making the business case more attractive. At the end of 2017, the company had installed fiber infrastructure passing more than 200,000 homes, predominantly in Muscat, and has some 40,000 connected end-users.

For more details, see appendix, page 183.

5.2. Wireless Access Networks

Wireless Broadband Access Technologies

As discussed in chapter 2.1, the advances of mobile broadband technology from 3G to 4G and 5G have allowed mobile technology to meet most of the current demand requirements for broadband access. In some countries, these technologies have gained majority market share from the copper-based incumbent (and reluctance to invest in fiber by the incumbent certainly contributed to the case). The continued investment by MNOs in expanding and upgrading their mobile broadband networks will further contribute toward increasing connectivity in rural areas.

However, in certain low ARPU countries mobile connectivity will not be able to expand beyond the main cities unless more innovative technologies and business models are applied.

With fixed wireless, by definition, there is a fixed antenna that is part of the solution, which increases capacity potential. These technologies have been recognized as a key component of national broadband plans for reaching rural areas.

A number of initiatives have recently emerged that use separate dedicated LTE spectrum and existing mobile masts to provide fixed wireless to rural areas. These initiatives (even those limited in scope) have been largely successful in delivering performance in line with copper networks (for example, ADSL/VDSL) with fixed antennas set up at the premises they served. In the United States, these types of initiatives are now supported by the Federal Communications Commission's (FCC) Connecting America Fund (CAF II). Beyond the last mile, in Romania, for example, LTE backhaul has been recognized as an adequate middle-mile solution.

Wireless Business Models

Seventeen wireless broadband networks were examined as part of this study.

Table 5.2: Business Models in Surveyed Wireless Access Networks

Case	Technology	Segmentation	Financing	Management	Revenue Generation
4Afrika	TVWS	Vertically integrated	Private funding; not for profit	Community managed	Usage based
AirJaldi	Wi-Fi	Vertically integrated	Private funding; largely not for profit	Private	Traditional: usage and subscription
Avanti Eco	Satellite	Vertically integrated	Private funding; largely not for profit	Private	Traditional and private sector subsidy
Isizwe	Wi-Fi	Vertically integrated	Private funding; not for profit; in kind contributions (masts, power, backhaul) of municipalities	Private	Contributions of funders and partners; free to users
Microsoft Airband	TVWS	Wholesale	Private funding	Private	Revenue share with ISPs

Case	Technology	Segmentation	Financing	Management	Revenue Generation
O3b	Satellite	Wholesale backhaul	Private equity and debt	Private	Traditional
Poa! Internet	Wi-Fi	Vertically integrated	Private equity and debt in kind contributions (masts, power) of communities	Private	Traditional
Rhizomatica	Wi-Fi	Vertically integrated	Local community	Once built, network run by community	Monthly subscription
SugarNet	Wi-Fi	Vertically integrated	Private	Private	Traditional, end-user subsidy
TENET	TVWS	Vertically integrated with academic and scientific institutions	Private; not for profit	Private	Traditional
VAST	Wi-Fi	Wholesale open access	Private	Private	Traditional

Note: "Vertically integrated" in this context means combined last-mile wireless network and retail service provider.

Source: TMG/Salience Consulting.

Wi-Fi for Innovative Business Models

Wi-Fi is an established, relatively low-cost wireless technology. Owing to the relatively low equipment cost, the availability of spectrum, and the large number of Wi-Fi-enabled devices, various innovative business models have been launched and some are beginning to prove themselves viable.

Subsidized free services. This model relies on the local authority paying for the build and operation of the Wi-Fi hotspot network. The network pays for itself through the increased tax revenues generated through the economic benefits of having connectivity within the local authority. Isizwe bringing free Wi-Fi connectivity to communities in South Africa is an example of this approach (see box 5.5).

Action-based payment models. These models have customers undertaking certain actions in order to receive blocks of connectivity time or capacity. Current proposed actions include recycling certain amounts of plastic (it is proposed that for every kilogram of plastic recycled 100 megabytes of data connectivity will be given) or undertaking and passing particular microtraining courses. These options are designed to allow users nonfinancial methods to pay for connectivity, and as Wi-Fi costs have fallen it is possible to exchange these services for a meaningful amount of connectivity. This creates options where public or aid spending can be effectively used to drive outcomes through the use of connectivity as a reward. These action-based payment models are relatively new and currently unproven although they do represent significant potential. Again, see box 5.5 for more details).

Build your own network models. These models allow communities with little or no coverage to build a local area network to cover their community at little cost and with limited experience required. They are designed to provide much lower ongoing telecommunications costs to locals as they will be able to make on-net calls in their local area for free.

Village Telco (see box 5.17) is an example of this approach. To date, the success of these models has been limited because of the need for more data capacity and the associated backhaul constraints. Once the backhaul issues are remedied, great potential exists for individual communities to build local networks. Rhizomatica is another example of an initiative enabling community-owned wireless networks for unserved areas.

Very low cost incremental pricing models. Once backhaul connectivity is in place, an opportunity emerges to provide users with very low-cost, time-based packages for Internet connectivity. Poa! Networks of Kenya has pioneered this service, which offers users the ability to buy access for one hour for as little as K Sh 10 (about $0.10) and allows payment through the use of a mobile phone.[25] This model has proven a success in driving additional connectivity.

Other notable Wi-Fi cases are:

- AirJaldi, using off-the shelf Wi-Fi equipment to supply service in rural India. AirJaldi has nine networks in five Indian states covering 24,200 square kilometers, with over 100,000 users; and
- VAST Networks, which offers carrier grade, open-access Wi-Fi network infrastructure.

Despite the various success cases across the world, there are number of reasons why Wi-Fi has not been as widespread or it failed, the reasons combine commercial, conceptual, and technical issues as listed below:

- **WI-FI is not really last mile**—it is the last couple of hundred feet and is dependent on a fine balance of the right topology and density for takeup to provide a decent service.
- **Very dependent on backhaul** from operators, which is often not available.
- **Sensitive to improvements in cellular**—solid 3G or 4G connectivity can often be as fast as Wi-Fi if backhaul is poor.
- **Not faster than fiber and less coverage than mobile.** Often it is not fast enough to be a fixed broadband replacement and does not have enough coverage to serve as a mobile replacement.
- **There is a misperception that it can be installed easily.** Wi-Fi can easily be installed in a house, but metro deployments require proper RF planning in order to provide a quality service.
- **Customers think Wi-Fi is free.**
- **Systems issues**—Billing systems and portals have been clunky and payment methods difficult.
- **Large operators will not support Wi-Fi deployments.** Some operators actively disrupt Wi-Fi deployments because of the risk of cannibalization of cellular revenue.
- **Coverage needs to be accompanied by other initiatives** which are often overlooked, such as education of the base and relevant content.

25 https://poa.co.ke/.

Box 5.4: SugarNet/Voneus: Bringing Fixed Wireless Broadband to Rural England

In the past few years, several U.K. broadband ISP startups have utilized fixed wireless technology to overcome the rural connectivity gap created by the lack of suitable fixed infrastructure available through the incumbent BT. Oxfordshire startup SugarNet and their acquirer, Voneus, use a hybrid fiber-wireless broadband solution that extends high-speed broadband to target communities. It offers packages of 20-50 Mbps symmetrical for less than £35 per month (about $46).

The business model is based on cooperation with local broadband activists or community action groups in rural areas. Voneus solicits expressions of interest from a minimum number of households in a community. Once community involvement is secured, it creates a backhaul connection to its core fiber network. Installation costs to Voneus are defrayed by the U.K. government's program of Better Broadband vouchers, which qualifying individual customers receive gratis and then give to Voneus. There is no installation cost to individuals.

In January 2018, Voneus was granted additional powers by the U.K.'s communications regulator, Ofcom, to help it accelerate the rollout of superfast broadband services to hard-to-reach rural U.K. communities. These powers allow Voneus to construct infrastructure on public land, and to take rights over private land, either with the agreement of the landowner or by applying to the county court. It also conveys certain immunities from the town and country planning legislation in the form of permitted development.

Figure B5.4.1: SugarNet/Voneus Mixed Fiber-Wireless Solutions for Delivering Rural Broadband Connectivity in the United Kingdom

For more details, see appendix, page 194.

Box 5.5: Project Isizwe: Bringing Free Wi-Fi Connectivity to Communities in South Africa

Project Isizwe is a South Africa-based nonprofit Wi-Fi service provider. Its business is based on convincing local authorities to rollout of a Wi-Fi network providing free access to end users across free Internet zones (FIZ). For the initial payment, the local authorities prepay for the rollout of the network as well as bandwidth for a period of time. Coverage is generally targeted at the most impoverished areas within the local jurisdiction. Since launching in 2013, Project Isizwe has set up six networks with more than 3.8 million unique connected accounts and 600,000 users per month across 1076 FIZ. Further rollouts are planned.

The business model for the local authority is based on the view that there will be an increase in GDP in their tax catchment area, thereby increasing tax revenues. This increase in tax revenue is expected to pay for the initial upfront investment and ongoing running costs, meaning that the project becomes self-funding (tax increment financing). In addition to the increase in tax revenue, there are also other opportunities for local authorities to generate additional revenue though selling advertising and sponsorship.

There is no authentication and users are required to provide their own Wi-Fi-connected device. Each device is generally limited to download in the range of 250-500 MB per day. Additionally, there is a significant amount of on-net information which is also exempt from the usage cap including relevant learning and teaching content (Siyavula); books designed to be read on a small format device (Fundza); jobs portal providing job opportunities, résumé-writing advice and interview skills (Gumtree); curated content in videos, televised lessons, digital textbooks, podcasts, presentations, worksheets, and past exam papers; and Wi-Fi TV (video-on-demand service covering range of topics including education, entrepreneurship, fashion, and sports produced by young community journalists).

In addition to this model, Isizwe is developing a new innovative business model through its Khaye-Fi project based in Khayelitsha, one of the poorest areas in Cape Town. The idea is to reward users with Internet connectivity in return for performing certain actions—in this case recycling. In the initial proof of concept, users will be offered 100 MB of data in return for every kilogram of recyclable goods delivered. Once the proof of concept is complete, additional mechanisms for users to gain access will be rolled out, including completing microlessons. The local authority investment Khaye is seeking to build relationships with local partners to sponsor the service as well as provide relevant local content, training, and data collection. Sponsors will have access to marketing, research, customers, and corporate social responsibility investment opportunities. In addition, Wi-Fi champions will be engaged in the community to drive community understanding and provide feedback on the project.

For more details, see appendix, page 177.

TV White Space as a Low-Cost Alternative for Rural Coverage

TV white space (TVWS) is an interesting low-cost alternative technology for rural coverage that has gained some momentum in recent years because of standardization by the Institute of Electrical and Electronics Engineers (IEEE). Nevertheless, no large-scale deployments are currently known.

The major advantage of this type of technology is that the frequencies used, in the range of 450 to 800 MHz, allow for non-line-of-sight (NLOS) transmission, with low power, over relatively long distances, typically 15 kilometers. This spectrum provides deep coverage for long-distance Internet connectivity to underserved communities over hills and through foliage. Another advantage is that the technology is useful in remote regions with difficult terrain, again because of the NLOS feature. A further advantage of the lower frequencies is that there is good penetration of the signal into homes.

The slight disadvantage is that because of the relatively low frequencies, the available bandwidth is restricted, although many vendors are now claiming that bandwidths of 100 Mbit/s are available on a shared basis.

The technology recently received a boost from the completion of the IEEE standard, 802.11af, or Wireless Regional Area Networks (WRAN), issued in 2014. The standard allows for spectrum sharing among white space devices and licensed services, and essentially ensures that the primary TV provider does not experience interference. As a result of this, many vendors are now producing standardized equipment, including Carlson Communications, Redline, Adaptrum, and many others.

Typically, TVWS wireless technology may be combined with DOCSIS 3.0 standards to be able to offer services into the home, with low-cost modems as the end device.

TVWS may be an interesting technology for remote rural districts, which consist of small and isolated villages. The NLOS feature enables the mast to be located in more convenient positions and the height of the mast does not need to be as high as with other technologies, significantly reducing costs. The technology is slowly gaining momentum but to date it is largely used in trial and niche situations, such as 4Afrika in Mawingu (see box 5.6). TENET, which partners with television broadcasters to deliver service to education and research establishments in South Africa, is another example.

TVWS solutions are not without some controversy, as they are arguably an anomaly resulting from inefficiently allocated spectrum. It may be that, considering the cost and benefits of narrowing these buffer channels and making more spectrum available, more traditional allocations might offer better solutions for more end-users.

As with all deployments into rural areas, one of the key components will be the middle mile as well as backbone connectivity, and it will be difficult to provide a commercially viable standalone solution. Interestingly, TVWS is now being explored as a middle-mile technology in rural areas where the required bandwidth may be more modest.

Box 5.6: 4Afrika: TV White Space in Rural Areas

4Afrika was launched by Microsoft, with stated aims to develop affordable access, skills, and innovation on the African continent. Since 2013, 4Afrika has brought more than 500,000 SMEs online, upskilled about 800,000 Africans, and helped 82 local startups to grow their ventures.

As part of the 4Afrika initiative Microsoft has launched 15 TVWS connectivity pilots across many countries in Africa, including Kenya, South Africa, Namibia, Tanzania, and Ghana.

Another TVWS project is Mawingu (which is Kiswahili for cloud), an initiative with the Kenyan Ministry of Information and Communications and Kenyan Internet service provider Indigo Telecom, to deliver low-cost, high-speed, wireless broadband in an affordable way (that is, for a few dollars per month). In addition, its aim was to create new opportunities for commerce, education, healthcare, and delivery of government services across Kenya. It is the first deployment of solar-powered basestations working together with TV white spaces to deliver high-speed Internet access to areas currently lacking even basic electricity. In most of Kenya, broadband penetration is at global lows: nearly 72 percent of Kenyans are without Internet, affecting the quality of education, politics, and even healthcare.

The project, part of Microsoft's 4Afrika initiative, has spurred several other programs, including a tele-medicine service, diagnosis applications, and efforts related to government participation and agriculture. Ultimately as a business model, traditional financial self-sustainability of these initiatives may not be possible (or even desirable). 4Afrika may be better thought of as a double bottom-line initiative for sponsors, for example, reliant on continued financial support to raise positive brand recognition or other CSR benefits.

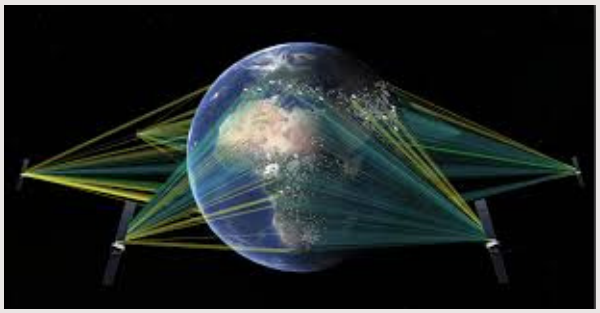
For more details, see appendix, page 159.

Current Satellite Business Models

There are a number of satellite systems that employ relatively new high-throughput technology to provide broadband backhaul and access services where fiber and terrestrial wireless broadband means are not available or too expensive to deploy. Avanti Eco provides access either through a vertically integrated model (serving end-users directly) or a wholesale play for local service providers. It has benefited from a startup grant from the European Space Agency and plans to rollout access to over 500,000 communities in Africa in the next few years.

O3b, short for "the Other 3 Billion," has been successfully providing backhaul to remote locations for several years. It supplies wireless backhaul to public service providers in Africa, the Pacific islands, and particular verticals such as the marine transport and energy sectors (see box 5.7).

Box 5.7: O3b – Broadband Backhaul and Access through New Satellite Technology



O3b advertises itself as providing a "fiber speed, satellite reach" technology with latency comparable to DSL or fiber, that is, below 150 ms.

The technology is based on deploying medium Earth orbit (MEO) satellites operating in the Ka band and using steerable spot beams to deliver connectivity to target customers. The satellite-earth gateway connectivity is delivered by a number of earth-based installations and the satellites feature seamless handover functionality. The initial satellites built by Boeing were deployed in 2013-14. Today there are nine in operational use with another eight more expected by 2019.

In addition to expanding coverage, O3b has been working on improving its technology. mPower satellites, promising delivery speeds of multiple gigabits to a single spot and having 30,000 spot beams, are planned to be deployed in 2021.

O3b has developed four key products aimed at verticals:

- O3bTrunk—providing backhaul Internet connectivity for ISPs,
- O3bCell—a mobile cell backhaul solution,
- O3bMaritime—marine vessel Internet backhaul, and
- O3bEnergy—offshore connectivity solutions for the oil and gas sector.

For more details, see appendix, page 182.

5.3. Challenges for Middle-Mile Initiatives in Rural Areas

Middle-mile initiatives reaching rural areas have generally been supported by state funds. However, delays and funds mismanagement have been observed.

Middle-mile developments aim to bridge the distances between the core national network and the individual access network "islands." The objective is to bring the network closer to the community from where it will be distributed via the access network to all the households and businesses.

The business model is usually based on subsidizing a national telecommunications provider or creating a new entity that will receive the funds to build and operate the new network (see table 5.3). The service is either passive (for example, dark fiber, as in the case of Est-Win in Estonia) or active (for example, as is the case for RO-NET Romania), and is provided on a carrier-neutral basis and priced based on cost or cost-plus principles. The allocation of network resources differs in each case, but it is generally based

on a "first come, first served basis." However, complaints have arisen of biased and unfair allocation of network resources among service providers.

Payment for the network is either upfront, in which the network is built from available funds (as in Estonia), or the successful bidder builds the network, also reusing its existing infrastructure to reduce costs, and then claims the money from public funds.

In some cases, funds are being utilized to support the upgrade of the existing incumbent's telecommunications infrastructure but this has been branded by service providers as "unfair" and not in keeping with the initial purpose. For example, in Estonia the middle-mile project was used as a subsidy for mobile tower connectivity instead of connecting rural areas with fiber (see box 5.8).

In Romania, the winners of the tenders to build a similar middle-mile network, RO-NET, were Romtelecom and Cosmote, both part of the Deutsche Telekom group, since merged into a single entity (for more details, see box 5.9).

A very different example is provided by TOP-IX, an initiative supported by the European Commission's Connected Communities Initiative (CCI) and implemented in partnership with the World Bank. TOP-IX currently operates an Internet exchange point and a neutral backhaul network of more than 30 points of presence (POPs) in the Piedmont region of Italy. TOP-IX controls a network of more than 1,000 kilometers of fiber-optic infrastructure providing broadband access to more than 200,000 end-users, and plans to add an additional 50 points of presence (POPs) for a total of €12 million. TOP-IX will leverage assets of existing utilities that have underused fiber-optic deployments, as well as high points, ducts, and other civil work passive infrastructure, that can be leveraged to deploy TOP-IX's backhaul network. A core partner will be the Italian electricity grid operator Terna. TOP-IX believes that it can greatly extend its backhaul network in the rural areas profitably enough to attract adequate private investment.

The CCI is also supporting other projects, for example, in the Friuli Venezia Giulia (FVG) region of Italy and in rural regions of Portugal. The GANDHI project in FVG will create a PPP SPV that provides technology neutral wholesale broadband access according to the conditions defined by the regulator, AGCOM. The PPP will be implemented in coordination between Regione FVG, its in-house telecoms team, Insiel, and the awarded private next generation access (NGA) operator(s). In Portugal, The DSTelecom project will deploy greenfield high-speed broadband infrastructure in four underserved regions—Alentejo, Algarve, Lower Minho, and the Northern Region. DSTelecom has received equity funding from a large European infrastructure fund, Cube Infrastructure Managers.

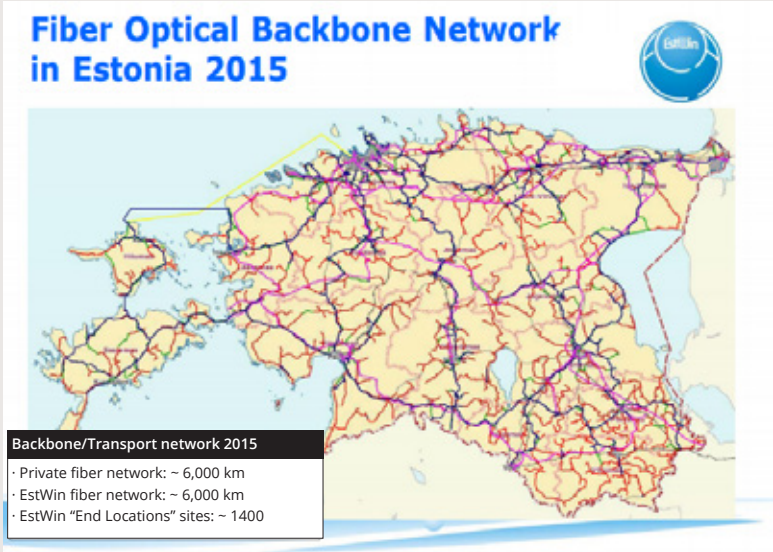
Table 5.3: Business Models in Surveyed Middle-Mile Initiatives

Case	Segmentation	Financing	Management	Revenue Generation
Est-Win	Wholesale open access passive infrastructure	Primarily state funding	Private representation from major operators in country	Traditional, volume commitment
RO-NET	Wholesale open access infrastructure	State	DBO model	Traditional
TOP-IX	Wholesale open access infrastructure	Private	Seeking strategic investor	Traditional

Source: TMG/Salience Consulting.

Box 5.8: EstWin Estonia – Middle-Mile Project with Mixed Success

Figure B5.8.1: Fiber Optic Backbone Network in Estonia, 2015



EstWin is a fiber middle-mile project established in Estonia in 2009 with the aim of reaching rural communities that were marked as "white areas" under EU broadband availability categories, meaning an absence of broadband suppliers and none expected in the near future. The project was initially established as a PPP project between four Estonian government ministries and the Estonian Broadband Development Foundation (ELASA) representing the private sector. The founding members of ELASA are Elion, Elisa, Eltel, EMT, Ericsson, Levira, Televõrgu, and Tele2—among whom are the biggest telecommunications operators in the country. EstWin is funded by European Structural and Investment Funds (ESIF), among others.

EstWin is a nonprofit organization with transparent and published financial information, providing equal access to its passive fiber infrastructure to all licensed service providers.

The network aims to bring fiber within 1.5 kilometers of 98 percent of all residential buildings, companies, and public authorities. In order to do that, about 6000 kilometers of fiber was to be laid out to 1400 fiber sites. As of 2017 the ELASA web site reports the rollout of 5,825 kilometers of fiber and 2308 total network connections, including 566 local government buildings.

The EstWin investments are intended to stimulate complementary deployments of last-mile connections by commercial telecommunications operators. However, market failures persist in many areas.

In some cases, the villages have taken the initiative. An example is the village of Rääka in Suure-Jaani municipality in Viljandi County, which established a 2.5-kilometer fiber connection from the village to a nearby broadband network at the beginning of 2013. Communications operator Elion prepared the design, the villagers bought the cable, the local firms laid it, and the local government sorted out the planning permission and offered as much support as it could. Each household had to invest more than €1000.

For more details, see appendix, page 171.

Box 5.9: RO-NET – Middle-Mile Open-Access Network Provider in White Areas in Romania

RO-NET is an initiative that started in 2014 with the aim of supporting the deployment of a back-haul network to white areas of Romania where broadband is not planned or available—areas comprising a total of nine million rural inhabitants or 47.2 percent of the total population. At the project start, the Romanian authorities identified 783 rural localities allocated among seven regional projects.

The project is defined as a design, build, and operate (DBO) model where financial assistance was applicable to the design and deployment of new backhaul infrastructure and no aid is to be granted for the operation of the network. The public support takes the form of grants. A significant part (about 82 percent) of the €84 million budget is funded from the European Regional Development Fund (ERDF) (€68.5 million) and the remainder from the state budget (€15.5 million). The infrastructure is to remain under public ownership and the concessionaires will pay a fee of 18 percent of the investment value for an 18-year concession and will have the right to retain the remaining revenues generated from managing and operating the networks. The concessionaire also has the option to purchase the respective network and its facilities, subject to a prior government decision transferring those assets from public to private property.

Selection was based on an open tender process for the seven regions with contracts awarded to the applicants presenting the most economically advantageous offer (that is, least financial subsidy required) among other parameters for selection. The process awarded Romtelecom and Cosmote agreements to implement the projects. The two companies are indirectly controlled by German group Deutsche Telekom. Romtelcom won the contract for four of the regions and Cosmote for the other three.

Infrastructure sharing was defined within the process and administered by the regulator, resulting in about 33 percent of the network planned in the project to be built on the basis of existing physical support infrastructure. Open access to the new network is given on the active layer, and made available on a "first come, first served" basis. Service pricing for wholesale access will be based on the prices already set by the regulator, ANCOM, for similar regulated services and, in the absence of such regulated wholesale prices, on the average wholesale prices in more competitive areas of the country.

However, issues were encountered during the implementation, especially delays in the authorization process, and by the end of 2015 works were completed for only 99 of the 783 localities planned. Further delays were reported in 2016 because of payment issues and, as of 2017, the project was still not reported as finalized.

For more details, see appendix, page 192.

5.4. TowerCo and Mobile Infrastructure Sharing Models

Infrastructure sharing models relevant to the last mile and middle mile can been seen along a spectrum of network component sharing, from the passive sharing of towers to backhaul sharing to increasingly involved forms of radio access network sharing.

Passive site sharing is an extremely common form of mobile infrastructure sharing. While MNOs typically build wholly separate networks in the early period of competition, they usually grow to appreciate the cost savings benefits in more mature periods of service delivery and begin to voluntarily share sites. Regulators have, of course, also often played a part in encouraging or requiring site sharing in the interest of reducing redundant building, as well as environmental and/or aesthetic concerns. In recent years, specialized TowerCos have emerged to take on joint builds and operation. One of the first developing world examples of MNOs transferring such passive assets to a third party for operation and further expansion was the creation of Indus Towers by Bharti Airtel, Vodafone, and Idea Cellular in India. An interesting intermediate form is where two or more MNOs effectively create a joint venture to plan the building and operating of new towers in rural areas that they then share. In Bangladesh, Grameenphone and Banglalink have a long history of such an arrangement. However, even when the operations are made sustainable through a shared-cost model, the initial CAPEX investment is still often a barrier to making the case commercially viable. In these cases, complementary government financial incentives might increase the model's viability.

Fiber backhaul sharing is where MNOs agree to jointly construct and operate or otherwise share connectivity from radio access sites to core network meet points. A recent example of this is the German Telefonica and Vodafone agreement to split the cost and/or construction of backhaul links. Telefonica and Vodafone subsidiaries have a long history of network sharing across Europe.

Geographic roaming is where two or more mobile network operators agree to share access networks to cover areas to mutually extend networks that one operator alone could not economically undertake on its own. There is also the mandated form of geographic roaming, typically referred to as national roaming, in which the state requires that incumbents provide access to their networks to ensure that new entrants can offer full national coverage. Typically, these mandates are effective for a set period of time so that new entrants are incentivized to continue their own rollouts. A voluntary example of this is the recent GSMA-spearheaded case in Tanzania managed to provide rural 4G coverage for 72,000 inhabitants by applying the network sharing concept—implemented as roaming across a triparty network (see box 5.10).

Mobile wholesale networks can take the quite common form of MNOs providing network infrastructure and service to mobile virtual network operators (MVNOs), or the newer form of single wholesale network, which in a sense turns other MNOs in the market into a type of MVNO for certain services.[26] A case study of the Mexican Red Compartida is provided in box 5.11.

26 MVNOs are differentiated by varying levels of dependency on the network of others. See, for example, OECD 2017.

Table 5.4: Business Models in Surveyed Wholesale Mobile Infrastructure

Case	Segmentation	Financing	Management	Revenue Generation
Even Telecom	Passive and active wholesale mobile infrastructure	Private	Private	Traditional, down payment
Red Compartida	Passive and active (including 4G spectrum sharing) wholesale mobile infrastructure	Private	DBO pays annual fee to state for right	Traditional, auction shares of spectrum
Tanzania Tri-Party	Active wholesale mobile infrastructure	Shared cost approach	Joint venture of two MNOs	Nonrevenue earning

Note: The Rwanda NFON and Madagascar Axian cases (see chapter 4) contain wholesale mobile infrastructure as well.

Source: TMG/Salience Consulting.

Box 5.10: Tanzania – Shared Mobile Rural Infrastructure via Roaming

The GSMA supported a rural connectivity project, the first of its kind in Africa, bringing together three of Tanzania's biggest operators (Tigo, Vodacom, and Airtel), in a bid to provide 3G connectivity to selected remote rural locations. Six 3G pilot sites (two from each operator) were activated in 2017. Rural network national roaming was enabled on all sites with an addressable market of 43,000 mobile customers benefiting from competitive retail offering from all three operators utilizing a single infrastructure deployment.

In July 2017, the GSMA visited two villages, Mingumbi and Nambpunga, located within the range of the new network pilot sites. Both villages are located about 30 kilometers from the nearest main road. It was observed that uptake of mobile broadband services around pilot sites showed positive results. Despite a hesitant first two months, because of technical issues and delayed roaming enablement, adoption levels increased significantly to reach 95 percent of the addressable market (64 percent of the population) by the end of month four. High demand limited the usability of the network during the day, leading many users to wait until the evening to make use of freer capacity.

The network sharing via roaming model revealed significant benefits on both the supply and demand sides. On the supply side, roaming has allowed operators to reduce their costs significantly, allowing for deployment in unserved rural areas. From an adoption perspective, roaming has boosted adoption as it introduced more choice and better availability of products, including SIM cards.

Despite a successful outcome, the investment case, given fiscal constraints, appears difficult and is a barrier for further rural mobile broadband coverage expansion. Over a short period, although the sites showed steadily increasing revenue reaching a level ensuring site viability from an operational cost perspective, CAPEX and tax levels render the rural sites unprofitable. Thus, the savings generated by the sharing agreement are not sufficient to compensate for the whole investment. Other solutions, such as government financial support in the form of grant or equity partnerships, implementation of low-cost access solutions, lower taxes for selected sites, or zero-rated long-term debt, will be necessary. GSMA's report concluded that the provision of correctly allocated subsidies can significantly help mobile operators to scale the current national roaming agreement.

For more details, see appendix, page 195.

Box 5.11: Mexico's Red Compartida Project: Mobile Wholesale Broadband Network

In 2014, the Mexican government passed wide-ranging telecommunications reforms that included instruction to the Mexican telecommunications regulator to establish a wholesale-only wireless network—a "carrier's carrier" known as Red Compartida that will sell mobile-network capacity to all newcomers. The network was defined to be deployed and operated through private capital, attracting large investments and jobs in Mexico. The initiative's aims are 1) optimizing the usage of assigned spectrum (700 MHz), 2) cost reductions, and 3) increased coverage in regions without services.

The bid was awarded in 2016 to a consortium called ALTAN—which includes Axtel, Megacable, the International Finance Corporation (IFC), and Dutch and Chinese investors. Under the terms of the PPP, the Mexican government is providing the radio spectrum and the use of the backbone network developed by the Federal Electricity Commission (CFE). ALTÁN Redes, as the private partner of the PPP, will contribute the financial investment and proven technical expertise. The network concession is for a term of 20 years with an option to extend for another 20 years.

In December 2017, it was reported that Red Compartida was set to exceed its March 31, 2018 obligation to begin operations and cover 30 percent of the Mexican population, with anticipated actual availability between 33 percent and 35 percent. Further, the network was on track to exceed 50 percent coverage by end-2018. Red Compartida launched on March 22, 2018 with coverage in excess of 30 percent. The network will grow to provide services nationwide using an all-IP network and 4G LTE technology reaching 92.2 percent of the Mexican population.

One advantage of a wholesale-only network is that many new entrants can enter the Mexican telecommunications consumer market at once. Nondiscriminatory price plans are approved by the Mexican regulator. Red Compartida can also be seen as a response to the persistent competition problems in the

Mexican mobile market, where competitive forces and other more traditional forms of regulation had proven ineffective in reducing the dominant provider's entrenched market position.

The project has received positive as well as negative comments on its impact on the competitive environment. Altan is progressing well in building out its network and gaining clients. Its impact on the market will have to be demonstrated over time.

For more details, see appendix, page 190.

5.5. Technologies with WIP Business Models

Innovations in Low-Cost Satellite Deployments

In recent years, several competing LEO satellite constellations have been funded that promise to change the current perception of satellite broadband service–expensive, poor latency technology which is a last resort for residents/businesses that can afford it.

Most of these business models focus on the satellite broadband providers offering wholesale broadband services to in-country players, such as ISPs and MNOs. In addition, these satellite providers intend to have arrangements with in-country operators who will assist them with: (i) managing customer relations and billing; (ii) distributing and installing the terminals; and (iii) applying for national service licenses. However, all of these initiatives are still in the technical concept development and testing stage, and the business models and pricing have not been fully disclosed or determined.

These satellite broadband providers differ in the services they plan to provide and their target customer:

- **Direct-to-Home (DTH)**: OneWeb plans to provide DTH broadband service to end users (see box 5.12). The system promises to provide global coverage and be relatively inexpensive with end-user terminals that can be self- or easily-installed. However, OneWeb mentioned in its response to a recent Ofcom consultation that the service might need to be subsidized for some rural deployments. The company also claims that it has sold most of the capacity of the initial 648 satellites, but the sums have not been disclosed.

- **Fixed Backhaul Service**: Other providers such as LeoSAT and Kalo are offering backhaul services to villages, mobile basestations, or business customers. This is more commercially viable because the capacity and service cost is then divided between the number of end users (as in the case of the village, or mobile cell) or provided to an entity that has much higher affordability.

- **Mobile Broadband Service**: Some providers, such as Kalo, are offering services to moving objects, such as cars and boats, through an innovative antenna design that allows high-speed satellite communications on the move.

- **Motorized Earth Station Antennas (MESAs)**: MESA systems track inclined orbit satellites for providing rural access. Concero Connect is an example.

Box 5.12: OneWeb – Low Earth Orbit Satellites for Internet Access

OneWeb has visionary targets of "connecting every unconnected school" by 2022, and "bridging the digital divide" by 2027. It is aiming to do this by deploying a constellation of satellites that are capable of beaming affordable Internet worldwide, enabling better and cheaper coverage for existing networks and connectivity in areas of the world that are currently offline.

OneWeb acquired the satellite spectrum that was formerly owned by SkyBridge and is planning to initially deploy 900 satellites at an altitude of 1200 kilometers that will work in Ku-band and Ka-band spectrum. The onground deployment has plans for 50 to 60 satellite network portals (SNPs) beaming Internet traffic to and from satellites. Pilot satellite launch is planned for late 2018 with full system deployment to be completed in the following years. To manufacture these low-cost, ultrahigh performing satellites at high volumes, the company has established a dedicated manufacturing facility as a joint venture between OneWeb and Airbus.

OneWeb will offer global, ubiquitous broadband services in a commercial agreement with Softbank. It will offer solutions for the retail market as well as carrier wholesale and enterprise solutions. From a coverage perspective, it could bring affordable Internet to wireless-dependent communities currently unserved or underserved by terrestrial networks and which remain so for the foreseeable future. OneWeb's system is designed to avoid interference with geostationary satellites as well as terrestrial wireless service.

The success of OneWeb will be dependent on its technical and operational success as well as its ability to achieve commercial success.

For more details, see appendix, page 184.

Drones, Balloons, and Other Nonpermanent Structures for Last-Mile and Middle-Mile Access

Recently, there has been significant investment in developing nonpermanent aerial infrastructure that can be used to provide middle- and last-mile coverage. These solutions can be categorized as short-term and long-term solutions (see table 5.5).

Table 5.5: Nonpermanent Structures for Middle- and Last-Mile Access

Short-term solutions	Drones, Helikites
Long-term solutions	Loon, Aquila

Source: TMG/Salience Consulting.

Short-Term Solutions

These solutions are designed to provide fast-to-deploy coverage in a particular geographical footprint for temporary periods—from a few hours to a few months. Often local power and local backhaul are required to maintain coverage. Individual footprints per device are relatively small; however, devices can, in some cases, be daisy-chained together to provide larger footprints.

The technologies used include:

- **Tethered drones.** These fly at between 400 and 1000 feet, attached to the ground by a thin tether that carries both power and connectivity. Each drone can provide coverage of about half a square mile and although they can be flown indefinitely using the tethered power supply, they are designed to fly for about three days. Once in a location with power and backhaul, they can be deployed quickly. Drones are normally equipped with 4G LTE antennas, but sometimes Wi-Fi is used. Customers are not required to have any particular equipment to connect. CyPhy Works' PARC drone is an example of a tethered drone.

- **Untethered drones.** These are similar to tethered drones but can fly to higher altitudes and provide larger coverage areas. Backhaul is through wireless connectivity, usually to the same location that is controlling the drone. Flight times are short—normally just a few hours.

- **Tethered Helikites.** These helium-filled kites rise to about 7000 feet and provide a much larger coverage footprint. They are designed to remain airborne for up to three months and are adept at coping with most weather conditions. The tether provides power to the Helikite, allowing it to ascend or descend, as well as powering the onboard 3G or 4G antennas. Backhaul is provided through satellite—the Helikite transmits in S-band spectrum to satellites, which would normally be terminated through K-band terrestrial receivers. Individual Helikites can be linked through microwave backhaul to create quite substantial coverage areas. Customers are able to use standard mobile phones to access the service.

While the use cases for drones and the Helikite are similar, drones are favored for shorter-term, smaller coverage situations when the speed of providing coverage is a high priority. Use cases for both drones and the Helikite include providing expedient coverage in the following types of situations:

- **Disaster relief.** If infrastructure is damaged because of disaster, these solutions can be deployed to provide coverage in critical areas while more permanent solutions are put in place.

- **Capacity relief.** These technologies can be used when significant spikes in capacity demands are expected. Examples include sporting events and concerts.

- **Planned temporary coverage.** They can also be useful to provide coverage in uncovered areas where the need for coverage can be planned. Examples include music festivals and sporting events.

- **Military applications.** In addition, these technologies can be used to provide coverage and surveillance in combat situations.

BUSINESS CASE

Currently, short-term nonpermanent solutions are deployed as part of a technical solution by carriers for particular short-term capacity or coverage needs. In our case studies, for example, EE Helikites, none have been used to provide permanent last-mile connectivity and it does not appear that this is being actively pursued. The low-flying drones are reliant on substantial ground infrastructure for their connectivity and, given their coverage areas, are unlikely to be particularly useful for providing coverage in regions that already have poor infrastructure. Helikites have better potential given the satellite backhaul, larger coverage areas, and longer flight times, but presently little research exists to support their use to provide a long-term last-mile access solution.

Long-Term Solutions

The two most cited initiatives that focus on creating long-term, nonpermanent last-mile and middle-mile coverage solutions are the Loon (see box 5.13) and Aquila projects (see box 5.14). The key differences between them are as follows:

- **Development Stage.** Loon was in development longer than Aquila and has completed proof of concept, and is complemented with an auto launcher. Successful trials have been undertaken in a number of countries with balloons staying airborne significantly longer than the planned 90 days. Although no date for commercial launch has been published, the technology appears to have passed through various key development hurdles. Aquila was conceived to support the use of high-altitude platform station for middle-mile connectivity to address the backhaul gap in suburban and rural areas. Following various years of technology development and testing. In June, 2018 Facebook announced it was no longer designing and building aircraft for project Aquila, and that it would instead focus on working with other companies developing high-altitude platform station technologies (Maguire 2018).

- **Business model.** Neither company has fully defined their project's business model, initially focusing on developing and testing the technology for these new connectivity platforms. Aquila was developed by Facebook's Connectivity Lab as an approach to closing the "backhaul gap" affecting broadband expansion, especially in suburban and rural communities. Loon is planning to provide wholesale access through operators on a revenue-sharing basis.

- **Technical.** Though there are clearly many differences in the technologies being used, it is currently too early in the development cycle to identify any clear differences from the customer's perspective. Both solutions sought to bring broadband speeds to large rural coverage areas using 3G/4G and possibly Wi-Fi.

Compared to traditional coverage networks, these solutions have a very different commercial structure. Particular points of note include the following:

- **These solutions both have significant upfront capital expenditure followed by lower ongoing operational expense.** While this is similar to traditional mobile networks, most of this capital expenditure is focused on the initial research and development rather than on building the network itself. Consequently, once these solutions are technically proven, it will be possible to cover large areas with much lower capital and operational expenditure costs than a traditional operator.

- **Time to deploy is much lower than traditional networks**, and in the event that network takeup is lower than expected, the equipment can be quickly repurposed to cover a different area.

- Given the investment required to develop these solutions, it is likely that for the foreseeable future **these coverage areas will best be served by at most two operators, and most likely one operator**—creating monopoly or duopoly market structures.

- **Content providers will now be network owners** meaning that the value chain is significantly larger than for pure network operators, giving additional breadth for commercial risks to be taken. This creates the opportunity for different revenue and business models based on selling or monetizing content opportunities that are not available for typical network operators.

These long-term nonpermanent solutions offer the potential for radically different business models, including:

- **Building at risk.** As the infrastructure can be redeployed relatively easily to other areas, it is possible to build coverage over an area with a more speculative risk profile. This means that areas that would be considered too marginal for traditional deployments, even if the costs were the same, can now be built to test the commercial viability.

- **Risk sharing between content and network providers.** As content providers, Google and Facebook are now investing in network infrastructure and the risk or success is being shared with local infrastructure owners. Google has proposed a revenue-sharing model whereby the local operator manages the sales and customer service and splits the revenue with Google. This means that the local operators can support operations in these areas with relatively little investment and, consequently, much lower risk.

- **International networks.** Depending on the scale of the deployment, it is possible that the network could cover areas across borders. While this could create significant regulatory issues, it provides the opportunity to leverage backhaul options in neighboring countries if these are more attractive than local alternatives.

- **Backhaul competition.** As these networks are easily able to change the backhaul being used, both in terms of the physical location of the backhaul and the technology used, they have the opportunity to take advantage of the technology improvements (for example if satellite becomes more economical) or to shift to new backhaul infrastructure when it becomes available. This may create more competitive backhaul markets and, as it is possible to aggregate backhaul demand from a large region to a single point, potentially this could justify building new terrestrial backhaul that is not currently viable.

- **Potential unblocking of regulatory and logistical issues.** As these solutions will cover large amounts of terrain requiring only a single point of backhaul, it is likely that regional bureaucratic logistical issues can be minimized. Further, in jurisdictions where the regulatory environment is complicated, the relatively simple nature of the requirements from the local country should improve the speed of deployment. Indeed, in the event that local backhaul is not available, it is possible that this could be obtained from a neighboring country or, with improved economics, from satellite services.

- **Content-based revenue models.** Tying into the content base, where the content providers are providing network infrastructure for last-mile access, there is also an opportunity for third parties to pay to subsidize the costs of Internet access (two-sided market model). While the concept of selling access to content providers to subsidize the costs of network deployment has been considered before, it has not been

commercially viable because of the upfront costs and the questionable ability of content providers to monetize the investment. With lower upfront costs (after the research and development) and proven ability of companies like Google to create value from content, there is a good opportunity to use content to subsidize the prices end-users pay. This could mean that end-users have Internet access at a substantial discount, or even for free.

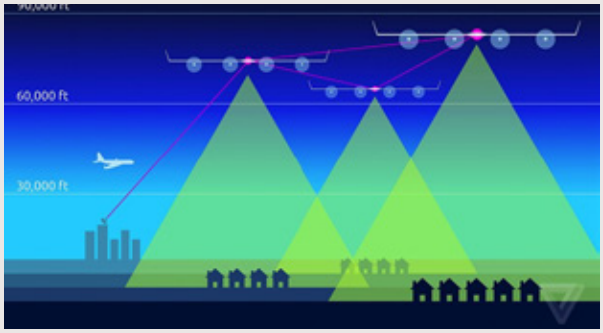
Box 5.13: Project Loon: Balloon-Powered Internet Access for Rural and Nonreachable Areas

Project Loon is a research and development project being developed by Google X with the mission of providing Internet access to rural and remote areas. The proposed solution is to use a series of balloons that act like mobile towers. Each balloon will cover an area of over 5000 square kilometers. For backhaul, the balloons will form chains of up to five balloons with the last linking to a ground-based tower with each chain in the link being up to 40 kilometers long. Initially, this means that ground towers could be up to 1,000 kilometers apart, which is expected to grow to 10,000 kilometers, compared to perhaps 40 kilometers for a ground-based network. To date, the longest a balloon has stayed airborne is 187 days, though commercial deployments are expected to be closer to 100 days. Once a balloon descends, it is collected and returned to a launching station for redeployment. Balloons are launched to provide coverage in a cluster over a certain area. In order to maintain position, the altitude of individual balloons is adjusted to move them into a prevailing wind that can move them in the appropriate direction.

The business model for commercialization of this technology has not been fully defined, though there are a few key elements. In order for customers to be able to use existing mobile phones and other connected devices, the balloons provide coverage using the LTE standard. This means that they are required to operate in spectrum bands owned by a local telecommunications company. For the moment, the proposal is for revenue generated to be shared between the local operator, who will provide use of the spectrum and ground backhaul, and Google, which will provide the balloons and related infrastructure. Google has stated that they see enormous revenue potential in the business given the huge number of people that could be covered. The current view is that, if successful, Project Loon could deliver in the order of $4-10 billion in revenues annually. There is also an opportunity for Google to restrict users to using Google services, though the company has stated that this is not their intention. While the technology is clearly the most innovative part of Project Loon to date, the business model is also groundbreaking. The investment, timeframe, and risk of the project mean that few companies possess the resources necessary to undertake such a project. Given the amount of risk involved and the lack of alternatives, it is possible that Google will be able to negotiate strong revenue shares from the local operators. Such a "mega play," offering the service in multiple countries, is rare given the level of risk and could serve as an example for similar large scale multicountry initiatives.

For more details, see appendix, page 188.

Box 5.14: Aquila: Drones Providing Connectivity to the Ground



Unlike Loon, solar aircraft solutions, like the one developed in the Aquila project, were intended to prove the viability of providing backhaul connectivity to fixed aggregation points on the ground (for example, mobile basestations, Wi-Fi hotspots, and so on) operated by retail service providers (for example, mobile providers, wireless ISPs). Each drone could cover a radius of around 50 kilometers and would connect to ground stations or gateways linking it to the Internet using microwave or millimeter wave spectrum. Each drone was anticipated to remain airborne for 90 days using solar power during the day, and stored battery power at night.

The business model for commercialization of drone-based services, as with balloons, continues to develop. In the case of projects focused on the middle mile, such as Aquila, backhaul connectivity to the base station or network access point would rely on frequencies designated for high altitude platform stations by the ITU. Once backhaul connectivity was delivered to the base station or access point, last-mile connectivity to the end user would then be offered by the mobile provider and/or wireless ISP using licensed or unlicensed spectrum.

The investment, timeframe, and risk of the project limit such undertakings to companies, such as Facebook, with significant resources at their disposal. Lessons learned from Aquila may support the many innovative business models based on high altitude platform stations in the future, provided that the technology can be deployed on commercially viable terms.

For more details, see appendix, page 161.

5.6. Business Model Enabling Technologies

Open-Source Software Applications

Using open-source software applications, rather than traditional cellular technology, provides opportunities for lowering solution costs and stimulating innovation.

OpenBTS, an open-source application that substitutes Internet Protocol and a software radio for traditional telecommunications cellular protocols and hardware, has been used by Endaga (see box 5.15), Vodafone Instant Network (see box 5.16), and Fairwaves projects to lower the cost of the overall solution. The solutions developed in this way are order-of-magnitude cheaper than traditional products—for example, Endaga's CCN1 network box is priced at only $6,000.

The advantages of these open-source approaches have been proven before in the software industry, where open-source software has replaced a good deal of license fee-driven and closed, proprietary software offerings. Anyone could download the software and start developing their own solution without any royalty or licensing restrictions—providing an ideal innovation platform for small startups.

Box 5.15: Endaga – Network in a Box, Owned and Operated by Rural Communities

Endaga is a community-owned network concept that targets remote communities cut off from cellular connectivity, road, and grid access using micro basestations and a flexible backhaul solution for Internet connectivity. The idea was developed by students at the University of California, Berkeley who built a mobile telecommunications network that can run out of a small box attached to a tree in a remote village.

The main product is a network box called CCN1, which stands for "community cellular network." It uses the open-source OpenBTS application as a replacement for traditional fee-driven radio products, delivering the turnkey box solution at $6,000 each. CCN1 communicates with mobile devices in the field using standard cell stacks and frequencies, converts them to Voice over IP (VoIP) and transmits via a satellite link or long-distance Wi-Fi. The box runs on dedicated 2G frequencies, provides cellular coverage across a 6.2-mile radius and draws about 80 watts of power, leading to the use of solar panels to power the first deployment.

Endaga's proprietary software includes a management layer that includes billing and analytics functions for the entrepreneur/network operator. Endaga's credit transfer system—where anyone on the network can move credit between accounts with an SMS—created a distribution system of credit transfer in the community. In a 1,500-person town in Papua, Indonesia, where the first box was installed in February 2013, the school with the box is collecting a total of $2,000 in revenue per month from 400 subscribers.

The main issue reported was that mobile operators own the radio spectrum, thereby making Endaga in theory an illegal service. Negotiating the business model with mobile operators has proved to be slow

and challenging. Also, the applicable spectrum licensing does not support the entrance of small players and, therefore, there is an unclear regulatory path to scale, which potentially deters future investors. In October 2015, the founders of Endaga joined Facebook effectively merging Endaga with Facebook's open-source development of OpenCellular and CommunityCallManager.

For more details, see appendix, page 170.

Box 5.16: Vodafone Instant Network and Digital School in a Box Concept

The Vodafone Foundation Instant Network is an initiative by which rapid mobile coverage and services can be extended to a region in the case of emergency, offering easy transportation, rapid activation, and smart connectivity.

The portable solution weighs 100 kilograms and can be transported on commercial flights in just four suitcases of less than 32 kilograms each. It can be activated within 40 minutes, and the established standalone network can support free local voice and SMS, as well as remote connectivity (GSM radio through satellite backhaul to a core network). Vodafone also deploys employee volunteers to deliver and run the missions.

More recently, an 11-kilogram mobile network in a backpack version was developed to support small humanitarian field offices in disaster areas. To date, Vodafone has delivered 11 emergency response missions in the past five years, supporting natural disaster relief in Fiji, Vanuatu, the Philippines, Kenya, and Nepal, and refugee crisis response in Greece, Serbia, the former Yugoslav Republic of Macedonia, and South Sudan.

Taking the initiative one step further, the Vodafone Foundation has partnered with the United Nations High Commissioner for Refugees (UNHCR) to launch their Instant Network Schools program, enabling young refugees and teachers access to digital educational content and the Internet in some of the most marginalized communities where Vodafone operates. This offers a vital service when considering that the average length of time of displacement is 20 years, meaning a child can be born, raised, and complete their entire schooling in the closed environment of a refugee camp with limited access to a quality education and the outside world.

Weighing just 56 kilograms, the digital school in a box can be set up in less than 20 minutes and can be used in classrooms where there is no electricity. The box includes a laptop, 25 tablets preloaded with educational software, a projector, a speaker and a hotspot modem with 3G connectivity. To date, 31 Instant Network Schools have been delivered in seven refugee camps in Kenya, Tanzania, South Sudan, and the Democratic Republic of Congo, benefiting more than 43,000 refugee students and 600 teachers.

For more details, see appendix, page 202.

Lowering Costs of Local Networking

There are a significant number of initiatives that are improving the rural network business case by lowering network CAPEX and OPEX. VANU and Virural offer compact carrier-grade outdoor basestations, a wide variety of media for backhaul, remote monitoring, and software upgrades, and a solar power energy source. Virural produces a low-cost package consisting of a 15-foot mast, small-cell basestation, and a satellite or microwave dish for backhaul, as well as solar panels with backup batteries to power the network. It is a network extension initiative carried out in partnership with existing service providers. Virural takes a share of end-user revenues.

Wrightgrid similarly provides low-cost network extension technology in the form of solar-powered equipment for Wi-Fi hotspots and device charging.

Village Telco (see box 5.17) offers a networking solution to connect local communities and telecommunications service providers at low cost. The network is designed to be self-installed by users with relatively limited technical knowledge.

Box 5.17: Village Telco, Do-It-Yourself Wi-Fi Mesh Local Community Network

Village Telco aims to provide low-cost Wi-Fi mesh networks for villages through the selling of "Mesh Potato" CPE. The Mesh Potato is a Wireless Access Point (WAP) combined with an analog telephony adapter (ATA) which gives a plain old telephone service (POTS) presentation. This means that standard fixed analog phones can be plugged into the Mesh Potato. All Mesh Potatoes automatically connect to one another, creating a mesh network. Effectively this is a low-cost way of deploying a local area telephone network. A Village Telco Entrepreneur Server, which will connect the local mesh network to the other telecommunications providers and allow for billing, network management, and so on, can easily be added by a local organization or entrepreneur.

Software releases in 2016 have upgraded the network to allow it to carry data as well. The village is required to supply its own backhaul, but the Mesh Potatoes can then create a Wi-Fi data mesh network to which any Wi-Fi device can connect.

The rationale for the idea was noting that up to 50 percent of disposable income in some areas is spent on telecommunications, and a significant proportion of this spending would be used to communicate with people within the local village. Village Telco's solution would mean that, for a single relatively small upfront cost, these local calls could be free and offnet calls would be cheaper than offerings from mobile networks. While not designed to fully substitute for mobile networks, Village Telco is designed to allow users to move a significant amount of their traffic onto a locally owned network and reduce the associated telecommunications costs. With the inclusion of data services, the network can scale to reduce dependency on telecommunications providers.

To date there have been eight publicized deployments around the world—three in South Africa and one each in Nigeria, Colombia, Puerto Rico, Timor-Leste, and Brazil. Though unpublished, total users are probably not more than in the tens of thousands. The various deployments have been prompted by different needs—for example to provide NGOs with an inexpensive network in Timor-Leste, or by entrepreneurs providing data services in poorly served areas of South Africa.

Village Telco's business model is a "network in a box" approach and requires some investment from the village or organizer to buy a server and the Mesh Potatoes. While this means that Village Telco is able to be installed globally, it does require local investment and education for each individual deployment. The current business model is really a simple vendor solution that does not require a technically sophisticated installation. Combining it with an effective marketing or education business could potentially increase the scale of deployments.

For more details, see appendix, page 200.

6. Cross-Sector Infrastructure Sharing

Cross-sector infrastructure sharing is not a business model per se. It is a means by which a market segment may be addressed by leveraging existing assets. Pursuing cross-sector infrastructure sharing as a means of lowering deployment costs and increasing market entry has recently caught on in many countries. As attraction to the wholesale model for fiber provision (both in backhaul and access) has grown over the past two decades, so has the interest of nontelecommunications players in becoming telecommunications companies.

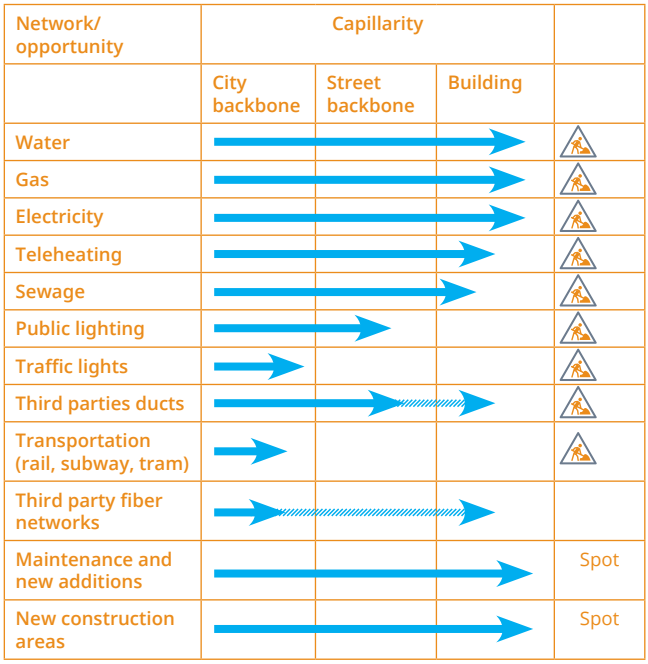
Utilities, especially electricity and water providers, have networks similar in structure to traditional telecommunications networks and specific infrastructure that could be shared for telecommunications purposes (such as ducts, poles, and service plants, as detailed in figure 6.1). The percentage of infrastructure capable of sharing will vary between countries and specific utilities, but in general it will be quite significant and may lead to lower per-home connectivity costs. For example, Italy's Enel announced duct shareability of 55-67 percent, and Norway's Altibox, formed by an energy utility owned by 16 municipalities, has reported an average build cost estimate of €2,500 per home compared €3,400 for the incumbent Telenor.

Moreover, utilities have generally far better rights of way and public land use arrangements, which are crucial for deployment of infrastructure, than telecommunications operators. Utilities are also the first service providers to reach new greenfield developments and deploy infrastructure (in order to provide their own services).

Traditionally, utilities have had a much wider role in backbone and backhaul fiber provision than access fiber. However, utilities in the developed world have often ventured into wholesale access and even retail plays.

The business cases for utilities vary from utilities as wholesale operators partnering with telecommunications operators to deploy infrastructure (for example, IWB and Swisscom in Switzerland), to state-created wholesale operators (such as Oman Broadband in Oman), to independent retail/wholesale operators (for example, M-Net in Germany and Optilink/EPB in the United States). Historically speaking, fewer utilities have offered full retail operations and more have focused on providing wholesale services that generate healthy new revenue streams without the distraction of selling and marketing telecommunications services to end-users. Figure 6.2 provides a selection of utilities involved in access fiber services across the globe.

Figure 6.1: Other Utility Providers' Presence to be Leveraged



Source: based on Pupillo 2008.

Figure 6.2: Selected Examples of Fiber Companies Set Up by Utilities

	United States	Ireland	Norway	Italy	New Zealand	Basel, Switzerland	Bavaria, Germany	Denmark
Utility	epb	ESB	36-utility partnership	enel	Northpower	IWB	SW//M	14-utility partnership
Fiber Venture	EPB Fiber	SIRO	Altibox	Open Fiber	Northpower Fiber	IWB Net	M-Net	WAOO
Trigger for FTTX	• Business diversification • Public funding	• Market opportunity • National policy	• Business diversification	• National policy • Public funding	• National policy • Public funding	• National policy • Market opportunity	• Business diversification	• Business diversification
Business Model	• Retail	• Wholesale	• Retail	• Wholesale	• Wholesale	• Wholesale • Retail (B2B)	• Retail • Wholesale	• Retail

Source: Arthur D. Little 2017.

The business case for provision of fiber access by utilities usually relies on a mix of additional revenue and own-use for metering purposes, as well as capitalizing on the potential access to government funding dedicated to enabling broadband.

More importantly, utilities can help to extend the reach of telecommunications operators to areas that were previously considered commercially nonviable (as in the case of Ireland).

In the developing world, the experience with utilities in telecommunications service provision has been more mixed.

Power and other utilities interested in telecommunications infrastructure provision in developing countries have enjoyed a measure of success when focused on dark fiber or transmission services on core and backhaul networks. Table 6.1 provides a number of examples of these utilities.

Table 6.1: Examples of Utilities as Telecommunications Provider

Country	Utility as telecommunications provider
Kenya	KETRACO (the Kenya Electricity Transmission Company) has been granted a Network Facility Provider Tier 2 (NFPT2) license by the Communications Authority of Kenya (CA) to enable the lease of excess fiber to licensed application and content service providers in Kenya. KETRACO will eventually have over 4,000 kilometers of optical fiber crisscrossing the country, spanning from Mombasa (submarine cables) to the borders of Ethiopia, Uganda, and Tanzania.
Zambia	ZESCO (the Zambia Electricity Supply Corporation) began leasing fiber cores when the first phase of its fiber-optic project was completed in 2008. This project, named FibreCom Broadband, has covered some 1,700 kilometers and connected most major centers and border areas. Several service providers, including MTN (Mobile Telephone Networks), Zamtel (Zambia Telecommunications Company), the Zambia Revenue Authority, and the Communications Authority of Zambia, are already using the ZESCO fiber-optic network.
Namibia	Nampower (the Namibian Power Corporation) is planning to lease spare fiber cores on its transmission lines to an ICT licensee that will operate the fiber on a commercial basis.
Botswana	BPC (Botswana Power Corporation) has recently embarked upon an extensive power network expansion program expansion with all new lines to be equipped with optical ground wire (OPGW). Furthermore, a business partner has been identified via an open tendering process. This entity will be responsible for the day-to-day operation of the planned fiber-optic commercialization business while BPC will receive a share of the revenue. BPC has also recently installed OPGW to the borders with Zimbabwe and South Africa. However, the utilities in these countries are yet to finish their respective installations to complete the international connections.
Zimbabwe	Powertel Communications, a subsidiary of ZESA (Zimbabwe Electricity Supply Authority) Holdings, is a public data network operator fully licensed by the Postal and Telecommunications Regulatory Authority of Zimbabwe (POTRAZ) to provide data communications services. Currently, Powertel, as a state-owned Internet access provider, supplies data services carried on ZESA's powerlines between Harare, Bulawayo, and Plumtree; more recently OPGW has been also been installed on the power line between Harare and Kariba.

Country	Utility as telecommunications provider
Malawi	ESCOM (the Electricity Supply Corporation of Malawi) has been awarded a Carrier of Carriers license and has installed fiber-optic cables on its lines between Blantyre and Lilongwe, while another cable is connected to Mozambique and terminated in Maputo. In 2011, MTL (Malawi Telecommunications Limited) set up a leasing arrangement with ESCOM and now leases capacity from ESCOM to circumvent outages caused by regular vandalism of its underground cables.
Tanzania	TANESCO (Tanzania Electric Supply Company) deployed a fiber-optic network serving 10 regions of Tanzania covering 2,050 kilometers as Phase 1 of a broader plan to rollout a fiber network. Financing for Phase 1 was secured through a development loan as well as a grant provided by the Government of Tanzania. Phase 2 is planned and involves extending the network to the North West of Tanzania allowing for the opportunity for international fiber connectivity to neighboring countries. The total fiber route length for Phase 2 will be about 1,500 kilometers.
Lesotho	LEC (Lesotho Electricity Corporation) registered a subsidiary communications company in April 2015 with a mandate to manage its fiber-optic infrastructure on a commercial basis. The subsidiary obtained a communications license in June 2015 to lease fiber cores and capacity and began operating in October 2015. The business model involves the commercialization of existing fiber cores and subsequent reinvestment of realized revenue to expand the existing fiber-optic network. The LEC subsidiary has, to date, concluded indefeasible right of use and lease contracts with two large telecommunications operators in Lesotho. These contracts include the leasing of existing fiber cores as well as the attachment of third party-owned fiber-optic cables to LEC's distribution poles.
West Africa	The West African Power Pool (WAPP) is planning to implement larger scale fiber projects. WAPP is a cooperation of the national electricity companies in West Africa under the auspices of the Economic Community of West African States (ECOWAS). The members of WAPP are working to establish a reliable power grid for the region and a common market for electricity. To date, the group has not successfully launched a specific fiber initiative.

Source: TMG/Salience Consulting.

However, there are notable failures. In South Africa, Broadband InfraCo has struggled to find success as a utility selling backbone transmission capacity, as detailed in chapter 4.3. In many cases, the lack of technical expertise and the bureaucratic obstacles that must be overcome have proven terminal to the effort or to supply of sophisticated active transmission services. Arguably, in many instances, a role as provider of passive infrastructure is a more realistically beneficial aim. Indeed, there have been instances in which even fiber installation has proven challenging to some utilities, suggesting that decision makers may wish to think twice before undertaking initiatives beyond laying ducts and erecting poles—core activities of utilities.

7. Recommendations

Chapters 3, 4, 5, and 6 examined the attributes and performance of various business models in the deployment of infrastructure and trends in spectrum policy and planning, as well as cross-sector infrastructure sharing. This examination leads to a number of lessons learned and recommendations for policy makers seeking to promote broadband deployment in their respective economies. The discussion of these recommendations begins by outlining general objectives policy makers may have for expanding and upgrading infrastructure and planning for spectrum use. This is followed by a list of more general recommendations for policy making that involve the possibility of government intervention in some form, as well as specific recommendations linked to the types of infrastructure deployment and issues of spectrum policy and planning discussed in this report.

7.1. Objectives and General Considerations

There are a number of objectives that a nation may be pursuing for which additional infrastructure deployment may be a key driver or enabler. These objectives include:

- **Meeting existing and/or projected demand** in areas that are currently served;
- **Bridging the digital divide** by extending service to areas that are currently underserved or not covered (that is, commercially unviable);
- **Promoting innovation** by stimulating the local ICT market and creating high-tech areas; and,
- **Achieving socioeconomic impacts** that are not able to be monetized by service providers.

In considering best-fit approaches to facilitating infrastructure deployment and spectrum planning to meet these objectives, experience has shown that it is important to keep in mind the following considerations:

- **Is the market for which the deployment is being considered currently or potentially competitive?** The existence of private players (which have gained significant market share) suggests that the market is buoyant enough to allow existing or new private network service providers to be the main actors in achieving the objectives. The absence of competition may both suggest that the market may not support solutions involving multiple actors and indicate that there are regulatory issues that may have to be addressed as part of the deployment.
- **Is there a positive business case for the private sector to deploy or upgrade the necessary infrastructure?** If the answer is yes, then it is quite likely that existing or new private network services will already be incentivized to achieve the objectives.
- **Does the necessary infrastructure represent missing links in existing infrastructure, an upgrade of existing infrastructure, or extension of existing infrastructure?** The answer to this question will suggest which actors—incumbents or new entrants—may be involved in developing an appropriate solution, that is, a solution involving upgrades of existing infrastructure will tend to involve incumbents, whereas the solutions to provide missing infrastructure may provide an opportunity to expand entry in the market.
- **Can the regulator effectively control dominant market power?** The answer to this question will determine what kind of market structure and entry solutions will have to be addressed beyond the network deployment itself.
- **Is the government regulation of the telecommunications and adjacent markets developed and integrated enough to enable the objectives?** This consideration seeks to understand whether the telecommunications regulator is both empowered and willing to utilize its authority to regulate the wholesale service providers in the country. The ultimate goal of the regulation is to encourage services that are carrier neutral, provided on an open-access basis and enable affordable end-user Internet. Are the various ministries capable of synchronizing regulation (such as civil works regulation advocating for street and in-building fiber deployment) and is there a basis for shared infrastructure deployment?
- **Is the government PPP-capable?** In other words, is there an enabling environment such that the government can in some form take a partnership role in the deployment and running of the infrastructure (see table 7.1).

Table 7.1: Is the Government PPP-Capable?

Attribute	Description
Local laws and regulations	If local statutes do not permit one or more forms of public-private partnership, the government's role in business models will be limited.
Previous experience	If the public sector has not been involved in such activity before, or if it has and proved an unreliable partner, then partnership is questionable.
Financial resources	Most public-private partnerships require a long-term financing commitment from the public sector. If the public sector lacks the resources or cannot commit resources over a long period of time, its role will be limited.
Consensus, political support, and leadership	If a government is unstable, lacks public support, or is otherwise divided in terms of policy or willingness and ability to lead, the public sector may not be capable of committing in the manner and degree necessary.
Specialist resources	From the beginning of the inception of the deployment concept to the launch and throughout the operation, the government will need expert opinion to inform their decision making for the partnership. If such resources are not available, decision making will suffer and trust may erode.

Source: TMG/Salience Consulting.

- **What is the government leverage to gain access to regional and global funds for broadband development?** The government needs to evaluate access to funds based on its participation in wider economic unions (such as the European Union or ASEAN) and the government's capability to raise funds on international markets. Most of the European broadband projects (for example, Poland, Croatia, Slovenia, Romania, and Estonia) have been implemented by using structured EU funds. There are also a number of infrastructure banks acting on the global or regional levels that support these initiatives, including vendor-linked funds. With regard to private investment, U.S.-based technology ventures (such as OneWeb and Kalo) have turned to venture capital (VC) funds and big technology investors to raise the capital required for their projects.

7.2. General Recommendations and Principles

There are five key principles that should form the baseline recommendations for a consideration of any policy for promoting broadband deployment:

- **Limited, incremental intervention.** Governments should intervene only in cases of clear market failure and only to the extent necessary to overcome market failure and complement private investment. The rapid success of private, market-driven projects such as Liquid Telecom, Ufinet, Baltic Optical Network, JADI, and RCN demonstrate the validity of these principles. The correct area classification based on service availability (such as the EU marking of black, grey, and white areas) will help the government quantify the intervention space.

- **Minimize regulatory failure.** Governments should not confuse market failure with regulatory failure. Before a perceived market failure is addressed with intervention through direct participation in the market as an operator, investor, or subsidizer, the state should first determine if it has contributed to the problems by creating barriers to beneficial entry, unduly raising costs, or being otherwise unsupportive to infrastructure deployment. The actions that governments should consider to obviate or minimize regulatory failure runs from best practice policy principles to specific regulatory measures. There are many publications covering best international regulatory practice for facilitating broadband infrastructure deployment (see, for example, Kelly and Rossotto 2012; MacMillan Keck and the Columbia Institute for Sustainable Development 2017; and GSMA 2018). The main features are summarized in box 7.1.

- **Consensus on a coherent vision, political will, and leadership.** Intervention should be based on clear policy objectives for the sector, be conducted with commitment on the part of leadership, and flow through to regulation implemented consistently with the policy objectives. These principles are particularly linked to success or failure. The evidence of the importance of this principle is particularly strong in cases where success has been elusive. In Qatar, for example, competing policy aims undermined the admirable intentions for broadband development.

- **Governments should take a sober view of what activity it can credibly and reliably carry out.** All states will have limits as to the skill sets, finances, and legal authority, among others, available to actively participate in infrastructure deployment. Governments should assess these capabilities and craft their participation accordingly.

- **Promoting competition.** Government intervention should be engineered to increase competition even when infrastructure competition is not viable, that is, service-based competition. This generally means that the government should support open-access wholesale arrangements. This recommendation finds expression in the wide variety of open-access network service providers in crossborder, national, middle-mile, and last-mile initiatives covered in this study.

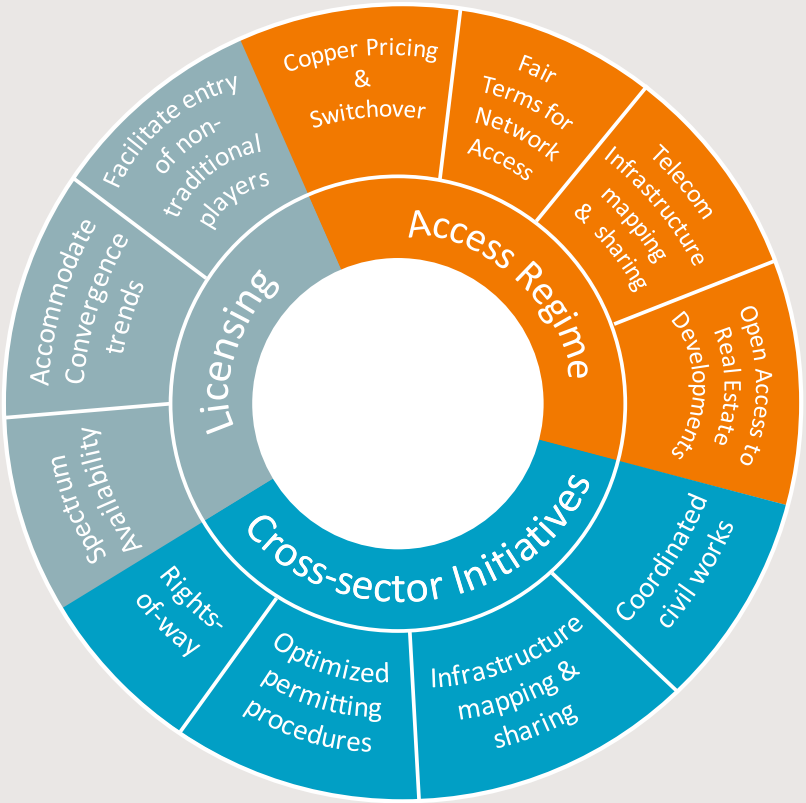
Box 7.1: Policy Principles and Specific Measure to Obviate or Minimize Regulatory Failure

With respect to best policy principles, included here are regulatory predictability, transparency, cost-benefit analysis, proportionality, as well as the attributes of minimal distortion (which applies, for example, to tax policy).

Specific regulatory measures include:

- spectrum policy measures that are the subject of chapter 7.3;
- service licensing to increase beneficial market entry of a wide variety of market players;
- improvements to the access, including, where justified by market concentration, open access and other measures to safeguard competition and reduce the costs of deployment; and
- cross-sectoral initiatives to lower the cost of network deployment, such as increased access to rights of way, less-bureaucratic permitting processes, and facilitating the sharing of infrastructure across utilities.

Figure B7.1.1: Policy Principles to Avoid Regulatory Failure



Source: Adapted from FTTH Council MENA 2015.

SPECTRUM-SPECIFIC PRINCIPLES

In considering how best to leverage spectrum resources to ensure effective and efficient use that improves and expands Internet access, the following core set of spectrum principles were used to develop the recommendations set forth in chapter 7.3.

- **Leverage flexibility to enable the introduction and growth of emerging technologies, notably 5G and the IoT.** Although 5G technology has been in development for several years and IoT devices and services are already in use, both technologies are expected to experience considerable further development and growth. Regulators and policy makers should ensure that their actions not only do not constrain such growth but, rather, facilitate and encourage it, building frameworks that maximize flexibility, enable innovation, minimize administrative burdens, and take into account the characteristics that make these technologies different from earlier innovations. These new technologies will both enable novel, flexible uses of spectrum, and also benefit from regulatory flexibility in considering the rules and policies that govern their deployment.

- **Maximize spectrum access for wireless broadband services.** Demand for wireless broadband services has continued to grow unabated, driven in part by the continuing improvement of wireless technologies and their new applications, and the increasing ability to flexibly use spectrum to serve different needs and users. Policy makers and regulators seeking to expand access to broadband should keep in mind that the most important method by which to increase capacity and improve the user experience is to ensure the availability of appropriate spectrum for use by wireless broadband services. This is even more important when considering the new connected applications supported by IoT. Identification of bands and transparency regarding the amount and availability of spectrum must be accompanied by appropriate—and sufficiently flexible—licensing and access models that are aligned with the likely use cases of the spectrum under consideration. In addition, regulatory frameworks should facilitate flexible use, allowing for pooling and sharing, to maximize use and efficiency, while at the same time promoting competition.

- **Implement strategies specifically targeting unserved and underserved populations.** Reaching areas and populations that continue to lack adequate—or any—broadband access will require new, more flexible approaches and reconsideration of the role of government. The advent of new wireless technologies with different characteristics and use cases than existing mobile networks should prompt actions that can strengthen existing successful approaches and leverage new technologies, business models, and spectrum authorization approaches to provide governments and regulators with a flexible set of tools with which to develop new sector strategies.

7.3. Spectrum-Specific Recommendations

Set forth below are a set of recommendations for regulators and policy makers considering new technologies and trends in the context of spectrum policy. These recommendations focus on the following three key policy objectives: promoting 5G and IoT deployment, supporting expected demand growth, and expanding wireless broadband to unserved and underserved areas.

Promoting 5G and IoT deployment: Society is moving towards a demand for ubiquitous connectivity, a trend which will accelerate with the expansion of new technologies, such as 5G and the IoT. Such technologies will also expand the possibilities for new services and applications. As they are in the early stages of development and implementation, regulators and policy makers should take steps to enable their continued deployment and availability. To achieve this objective, the following action items should be considered:

- Review national broadband policies to consider the use of different wireless broadband technologies for the expansion of connectivity. The availability of multiple spectrum bands and new technologies provide regulators with increased flexibility to meet broadband access goals using a variety of technological tools.

- Identify spectrum to enable the next wave of wireless broadband growth, including new mobile services, intended to enable 5G and the IoT. This includes existing spectrum identifications below 6 GHz and new spectrum ranges between 24 GHz and 86 GHz. 5G technologies, in particular, will benefit from the availability of low-band, mid-band, and high-band spectrum.

- Ensure that the legal and regulatory framework provides maximum flexibility for spectrum users to deploy new and updated technologies, including in unlicensed spectrum. Given the high reuse potential of bands above 24 GHz, infrastructure requirements, interference management, and valuation approaches will change radically. In this regard, spectrum and infrastructure sharing initiatives could play a significant role in accelerating 5G, the IoT, and smart city developments. Regulators should elaborate a more developed set of sharing regulations—addressing both infrastructure and spectrum—as well as spectrum assignment and valuation approaches for 5G operators.

- Define the differing spectrum needs for various industry verticals supported by IoT applications. Spectrum and service needs will vary, as can be seen when comparing the needs of a high-precision autonomous vehicle, industrial machinery, and a low-cost energy meter.

- Certification processes should be streamlined so as to meet requirements while avoiding delays and reducing costs for both suppliers and regulators, easing the introduction of new and emerging technologies. A simplified approach to ensuring adherence to technical standards is key to ensuring equipment compatibility, quality of service, and reduced interference while minimizing barriers to expansion of the sector. Similarly, certification fees should be reduced to levels that cover administrative costs, rather than generating revenue.

- Establish technical criteria for the use of spectrum bands based on international recommendations and take the same considerations into account when drafting new regulations. Harmonized technical characteristics allow for economies of scale that reduce both network deployment costs and user equipment prices.

Supporting expected demand growth: Given the explosive growth in demand for wireless services, the ongoing development of new wireless technologies and spectrum usage paradigms, and the rise of new licensing and authorization mechanisms, regulators and policy makers should consider the following action items in order to increase the amount of spectrum that can be used to expand broadband services:

- Assess future spectrum demand, particularly for IMT, Wi-Fi, and the IoT, to meet capacity and deployment needs, through:
    - engaging relevant stakeholders in the process, consulting with industry on expected uses cases and spectrum needs;
    - reviewing international studies on spectrum demand for different services and bands; and
    - modeling demand, considering new or emerging technologies, such as 5G and the IoT.
- Revise the national table of frequency allocations—to the greatest extent possible—to reflect global and regional allocations in accordance with the ITU Radio Regulations, as well as identifications for IMT services (for example, 3G, 4G, and 5G). Update the table in line with the changes to the Radio Regulations that are decided at World Radiocommunication Conferences.
- Refarm mobile broadband spectrum from previous technology generations to increase block sizes and allow use of newer technologies, taking into account regional and global developments in order to maximize harmonization opportunities.
- Identify spectrum in use by other technologies and services that would provide greater value through use by wireless broadband technologies and services (for example, digital dividend), and then repurpose that spectrum.
- Implement a flexible spectrum regulatory framework that promotes and allows practices such as trading, sharing, aggregation, and lower barriers to accessing and using spectrum.
- Implement assignment processes that maximize the social and economic benefits of spectrum use (for example, coverage, speed, quality, industrial development) rather than maximization of license revenues. Assignment approaches intended to meet service and coverage goals are more likely to result in increased broadband access than those designed to maximize revenue generation through license fees.
- Develop a spectrum licensing schedule to assist service providers—including potential new entrants—to make decisions regarding network and service planning. The schedule should be published online in order to allow all interested parties to have equivalent information when determining how and when to invest in spectrum licenses that will enable them to meet their objectives.
- To achieve economies of scale for deployment, require licensees to deploy networks and infrastructure that comply with widely adopted international standards, but take caution to ensure implementation of technology-neutral regulations to avoid limiting operators' ability to adopt new technologies.
- Mandate spectrum license conditions that ensure efficient use of the spectrum, the potential for sharing appropriate spectrum with other services, mechanisms and rights for spectrum trading, and clear renewal provisions. Well-defined spectrum licensing regimes ensure that mechanisms are in place to allow licensees and other interested parties to make the most efficient and effective use of spectrum resources. Flexibility of spectrum use conditions can help to create a positive sharing dynamic among spectrum users. Wi-Fi bands are perhaps the best example of flexible and shared use leading to an innovative environment.

- Empower regulators to respond to inefficient spectrum use or other license condition breaches through remedies that maximize spectrum use and social benefit. For example, licensees making inefficient use of licensed spectrum could be compelled to pursue opportunities to trade and/or share their underutilized spectrum. In cases of severe license condition breaches, regulators should be empowered to withdraw licenses altogether.

Expanding wireless broadband to unserved and underserved areas: Expansion of wireless broadband to currently unserved or underserved areas, especially in conjunction with the development of newer wireless technologies, will likely require approaches and incentives different from initial mobile network deployments. To achieve these objectives, the following action items should be considered:

- Develop a sector policy that prioritizes expansion of wireless broadband services, especially in unserved/underserved areas. This policy should take into account backhaul and last-mile access, as well as access to spectrum and public infrastructure (for example, government-owned facilities, electric power), while keeping the flexibility to choose appropriate technologies and viable business models.
- Promote the creation of community Internet service providers and small connectivity providers, particularly by providing access to spectrum, backhaul, and other public infrastructure, and by resolving any unfair impediments to their deployment. Community-owned companies and small providers could be allowed access to these key resources at preferential rates, which can be particularly important for business models that are often tailored to low-income populations with low levels of technology literacy.
- Implement a flexible framework for spectrum use by broadband providers, including multiple approaches to spectrum access (for example, unlicensed spectrum, experimental/social licenses, and shared spectrum) to facilitate innovation and efficient spectrum use.
- Identify whether and how government should directly participate in the delivery of wireless broadband services jointly with the private sector, such as through PPPs.

7.4. Infrastructure Deployment Options: Specific Recommendations

The five baseline recommendations above are relevant to most interventions a government might consider, irrespective of sector or objective. The analysis of projects presented in chapters 4 and 5 also suggests some specific recommendations for infrastructure deployment, should a government decide that it must be involved beyond standard tools of regulation. The recommendations below are specific to infrastructure deployment where higher levels of government intervention are required:

- **Private-sector participation.** Government intervention in infrastructure deployment should include private-sector involvement wherever possible. The advantages of private-sector participation include the sharing of costs and risks, building expertise, and adding critical financial insight. The projects reviewed include numerous public-private partnerships (PPPs) where an initiative was simply not possible without private capital or benefited significantly in terms of rollout and financial viability from having private entities involved in constructing and running the network. Even where government intervention is indirect, implemented through policies such as taxation, subsidization, or regulatory obligation, the private sector impacts should be taken into consideration.

- **In the presence of state-owned incumbents, structural changes should be considered as part of an overall national plan.** If the state-owned incumbent is part of the solution, then it is quite likely that some sort of repositioning will be necessary. In The Gambia, for example, the state-owned operator has yet to be restructured and broadband policy is suffering as a result. The role of the state-owned incumbent, Onatel, in the Burundi Backbone System proved a major flaw. OpenNet provides examples of structural changes called for in the transition to more aggressive broadband policies.

- **Utilities' collaboration and enabling reuse.** In many cases, there is existing or planned utility infrastructure that telecommunications policy makers have not considered or are not aware of when developing national broadband expansion plans. State utilities have valuable assets, such as ducts and poles, buildings, land rights, and even fiber networks (such as SCADA) that could be leveraged for cost-effective deployment of the new infrastructure. The more this infrastructure is shared, the lower the cost to pass premises. In addition, joint projects are feasible—civil works initiatives that can also include parallel deployment of telecommunications networks and other utility networks.

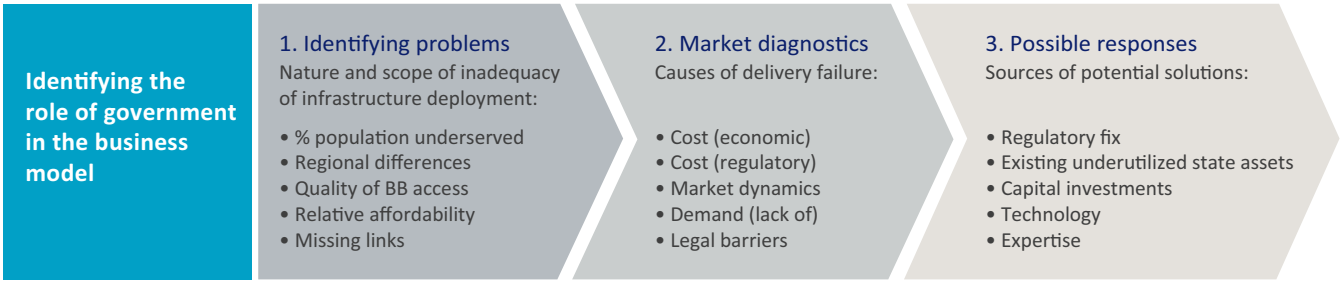
- **Justification should be based on realistic business case and socioeconomic cost-benefit analysis** with a view to local, national, and regional trends in the future. The intervention should be undertaken with the objective of mimicking a risk-adjusted, externality-adjusted market outcome. In other words, economic net present value (ENPV) should be calculated and the initiative reconsidered or abandoned if not positive. Most, if not all, of the EU cases had to demonstrate positive ENPV before the government would commit funds to the venture. There are a number of municipal cases in the United States where overexuberance led to poor project choices, for example, iProvo and Burlington Telecom.

- **One business model's failure can lead to another's success.** The history of telecommunications infrastructure is filled with examples of overbuild, asset stranding, underutilization, and failed commercial endeavors of all sorts. While in the short run some projects may be wasteful, nevertheless, in the context of increasing long-term demand, long-lived assets can often

be repurposed, commercialized, or otherwise brought back into productive use and facilitate new entry for the benefit of all. This notion applies to much of the infrastructure of utilities, government-owned networks, and facilities of bankrupt public service providers. Policy makers can act to reduce the time that assets lay idle by (re)commercializing and reducing barriers to cross-sectoral engagement.

- Finally, the history of successful business models provides a rich collection of **lessons for policy makers seeking to intervene to deploy broadband in underserved areas.** This report has presented such lessons throughout. Below we provide a decision-making tool that facilitates identifying experiences that may be particularly relevant for policy makers given the attributes of the particular infrastructure challenge they face. Figure 7.1 summarizes a process to determine the proper role for the state in any particular infrastructure deployment scenario. The first step is to determine if there is an infrastructure deployment problem and, if so, its nature and scope. The second step is to identify the underlying causes of any problems that are found to exist. The third step is to consider possible responses to address those problems.

Figure 7.1: Identifying the Role for the State



Source: TMG/Salience Consulting.

Figure 7.2 provides a decision-making tool to facilitate selecting the appropriate role for the state to play. First the **"null" scenario** is identified, where the state should reconsider any proposed intervention. Where there is no demonstrable market or regulatory failure to address, state action is generally not justified. There are at least three examples in the list of reviewed projects where the state may have been unnecessarily ambitious in its objectives—the second phase of Rwanda NBFON (involving the pursuit of a single wholesale mobile network for 4G), Peru RNDOFO, and South Africa's Broadband InfraCo. In the latter two, state investment was made in national backbones in markets in which the private sector was capable of delivering infrastructure on its own. Figure 7.2 goes on to address additional scenarios to assist policy makers in identifying a potential course of action in a variety of contexts.

Scenario 1 results when there is no inherent market failure, but counterproductive regulation, unnecessary legal constraints, or unduly burdensome financial obligations are imposed by the state. In this scenario, the state's role is simply to eliminate or minimize the self-created cause of infrastructure inadequacy. In most cases, this amounts to improving licensing—simply authorizing the entry of new players, ensuring spectrum is available, and so on. In this regard, a recommendation to lift regulation does not imply that the state should discontinue good regulatory practice. Indeed, as market dynamics often lead to concentration and vertical integration, the state should continue to monitor market developments. Successfully addressing regulatory failure in such a way as to facilitate new infrastructure in the short or medium term may lead to market failure in the form of dominance in the longer term.

Scenario 2 is the case of market failure primarily arising from dominance in the market. Here more active regulatory intervention may be required. This may take the form of more active encouragement of private-sector competitors, for example, the creation of WIOCC in the crossborder market of East Africa, mandated access of dominant player networks, or more radical solutions such as structural separation.

Before addressing other, more interventionist, roles that the state may play in infrastructure development, it must first answer the question of whether it is capable of taking on a role that involves the creation of missing markets or infrastructure. The vast majority of states are in some way capable of playing a constructive role; however, there are states that have severe institutional issues, or an inability to commit to required policy or provide appropriate leadership. In these cases (**Scenario 3**), dealing with fundamental governance weaknesses must be a central part of any development program implemented.

Consistent with the principle of promoting competition, the next question that should be asked is whether a more active role for the state can be used to create service-based competition. Note that this refers specifically to service-based competition rather than competition in general or infrastructure-based competition. This is because if the market can support infrastructure-based competition, then the absence of such competition is a result of regulatory failure or behavior of a dominant firm and would be addressed in Scenario 1 or Scenario 2, respectively. If the market cannot even support service-based competition (**Scenario 4**), then it is probably very thin. These cases tend to be remote local markets. There are a number of innovative technologies and business models discussed in this report that address these particular circumstances.

Scenarios 5, 6 and 7 address state action that is progressively more interventionist. In each case, the state's financial commitments should be justified on the basis of a robust cost-benefit analysis, which forecasts an economic net present value (ENPV) for the project or initiative that is not negative. ENPV is a calculation that includes the socioeconomic benefits of the project (see box 7.2 for further details).

Scenario 5 is the case where the state can limit its intervention to subsidy, preferential financing, or sales commitments, which offset low or uncertain nonstate revenues. In this case, the state avoids management or ownership of the entity undertaking the project. Ideally, incentives would be competed for through an appropriately structured tender process.

Scenario 6 represents those cases in which the subsidy required to interest the private sector in taking up the opportunity is too high for the state to afford. In these cases, the state must take on more of the project risk in order to attract the private sector. As discussed in chapter 2, there are a number of public-partnership forms in which the state cedes (increasing degrees of) management control to a private contractor: contracting, leasing, concessions, and SPVs. Various development organizations have provided guidance on how to decide which of these PPPs would be preferred (based on a combination of expertise and risk-sharing requirements) and how they should be structured.[27]

Regarding **Scenario 7**, it is recommended that it is limited to those instances in which the state cannot build a sufficiently attractive offer of financial incentives and risk-sharing to interest the private sector. This represents a small set of cases. Of the projects reviewed in this report, arguably, only the Tonga submarine cable meets this criterion. However, there are other pure state-play examples in our review that have enjoyed success. The first is Oman Broadband Company, which operates in a region of the world

27 For a list and review of these documents, see Aizawa 2018.

where state ownership is still the default approach to infrastructure. Another pure state-play example is Lithuania RAIN. However, Oman Broadband and Lithuania RAIN are likely to be the exceptions that prove the rule. Both examples involve circumstances that are unlikely to be replicable in many developing nations.

Box 7.2: Importance of the Calculation of Socioeconomic Benefits

It has been demonstrated that broadband infrastructure deployment contributes to the wider economy.

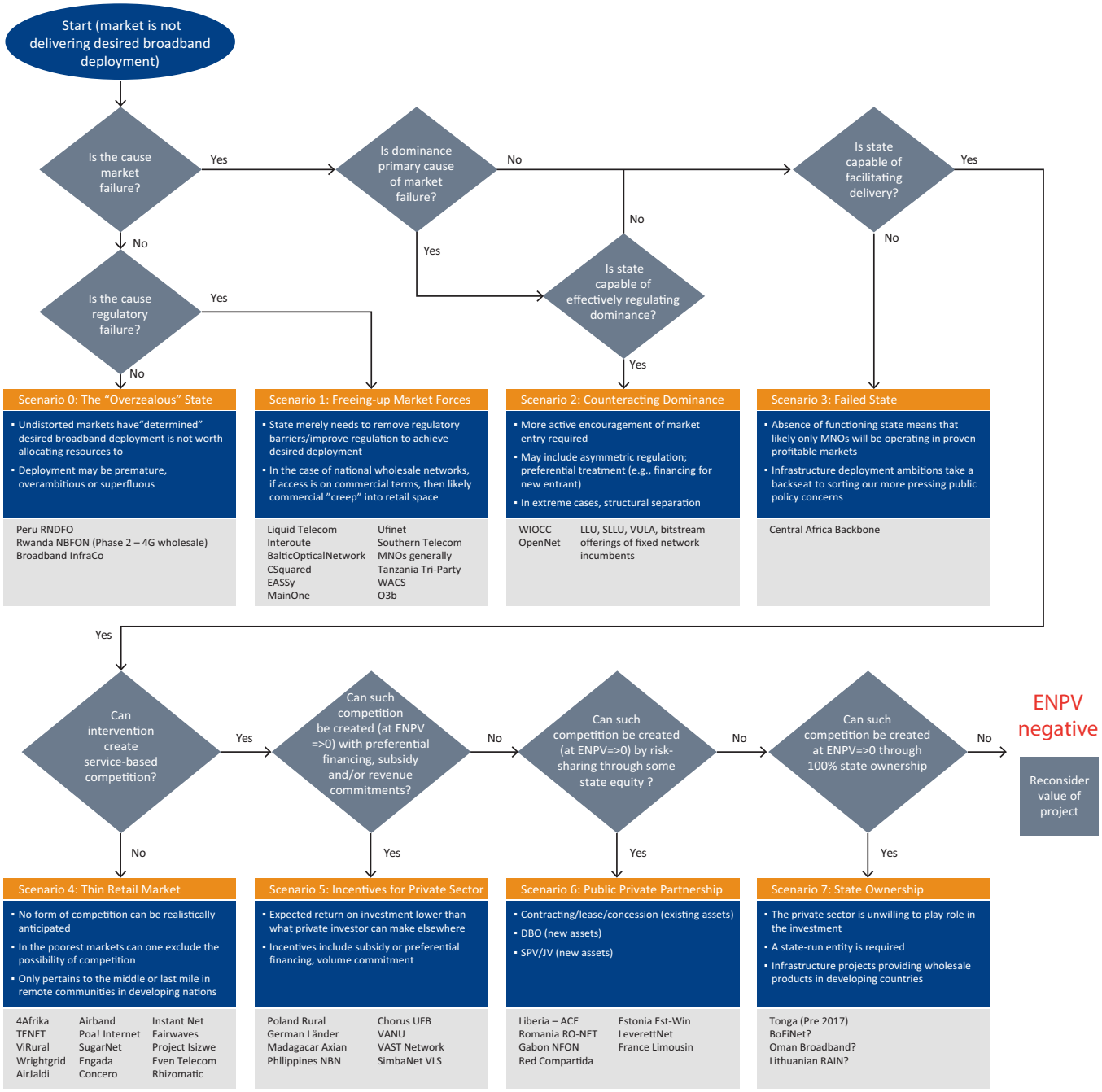
These impacts arise from:

- Increased GDP and employment, resulting from the broadband infrastructure investment itself and indirect and induced effects of investment, as well as the cost reduction and innovation enabled by increased penetration and speed.
- Increased productivity and innovation, resulting from faster communications, ability to deal with larger amounts of digital content, time savings, and the new forms of organizing business and social activities and new forms of sales.
- Improved general welfare, resulting from increased income borne of higher productivity, increase in the spread of knowledge, increased e-learning opportunities, the expansion of health services through e-health, and improved government service delivery through e-government.
- Increased consumer benefits, resulting from the expansion of new types of computer applications, network services, increased media content and quality online, increased quality of remote communications, and time saving innovations of shopping online.
- Positive environmental effects of reducing daily commuting and business traveling and the reduction in the need for paper consumption.
- Without consideration of these impacts, that is, only considering the financial rationale of the project, value creation will be underestimated and the project not undertaken or underfunded.
- There are a number of ways that these benefits can be taken into account to determine whether there is a net economic benefit of investing in a given project. In one approach, the revenue line for the business case is effectively replaced by quantified socioeconomic benefits. Ideally, an ENPV calculation would also modify business case costs to reflect social opportunity cost of inputs rather than those based on observed prices.

For a fuller discussion, see, for example, European Commission 2014.

Finally, if the project is not ENPV positive for the state to take on, then it is almost certainly not a project worth undertaking. Note that an overly sanguine business case—one that generates a positive ENPV when reason suggests it should be negative—will lead to the null scenario, that is, an overzealous intervention by the state in infrastructure deployment.

Figure 7.2: Decision-Tree for Scenarios for the State's Role in Infrastructure Deployment



Source: TMG/Salience Consulting.

7.5. World Bank Group Lessons Learned

Since 2007, the World Bank Group (WBG) has allocated more than $1.2 billion in broadband connectivity infrastructure financing with a focus on projects for submarine cables and terrestrial backbone networks and for regional integration in the South Pacific, the Caribbean, and in East, Central, and West Africa regions. In 2018, a new regional connectivity program was approved to improve connectivity in landlocked countries in Central Asia and parts of South Asia. Financing of investments in connectivity infrastructure have been complemented by technical assistance on policy, regulatory, and institutional reforms with the aim of assisting governments to become more effective in the fast-moving ICT sector, where traditional telecom infrastructure, services, devices, and content are converging toward a single platform. In almost every case, the development objective was to enhance economic growth by contributing to lowering the price of broadband capacity and extending the reach of backbone networks, and in every case a set of commitments was required before financing was made available to the participating government. Such commitments typically included sector liberalization, open and nondiscriminatory access to communications infrastructure, and public-private partnerships (PPPs) to own and/or manage the investments.

Rapid evolvement of the sector meant that WBG support also needed to evolve quickly from the traditional approach of public financing. A range of PPP approaches were implemented across the globe both regionally and at the national levels and were adopted depending on the country contexts. These include cases that were reviewed in this report, such as the Central African Backbone (CAB), the Eastern Africa Submarine Cable System (EASSy), the African Coast to Europe submarine communications cable (ACE), SimbaNET in Malawi, the Burundi Broadband System (BBS) and the Tonga subsea cable. As a result, several lessons for the WBG have emerged, in particular:

- **A constructive, trusting, and cooperative relationship between the public and private sector is important for successful development of the broadband market.** In the case of Malawi, while the implementation was done under a private design, build and operate (DBO) model, the bulk capacity purchase by the government helped stimulate investment by the private sector through the aggregation of demand (see chapter 4.3). On the other hand, the role of the state-owned incumbent, Onatel, in the Burundi Backbone System proved a major flaw. A transparent governance structure is required to enable appropriate levels of risk sharing between public and private partners.

- **Investors will likely have different incentives, requiring extensive upfront consultations and legal/transactional support.** Technical assistance to support implementation of project activities can play an important role in areas new to the government. Significant capacity is needed for negotiating with the private sector and establishing the new business models. For example, the EASSy suffered from setup issues that are typical in a large consortium (see box 4.1). It is important to ensure that the final institutional model adequately addresses the expectations of different players.

- **Legal and regulatory reforms must go hand-in-hand with infrastructure investments.** Country commitment is a key success factor that requires continuous government support for the reforms or the outcomes may be diminished. The legal and regulatory environment needs to support open access to capacity on international connectivity and wholesale pricing needs to be cost based, nondiscriminatory, and transparent. When new business models are created or new services offered, a new licensing regime may be

necessary which, in turn, may require new policies and legislation. For example, significant technical assistance was provided in Liberia under the West Africa Regional Communications Infrastructure Program (WARCIP) to ensure appropriate regulatory reforms took place prior to the implementation of the ACE cable landing station.

Close coordination between the World Bank and the IFC have also proven to be effective. For instance, in the implementation of the Red Compartida in Mexico, the IFC and IFC Asset Management Company committed $205 million in equity to the winning financial consortium (Morgan Stanley Infrastructure, Megacable, Axtel and pension funds), while the World Bank provided technical assistance for carrying out analysis on regulatory and technical aspects of the concession, including quality and coverage.

On the other hand, the Multilateral Investment Guarantee Agency's (MIGA) investment guarantees in the ICT sector have, to date, focused on the mobile market, most significantly in Sub-Saharan Africa. Nonetheless, political risk insurance issued by MIGA has significantly contributed to improving mobile coverage and services, supporting rapid expansion of mobile broadband. The WBG continues to seek ways to improve coordination to maximize its support to client countries and offer innovative solutions for extending broadband infrastructures and services.

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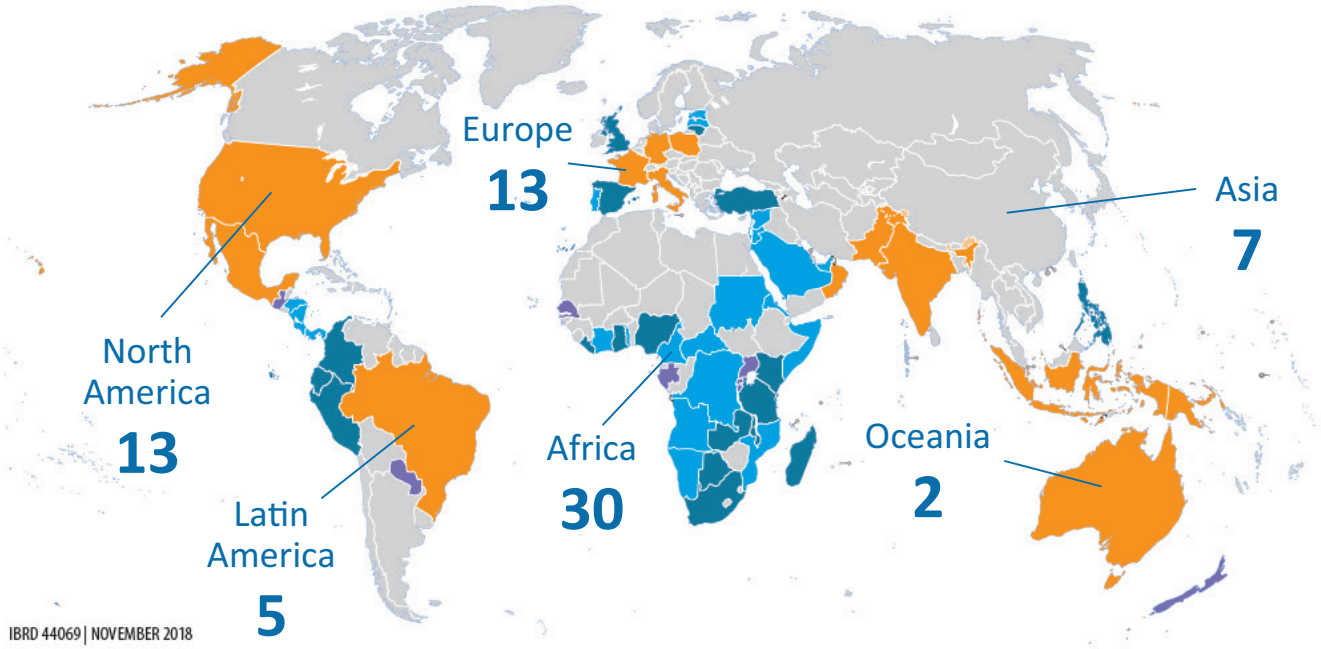
8. Appendix: Case Studies

70 individual cases were analyzed



12 Cross Border

- Baltic Optical Network
- Central African Backbone
- EASSy
- Interoute
- JADI
- Liberia ACE
- Liquid Telecom
- MainOne
- Tonga Submarine Cable
- Ufinet
- WACS
- WIOCC

13 National Backbone

- BoFiNet
- Broadband InfraCo
- Burundi Backbone System
- Gabon NFON
- Gambia ECOWAN
- Lithuania RAIN
- Madagascar Telma
- Peru RNDFO
- Philippines NBN
- Rwandan NBFON
- Senegal (ADIE)
- SimbaNET VLS
- Southern Telecom

45 Middle/Last Mile Projects

- 4Afrika
- AirJaldi
- Aquila
- Australia NBN
- Avanti ECO
- Burlington Telecom
- Chorus
- Concero
- CSquared
- CyPhy Works
- EE - Helikite
- Endaga
- EstWin
- Even Telecom
- Fairwaves
- France - Limousin
- Germany Länder
- iProvo
- Isizwe
- Kalo
- LeoSAT
- LeverettNet
- Microsoft Airband
- O3b
- Oman
- OneWeb
- OpenNet
- Poa! Internet
- Poland Rural
- Project Loon
- Q.NBN Qatar
- Red Compartida
- Rhizomatica
- RO-NET
- RUNE
- Sugarnet
- Tanzania Tri-party
- TENET
- TOP-IX
- VANU
- VAST
- Village Telco
- ViRural
- Vodafone IN
- Wrightgrid

Cross Border | National Backbone | Middle/Last Mile

Baltic Optical Network

Alliance of service providers based on telecom infrastructure of power companies

URL: http://www.datalogistics.lt/en/node/90

Narrative

HQ: N/A

The Baltic Optical Network (BON) was established in 2002 through linking the telecommunications networks of power utilities in the three Baltic states of Estonia (Televõrgu), Latvia (Latvenergo) and Lithuania (Data Logistics Center, part of Lietuvos Energija). BON is an alliance rather than a commercial entity.

BON has found a market opportunity to offer services to customers across borders to better compete against traditional telecoms players. BON provides transmission capacity speeds of up to 10 Gbps between the main nodal points of telecommunications in the region and in the transit running through the region.

BON coverage of over 8 km of fiber extends to practically any city or town of the Baltic states. BON has joined the For Connecting Europe alliance (4cE) aimed at providing modern and high quality telecommunication services in Europe.

In 2017, Telia Lietuva bought the Lithuania partner, Data Logistics Center.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	Competitive market both in terms of vertically integrated regional players (e.g.,Tele2) and purer cross-border players (RETN); in certain cases, members may even compete against one another	Baltic states are ranked between 30 and 44 of 188 countries in the HDI. GNI per capita between 26k and 29k PPP USD	Carrier neutral	EU member states so regulatory and policy framework advanced	Market Segment: Cross-border, 2LCA (active and passive commercial access); Management: operates coordinate their services and resolve technical and commercial issues; Revenue: traditional	The BON is not a legal or commercial entity. Rather, it is a commercial alliance among three separate and independent operators	Utilize transmission lines of power companies

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	Coordinated the construction of a 3 km seamless fiber backbone across the Baltic region	The 3000 km optical fiber network is distinguished for its reliability, low 35 milliseconds latency, capacity of 100G per channel and 9.6 Tbit/s total throughput	Lithuania: 506,811.56 subscribers ('01-'16) Estonia: 259,450.13 subscribers ('01-'16) Latvia: 285,233.71 subscribers. ('00-'16) Not attributed to BON	Not attributed to BON	Around US$2m. Less than $1000 per kilometer	Built Baltic highway over 2009-2014. Original plans not public

Lessons Learned

- Cost savings of using existing overhead power facilities
- In addition to cross-border connectivity, leverages capillarity of national utilities
- Example of regional cooperation to exploit for unique offering for service providers in the region

Cross Border | National Backbone | Middle/Last Mile

CAB

Central African Backbone – CAB(1)

Regional PPP fails to gain acceptance

URL: N/A

Narrative

HQ: N/A

The Central Africa Backbone represents an example of the type of venture, in which the World Bank attempted to construct cross-border fiber connection through the poorest of countries. It runs from Chad to the Democratic Republic of Congo.

The CAB structure called for the establishment of new regional telecom operator(s) for reselling international, regional, and national capacity to existing national operators and service providers at discounted rates and for a regional Public-Private Partnership (PPP) entity to invest in and manage the CAB infrastructure.

In CAB(1), Chad, Cameroon and the Central African Republic (CAR) were to create a PPP to build backbone cross-border links and manage the CAB infrastructure.

Because of the reluctance of their incumbents to relinquish sole control over their international gateways, both Cameroon and Chad took actions that would eventually lead to the cancellation of CAB1B in 2012.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	ICT sectors dominated by state-owned incumbents: Camtel (Cameroon); SOCATEL (CAR); SOTEL (Chad)	The HDI of Cameroon, Chad and CAR rank among the lowest in the world at 153, 186 and 188 out of 188 countries	CAB 1 concept was a carrier neutral cross border network	Immature	Details never developed	World Bank sought to diversify the risk among public and private actors through a PPP	Leverage an existing fiber optic network laid along the Chad-Cameroon pipeline

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	In Cameroon and Chad, some 10k and 3k of national backbone fiber and cross-border interconnection links were deployed	Between year-end 2008 and July 2012: Bandwidth per person (in bits) increased from 10.95 to 30; 0.37 to 2.38 and 18.58 to 9.06 in Cameroon, CAR and Chad respectively	Between 2010 and 2012 Internet users as a share of the population increased from 4.3% to 5.7%, 2% to 3% and 1.7% to 2.1% in Cameroon, CAR and Chad respectively	Average E-1 monthly USD price to Europe hub year end 2008 to March 2016: Cameroon - 6000 to 920; CAR - 7000 to 3200; Chad – 7000 to 108.76. Retail Internet fell between 50% to 66%	N/A	Original plan was for a seven year period (1/2009 to 3/2016); half way through project was cancelled

Lessons Learned

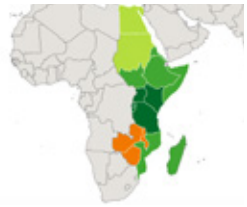
- Not all nations are capable of engaging in a PPP and coordinating among different developing nations to create a regional PPP may overcomplicate the task
- Working with each country separately at its own pace may be a more effective strategy
- Adopting a less complex PPP model that uses approaches such as advance capacity purchases and demand stimulation may also help in simplifying implementation
- In additional to political crisis in CAR, generic economy issues in Chad and Cameroon, the political strength of the incumbent may undermine an initiative

Cross Border | National Backbone | Middle/Last Mile

EASSy

Submarine cable system in East Africa

URL: http://www.eassy.org/



Narrative

HQ: Nairobi, Kenya

Conceived in 2003, the Eastern Africa Submarine System (EASSy), is a submarine cable system linking Sudan to South Africa, via most Eastern African countries: Sudan, Djibouti, Somalia, Kenya, Tanzania, Comoros, Mozambique, Madagascar and South Africa.

From inception, EASSy was structured as a consortium of public and private operators, though mostly run by private institutions.

Designed by Alcatel-Lucent, the system runs 10,000 km of route, landing at nine different stations, and comprises two fiber pairs configured as a flat ring for higher resilience. Like most subsea cables, EASSy uses DWDM technology, transmitting SDH frames. The flat ring architecture, also referred to as a collapse ring, enables full protection of the system in case of rupture of one branch or any termination card or equipment at the landing station.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	Prior to 2008, East Africa was the only region not connected to any international cable. EASSy is the second optical fiber connection for the countries in East Africa to the global optical fiber network after SEACOM	The network mainly covers countries which are ranked low in HDI and have low GNI per capita	Emphasized the open access principle and the need to include landlocked countries during dialogue and project preparation	There are no specific regulatory that apply specifically to the organization. It is subject to the domestic policies and regulatory frameworks where it lands	Market Segment: unlit subsea cable capacity. Management: privately owned consortium of 16 African (92%) and international (8%) telecom operators and service providers Revenue: traditional and down-payment for capacity	EASSy is operator owned. Significant share of ownership underwritten by a substantial loan of syndicate of DFIs (World Bank/IFC, EIB, AfDB, AFD, and KfW.) US$70m loan to WIOCC to fund its 28% investment in EASSy	In addition to parties in landing countries. World Bank under the Regional Connectivity and Infrastructure Program (RCIP) assisted interconnection of landlocked countries with the cable. No synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	10,000 km submarine fiber optic cable to connect South Africa, Mozambique, Madagascar, Tanzania, Kenya, Somalia, Djibouti and Sudan	Cable was constructed to provide initial capacity of 320 Gbps, upgradeable to a design capacity of 10 Tbps. The International Bandwidth Usage (Mbps) increased five times on average per country	The total Broadband Internet Subscribers increased from 4.08 million in 2010 to 13.1 million in 2015	Services on EASSy can be purchased through any of the consortium members. Services are available on EASSy include short-term and long-term contracts	The total cost of the EASSy cable was US$235 million or approximately US$22k per kilometer	Long gestation period as required. Started activities extensive dialogue among several east African governments, operators and development partners. MoU signed in 2003. The supply contract, which represents the beginning of the deployment, came into force in May 2008. This ran over two years for a Ready for Service date celebrated in September 2010

Lessons Learned

- EASSy's consortium members are all operators of terrestrial cables, and/or members of other subsea consortia, providing extensive onward connectivity, around and throughout Africa, and towards Europe and Middle East
- Sister lending program to connect landlocked countries in East Africa
- Deployed in an underserved "grey" area for subsea cable market
- Example of concept of independent private-sector owned vehicle to sell capacity on an arms length basis
- Highly complex stakeholder group led to long lead time

Cross Border | National Backbone | Middle/Last Mile

Interoute

Among first carrier independent cross-border companies in Europe

URL: https://www.interoute.com/

Narrative

Interoute is the operator of one of Europe's largest networks and a global cloud services platform.

Born at the time of the market liberalization sweeping across Europe, Interoute fell victim to the burst of telecommunications bubble and capacity overbuild in the early 2000s, but kept to its ambition to link all the major business centers in Europe with a carrier-neutral cross-border wholesale and enterprise play.

HQ: London, UK

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	Operating in the most competitive markets	Operating among most developed markets	Wholesale commercial access to international, national and backhaul facilities	Advanced. EU member state, so has a well developed regulatory framework	Market segment: historically – wholesale commercial access now expanding downstream; mixed procurement strategy of build, lease and swap. Revenue: traditional Management: private	Interoute is privately held. Debt to equity ratio of about 3:1 in 2015	Shared wholesale network model. No significant synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	70,000 route kilometers of network connecting the business hubs of Europe, nearly 200 data centers and colocation facilities to America, Africa, Asia, the Middle East and network partners across the globe. Incorporating 15 of its own data centers and 33 colocation facilities	N/A	N/A	N/A	N/A	In 2015, ran €473 million in revenue with an EBITDA of €95 million

Lessons Learned

- Private sector was able to make use of opening of markets to expand to meet demand of retail service providers
- Opportunistic focus on the best markets in Europe
- Opportunistic procurement to expand into markets: build or lease, avoiding duplicating network, increases investment efficiency
- From the beginning not just a wholesale play – enterprise clientele

Cross Border | National Backbone | Middle/Last Mile

JADI

JADI – Saudi Arabia, Jordan, Syria, Turkey

Consortium of interconnecting of terrestrial networks

URL: N/A

Narrative

HQ: N/A

Large cross-border networks are traditionally formed through bilateral connection of various existing national networks. Two initiatives in the Middle East – the Jeddah-Amman-Damascus-Istanbul (JADI) cable and the Regional Cable Network (linking UAE, Saudi Arabia, Syria, Jordan and Turkey) – were born of efforts to improve on this traditional mode and reduce and diversify from existing cross-border bottlenecks in the region.

The system provides access to multiple submarine cables and border points through its members and provides a diverse and a shorter route to Europe.

The system is run by four leading operators in the region: Saudi Telecom Group, Orange Jordan, Syrian Telecom Establishment and the Turk Telekom Group

Attributes & Success Criteria

Attributes	**Market Structure**	**Economic Context**	**Carrier Neutrality**	**Regulatory & Policy Efficacy**	**Business Model**	**Financing & Risk-Sharing**	**Infrastructure Sharing**
	Competes with national operator in the region and other transnational terrestrial and subsea cables	The network mainly covers countries which are in the rank between high human development and medium development countries	The consortium is operated by both private and state owned telecom operators	There are no specific regulations that apply specifically to the organisation. It is subject to the domestic policies and regulatory frameworks where it operates	Market segment: international wholesale on commercial access terms. Management: private; Revenue: traditional pipe and usage	The initiative is financed by the consortium operators	Shared terrestrial platform. No significant synergies with power, transport and water utilities

Success Criteria	**Geographic Reach of Network**	**Increased Bandwidth / Volume**	**Take-up: Utilization of Network Relative to Legacy**	**Prices Relative to Legacy, Affordability**	**Investment and Unit Investment (per fiber km)**	**Performance to Plan**
	The cable covers a total length of 2,530 km, of which 770 km is in Turkey, 480 km in Syria, 360 km in Jordan and 920 km in Saudi Arabia	N/A	N/A	N/A	N/A	Inactive due to the instability in Syria

Lessons Learned

- Variant on traditional bilateral terrestrial cross-border network, allowing a means of competing with subsea cable facilities

Cross Border | National Backbone | Middle/Last Mile

Liberia ACE landing

Standard model for PPP open access cable landing

URL: http://www.ccl.com.lr

Narrative

HQ: Monrovia, Liberia

The West Africa Regional Communications Infrastructure Program (WARCIP) assisted with the financing of the West Africa portion of the approximately 17,000 km ACE submarine cable system connecting 23 countries from South Africa to Europe, including the landing station in Liberia.

As in a number of other West African countries (e.g., The Gambia, São Tomé and Príncipe), the World Bank help create a special purpose vehicle on a PPP basis to manage the landing station on an open access basis.

Cable Consortium of Liberia (CCL) was launched in 2013 and owned jointly by the Government of Liberia (55%), Libtelco (20%) and the three mobile network operators (MNOs): Lonestar (10%), Cellcom (10%) and Novafone (5%).

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	Four mobile operators: LoneStar (majority owned by MTN), Novafone and Cellcom. Libtelco is the financially struggling fixed network operator. There are also a half dozen ISPs	Liberia's HDI puts it at 177 out of 188 countries and territories. It has a GNI per capita of 683 in PPP USD	Wholesale international capacity on an open access basis	Maturing	Market Segment: wholesale international infrastructure Management: Public-private partnership where the government have 55% stake. In 2016 World Bank supported divestiture strategy to sell the government's stake. Revenue: upfront payment and traditional	The World Bank project has supported the setup of Cable Consortium of Liberia (CCL), a public-private partnership, to manage operations of ACE landing in Liberia. World Bank financed state's participation	Shared international platform; No synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	Connection to the submarine cable system ACE. The arrival of ACE has displaced earlier use of costly and lower quality Internet services in Liberia provided by satellite	Volume of international traffic - International Communications (Internet, Telecoms, and Data) bandwidth per person increased 13 times 2013-2016	N/A	N/A	World Bank was supporting the connectivity initiative with around $20.40 million	Completed

Lessons Learned

- Has become a standard model for using PPP to establish an open access bottleneck facility
- Successful positioned as dominant open access facility that does not compete with customers for end-users
- Some questions remain:
  - how well will the "incumbent" SPV founders accommodate demand of new entrants not within the membership
  - Will the advent of improved cross-border terrestrial links undermine the sustainability of the landing station

Cross Border | National Backbone | Middle/Last Mile

Liquid Telecom

Private sector fiber optical network infrastructure breaking cross-border bottlenecks

URL: https://www.liquidtelecom.com/

Narrative

HQ: Ebene, Mauritius

Started as Econet Satellite service operating in Zimbabwe for its first 10 years. International expansion triggered by need to access subsea capacity: created a fiber network to South Africa. In 2004 it rebranded as Liquid Telecom and has since searched for growth mainly through acquisition.

Acquisition of Neotel in South Africa in 2016 doubled network size. Originally a wholesale-only play has recently been expanding into the retail space. Now may be the largest pan-African fiber network.

Liquid Telecom extended most of its reach through acquisition (Zimbabwe, Kenya (KDN), Zambia, Rwanda (Rwandatel), Uganda, etc.) but also creates joint ventures with utility companies, especially those reaching the lucrative mining industry (the Copperbelt Energy Corporation in Zambia, the Botswana Power Company, the Kenya Electricity Transmission Company and the SNEL in Democratic Republic of Congo (DRC)). However, once in a country, Liquid Telecom improves network with a new deployment, but also leverages swaps and leasing.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Played a role in new entrant in cross-border space. Competes with national networks and other cross-border networks in each of its markets. Enterprise space where it has entered more recently is also competitive	Covers countries which are in the rank between low and medium human development according to the United nations Human Development Index	Historically perceived as carrier neutral, but expansion into retail space may raise questions in thinner national markets	Subject to domestic policies and regulation, which tend to be very challenging. In one or two cases market strategy has clashed with national development measures, e.g., Botswana	Market segment: historically – wholesale commercial access now expanding downstream; mixed procurement strategy of build, lease and swap. Revenue: traditional Management: private	Liquid Telecom is a subsidiary of Econet Global with 51% equity share. Has financed much of its recent expansion through debt financing	Has utilized deals with power utilities effectively for expansion. See case study in World Bank Toolkit on Cross-sector Infrastructure Sharing for relationship with Copperbelt Energy Corporation in Zambia

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Fiber network: 50,000 km across Botswana, DRC, Kenya, Lesotho, Mauritius, Rwanda, South Africa, Uganda, Zambia, Zimbabwe	Has been key to breaking cross-border bottleneck in several landlocked nations, e.g., Zimbabwe, Zambia, Uganda, Lesotho	N/A	Price reduction in several landlocked countries may be attributable to Liquid Telecom expansion	N/A	Ongoing. Since it was established in 1997 and rebranded in 2004, the company has been constantly expanding its operations across Africa, becoming the largest independent fibre network. EBITDA reportedly around $300 million in 2017

Lessons Learned

- Private sector was able to make use of opening of markets to expand to meet demand of retail service providers
- Opportunistic procurement to expand into markets: build or lease, avoiding duplicating network, increases investment efficiency
- Example of market entry facilitated by exploiting pre-existing investment in utility infrastructure
- Exploited wholesale-only niche in underserved markets
- Strategic commercial ambitions leading to downstream (into retail) expansion

Cross Border | National Backbone | Middle/Last Mile

MainOne

Subsea cable with a narrower ownership structure than the typical consortium build

URL: https://www.mainone.net/

Narrative

HQ: Lagos, Nigeria

Launched in 2010, MainOne's current cable system is a 7,000 km submarine cable with landing stations in Nigeria, Ghana and Portugal.

MainOne began as a comparatively small operation providing connectivity for service providers in Ghana and Nigeria. It has compensated for this small scale by implementing a number of prudent business model attributes.

For example, it has largely outsourced significant parts of its deployment to specialized partners and found preferential funding through the Pan-African Infrastructure Development Fund. Furthermore, it has gained scale by pursuing a different segment strategy: providing metro fiber and services in Nigeria and Ghana as well as datacenter, cloud and managed security services.

Attributes & Success Criteria

Attributes	**Market Structure**	**Economic Context**	**Carrier Neutrality**	**Regulatory & Policy Efficacy**	**Business Model**	**Financing & Risk-Sharing**	**Infrastructure Sharing**
	For close to a decade, SAT3 was the lone player in the fiber Internet connectivity marketplace for West Africa. Today, besides MainOne, there are a few players including WACS, ACE, GLO-1	Covers countries which are in the rank between Low and Medium (except Spain with Very High HDI) Human Development according to the United Nations Index	Carrier neutral; commercial access	No specific regulatory or policy developments that apply specifically to the organization. However, the organization is subject to domestic policies and regulation where it operates	Market segment: Wholesale Commercial Access subsea cable Management: the cable is 100% privately owned Revenue: Traditional, Volume commitment	Privately owned by Main Street Technologies, Africa Finance Corporation and the Pan-African Infrastructure Development Fund (PAIDF) and a couple of Nigerian banks	Shared international subsea cable. No significant synergies with power, transport and water utilities

Success Criteria	**Geographic Reach of Network**	**Increased Bandwidth / Volume**	**Take-up: Utilization of Network Relative to Legacy**	**Prices Relative to Legacy, Affordability**	**Investment and Unit Investment (per fiber km)**	**Performance to Plan**
	MainOne's current cable system is a 7,000 km submarine cable with landing stations in Nigeria, Ghana and Portugal	The submarine cable currently delivers high speed bandwidth of 1.92 Tbps and has been proven to provide capacity of at least 4.96 Tbps	N/A	N/A	Total project cost amounts to about $240 million. African Development Bank Group (AfDB) provided a loan of $61 million. The cost per fiber km was around $34,280 (authors' calculation)	Partially completed. Several possibilities still exist with branching out units along coast of West Africa in Morocco, Canary Islands, Senegal and Ivory Coast as options to cater to expected surge in demand

Lessons Learned

- Particularly useful in the context of multiple-country cross-border cases where leveraging international partners important
- State actively encourages market entry and private sector capital
- Solutions may involve tax incentives and diverse means of lower cost of entry

Cross Border | National Backbone | Middle/Last Mile

Tonga Submarine Cable

With funding from international institutions to connectivity for island nations

URL: http://www.tongacable.net/

Narrative

HQ: Nuku'alofa, Tonga

The World Bank and the Asian Development Bank embarked on a project to provide financing for regional submarine cable to connect Tonga with Fiji. International cable service was launch in 2016.

Tonga further added an extension to the outer Islands through savings on the international segment of the cable and partial privatization of the entity. The Tongan government holds 66.6% ownership share, incumbent TCC 16.7% and new entrant Digicel 16.7%.

The contract for the domestic cable was signed with ASN in February 2017 for a repeater-less system of approximately 400 km in total, with a design capacity for Ha'apai of 1.2 Tb and Vava'u 600 Gb. The domestic cable system was commissioned in March 2018.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	Thin market with weak competition in upstream and downstream markets	Tonga's HDI puts it at 101 out of 188 countries and territories. Gross national income (GNI) per capita (2011 PPP$) is 5,284 USD	Open access international facility	Communications Act and Communications Commission Act (2015) is key legal act governing this area. Responsible institution is Ministry of Information & Communications	Market Segment: Wholesale Open Access subsea cable and landing station Owned and operated by Special Purpose Vehicle: Tonga Cable Ltd (TCL), 66% state owned	The submarine cable system included finance from the World Bank in the amount of $32.20 million	Shared international subsea cable. No significant synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	827 km cable connecting Nuku'alofa, Tonga to Southern Cross Cable Network in Suva, Fiji	International Internet Bandwidth (Mbps) increased from 37 in 2011 to 920 in 2016	Total subscribers increased to 3,000 (2016) from 1,300 (2011). Volume of International Traffic (Mbps) increased from 30 in 2011 to 700 in September 2016 with a target of 750 by July 2018	Price of Wholesale International Capacity Link (US$/Mbps/Month) decreased to 395 (from 495), target of 150 by July 2018. Household price per GB, has fallen 60% (World Bank)	Regional Connectivity Project financed submarine cable delivering broadband. Supported by World Bank Group, ADB, and TCC. Cost per fiber kilometer, ~US$39,661	Completed

Lessons Learned

- In the cases where the private sector is unwilling to play role in the investment, a 100% state-run entity may be required
- Infrastructure projects of national interest in developing countries providing wholesale products. In the case of countries with small markets and economies it is important to leverage the support of international organizations
- Successful positioned as dominant open access facility that does not compete with customers for end-users

Cross Border | National Backbone | Middle/Last Mile

Ufinet

Rapid success of a private, market-driven project

URL: https://www.ufinet.com/

Narrative

HQ: Madrid, Spain

Ufinet was formed by the merger in 2009 of Desarrollo del Cable and Unión Fenosa Redes de Telecomunicación, which itself was born of the commercialization of telecoms assets of Spanish natural gas utility, Union Fensosa.

It then expanded into Central America through acquisitions and new fiber investments. The company has positioned itself as a carrier neutral core and cross-border network service provider and successfully benefited from market liberalization.

Owns telecom networks in Portugal, France, Andorra and Gibraltar, which it extends through lease agreements enabling access to all European countries.

In LATAM the extension of the network begins in Mexico and runs all the way down through Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama (all of them interconnected by multiple fiber rings) as well as Colombia, Ecuador, Peru, and Paraguay. Ufinet has capacity on subsea cables in the Caribbean region, permitting connection to the United States.

In all countries, UFINET combines national and international network for long-distance transportation with significant coverage in metropolitan areas (local loop).

Attributes & Success Criteria

Attributes	**Market Structure**	**Economic Context**	**Carrier Neutrality**	**Regulatory & Policy Efficacy**	**Business Model**	**Financing & Risk-Sharing**	**Infrastructure Sharing**
	The company tends to operate as a One Stop Shop and to customers with all connectivity services according to their requirements, in a single fiber optic network	Covers countries which are in the rank between Low and Medium (except Spain with Very High HDI) Human Development according to the United Nations Index	Carrier neutral wholesale service provider offering local, national and international fiber (and satellite)	Subject to domestic policies and regulation, which are diverse from developed EU markets to maturing Central American. However, operates in a space that is relatively unregulated	Market Segment: wholesale commercial access across international, national and local segments; based on build and lease arrangements Revenue: traditional pipe and usage Management: private	Privately owned – Ufinet Telecom was acquired in 2014 by U.K.-based venture capital fund Cinven	Born of telecom and other linear assets of natural gas utility in Spain. Has exploited cross-sectoral infrastructure sharing in other markets as well

Success Criteria	**Geographic Reach of Network**	**Increased Bandwidth / Volume**	**Take-up: Utilization of Network Relative to Legacy**	**Prices Relative to Legacy, Affordability**	**Investment and Unit Investment (per fiber km)**	**Performance to Plan**
	Ufinet possesses a large network deployment of more than 58,200 km of fiber optic in 20 countries in two regions (Europe and LATAM). Caribbean subsea cable, satellite platforms in Spain and Panama	Scalability of connections from 64 Kbps up to 100 Gbps. Wide range of technologies and interfaces available (up to 100 Gbps)	N/A	N/A	Cinven bought Ufinet in 2014 for €510 million	Ongoing. The company operates a carrier neutral wholesale network with ambitious growth strategy

Lessons Learned

- Private sector was able to make use of opening of markets to expand and meet demand of retail service providers
- Example of market entry facilitated by exploiting pre-existing investment in utility infrastructure
- Opportunistic procurement to expand into markets: build or lease
- Wholesale-only play can be successful in competitive markets in upper- and middle-income countries like those in Central America.
- Strategic commercial ambitions can be met by geographic and upstream (international) expansion, not just downstream (into retail)

Cross Border | National Backbone | Middle/Last Mile

WACS

Leveraging the power of consortium and regional collaboration to connect Africa

URL: https://www.wacscable.com/index.jsp

Narrative

HQ: Western Cape, S. Africa

Launched in 2012, the West Africa Cable System (WACS) is owned and operated by a consortium of 18 international and regional carriers.

WACS consortium includes Telkom, Vodacom, MTN, Tata Communications (Neotel), Broadband Infraco, Cable & Wireless, Portugal Telecoms, Congo Telecoms (formerly Sotelco), Telecom Namibia, Togo Telecom, OCPT (Office Congolais des Postes et Telecommunications), Angola Cables.

Standard subsea cable consortium model.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	For close to a decade, SAT3 was the lone player in the fiber internet connectivity marketplace for West Africa. Today, besides WACS, there are few (MainOne, ACE, GLO-1)	Covers countries which are in the rank between low human development and medium development according to the United nations Human Development Index	Not carrier neutral, reinforces landing parties market strength	No specific regulatory or policy develop-ments that apply specifically to the or-ganization. However, the organization is subject to domestic policies and regulation where it operates	Market Segment: wholesale international connectivity. Management: The cable is 100% privately owned. MTN Group has invested around $90 million in the cable making it the largest investor. Revenue: traditional	The total cost for the cable system was $650 million financed by the stakeholders	Shared international subsea cable. No significant synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	The total length of WACS is 16,000 km and links Southern Africa and Europe, with a 4 fiber pair system	WACS is owned and operated by consortium of 18 international and regional carriers. Launched in 2012, was deployed with 10 G technology, and an initial design capacity of 5.12 Tbit/s	N/A	WACS offers capacity with lease options. The bandwidth can be activated on the system ranging from STM-1 to STM-64, with 10 Gbit/s and 100 Gbit/s options as required	The total cost for the cable system was $650 million financed by the stakeholders. The cost per fiber kilometer was around $40,625 (authors' calculation)	Significant deployment plan milestones met

Lessons Learned

- State contributes to market development by simply doing its job of granting needed authorization
- Power of consortium model for subsea cable deployment
- Landing station access not guaranteed for non-consortium members and only one landing party – the dominant player in the country

Cross Border | National Backbone | Middle/Last Mile

WIOCC

Independent private-sector owned vehicle to sell capacity on an arms length basis

URL: http://wiocc.net/

Narrative

HQ: Ebene, Mauritius

West Indian Ocean Cable Company (WIOCC) is an African wholesaler, providing capacity to Africa's carriers.

WIOCC is the largest sharing holder in EASSy. WIOCC has also made strategic investments in EIG and WACS (connecting Africa's northern and western seaboards respectively) and owns capacity on other systems, including SAT3/SAFE, SEACOM, SMW3 and TEAMS.

WIOCC owners, 14 major African telcos: BoFiNet (Botswana), ONATEL (Burundi), U-COM (Burundi), Djibouti Telecom (Djibouti), Telkom Kenya, Lesotho Communications Authority (Lesotho), LPTIC (Libya), TDM (Mozambique), Gilat Satcom (Nigeria), Seychelles Cable System Company (Seychelles), Dalkom Somalia (Somalia), Zantel (Tanzania), Uganda Telecom (Uganda), TelOne (Zimbabwe).

The World Bank played a critical role in the creation of WIOCC. It is an example of achieving regional synergy and scale through consortium, which in addition to playing a role in EASSy cooperated for terrestrial expansion. WIOCC now runs a core network running from South Africa to Kenya.

Attributes & Success Criteria

Attributes	**Market Structure**	**Economic Context**	**Carrier Neutrality**	**Regulatory & Policy Efficacy**	**Business Model**	**Financing & Risk-Sharing**	**Infrastructure Sharing**
	The competition mainly comes on national level where the WIOCC owners compete on their markets	Covers countries which are in the rank between low human development and medium development according to the United nations Human Development Index	Carrier neutral-commercial access	No specific regulatory or policy developments that apply specifically to the organization. However, the organization is subject to domestic policies and regulation where it operates	WIOCC is jointly owned by 14 major African telcos	All 14 African telcos have share in WIOCC and share risk for the operations. For additional investments, WIOCC uses external funding	No significant synergies with power, transport and water utilities

Success Criteria	**Geographic Reach of Network**	**Increased Bandwidth / Volume**	**Take-up: Utilization of Network Relative to Legacy**	**Prices Relative to Legacy, Affordability**	**Investment and Unit Investment (per fiber km)**	**Performance to Plan**
	WIOCC's network integrates the terrestrial fiber networks which extends across more than 55,000 km of terrestrial fiber-optic network interconnecting more than 500 African locations across 30 countries. WIOCC's international reach extends to 100 cities in 29 countries in Europe and more than 700 cities in 70 countries globally	N/A	N/A	N/A	N/A	N/A

Lessons Learned

- Addresses the terrestrial connectivity issue so that fuller advantage can be taken of the subsea cable facilities
- WIOCC represents a clear example of finding regional synergy and scale through consortium

Cross Border | **National Backbone** | Middle/Last Mile

BoFiNet

Fibre network and Wi-Fi hotpots in strategic locations across Botswana

URL: http://www.bofinet.co.bw/

Narrative

HQ: Gaborone, Botswana

Initially created with assets separated from incumbent fixed network monopoly, BoFiNet has deployed own fiber network and Wi-Fi hotpots in strategic locations across Botswana. It manages the Botswana government's stakes in the EASSy and WACS submarine cables.

BoFiNet is an example of a government-supported build-out involving the execution of the network build-out directly by a government-owned entity. Financing of this roll-out is undertaken by the entity itself with support from government subsidies, to expedite the deployment of backbone links in areas that would otherwise not be commercially viable.

BoFiNet is a wholesale provider of national and international telecommunication infrastructure that does not sell directly to users. It received its license in 2013.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
BoFiNet holds a strong position in national backbone services leveraging rights to Botswana international connectivity capacity. Faces some competition from incumbent BTC, and Liquid Telecom threatens with tie up with Botswana power company	Botswana's HDI puts it at 108 out of 188 countries and territories. It has a GNI per capita of 14,663 in PPP USD	Active and Passive Layer Open Access Network (A-PLOA)	Maturing	Segment: wholesale only national and international capacity. Management: BoFiNet is owned by the Botswana government, but there are plans to partially privatize. Revenue: BoFiNet was established as a commercially self-sustainable business on traditional streams	100% state owned with share capital and in-kind network assets	N/A

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
More than 9000 km of fiber across the nation. Wi-Fi covering close to 600 sites, including hospitals, schools, and hotels	Since 2014 has deployed more than 1,000km of fiber. International internet bandwidth grew from 5,146 Mbps in 2010 to 25,678.8 Mbps in 2016	Broadband internet subscribers: in 2012 the number of subscribers were 22,236 and reached 59,057 subscribers in 2016	N/A	N/A	Profitable as of 2015/16

Lessons Learned

- Good example of using a new entity to ended vertical monopoly of incumbent
- Successful positioning as dominant open access network that does not compete with customers for end-users
- Market risk of not having private sector players involvement; not clear how well it will perform in the face of a challenge from the private sector

Cross Border | **National Backbone** | Middle/Last Mile

Broadband InfraCo (BBI)

National long distance fiber optic network in South Africa

URL: http://www.infraco.co.za/

Narrative

HQ: Johannesburg, S. Africa

Broadband Infraco SOC Limited primarily engages in the establishment of national long distance fiber optic network in South Africa. It is also involved in the establishment of an international marine cable network deployed between South Africa and the United Kingdom.

The company provides high capacity managed bandwidth from point of presence (POP) to POP within its national long distance fiber-optic network. Its services are based on various technology portfolios, including synchronous digital hierarchy, colocation, dense wavelength division multiplexing, optical transport network, and carrier ethernet. The company was founded in 2007 and is based in Sandton, South Africa.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	Broadband InfraCo operates in a very competitive market, with several network operators who invest in their own networks	South Africa's HDI puts it at 119 out of 188 countries and territories. It has a GNI per capita of 12,087 in PPP USD	Broadband InfraCo provides wholesale broadband connectivity products	Regulatory Regime: Maturing	Market Segment: wholesale broadband connectivity Management: state owned and operated Revenue: traditional wholesale pricing	Broadband InfraCo is a state owned enterprise with the Department of Public Enterprises (74%) and the Industrial Development Corporation of South Africa (26%) as shareholders	Leverages the telecoms assets of utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	The network covers all nine provinces, major cities and towns of South Africa and also extends to the borders of the neighboring countries of Botswana, Lesotho, Mozambique, Namibia, Swaziland and Zimbabwe to provide required interconnectivity	Network capacity increase from 40 Gbps to 120 Gbps	N/A	InfraCo offers affordable, high capacity data services	N/A	Broadband InfraCo could not keep the interest of the network operators who proceeded to invest in their own networks and the company has not made profits since its establishment

Lessons Learned

- Illustrates the overzealous state initiative in which many of the elements of the project were right, but the market did not need the capacity in the form it was offered and now assets are stranded
- Private sector insight and management can be better exploited

Cross Border | National Backbone | Middle/Last Mile

Burundi Backbone System

National backbone network with Internet connectivity

URL: http://www.bbs.bi/

Narrative

HQ: Bujumbura, Burundi

BBS was established as a PPP to finance, build and operate a national backbone network with international connectivity. All major network operators were included in the corporate structure of the PPP entity.

BBS operated networks open to all service operators and intended for public services, businesses and individuals. It partnered with government institutions in the framework of the "Government Communication" network (COMGOV), universities, banks. It also constructed virtual landing station and IXP.

It was designed to be complementary to the construction of the East African Submarine Cable System (EASSy). Originally intended to build out network from 2007 to 2011, negotiation difficulties extended the build out period with most of the capacity installed over 2012-2014. BBS became commercially operational in 2013. BBS financial basis proved too weak. Some of the private operators failed to contribute the funds they had promised and others, like Africell, effectively exited the market. ONATEL faced bankruptcy, following a failed privatization process. It also faces severe competitive pressure with the market entry of Lumitel in 2014. The government in January 2017 revoked the BBS PPP status and took it into government ownership.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
BBS is the dominant national backbone operator with access networks as both owners and clients (state-owned Onatel, Ucom, Econet wireless, Africell and Cbinet). Viettel Burundi (Lumitel) has its own national backbone network	Burundi's HDI puts it at 184 out of 188 countries and territories.It has a GNI per capita of 691 in PPP USD	Active and Passive Layer Open Access Network (A-PLOA)	Sector regulator undeveloped. The interactions between the implementation unit (SETIC) and the regulator proved to be difficult over the whole duration of the project. Ministers at the sector ministry changed 5 times over the 7 year life of the project	Market Segment: wholesale only national and international capacity. Management: JV member ISPs own the infrastructure, the government owns major ISP member, Onatel. ISP owners safeguard open access terms (at least for members)	ISP and Government through Onatel ownership. Capex grant from government financed by World Bank. State Capex subsidy limited to start up, set to make NPV=0.	N/A

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Around 1200 km of national backbone linking the regional centers and cross-border links in Burundi	International bandwidth increased from 250 in 2007 to 763 Mbps in 2014	The total number of subscribers in 2007 was 2,000 compared to 119,513 (in 2013) and 593,088 in 2014; however, little of this can be attributed to BBS. But several ISPs created after BBS and uptick in new valued-added services noted	Price of wholesale international E1 capacity link decreased from $8,000 in 2007 to $300.00 in 2014 (Burundi Backbone System)	The total value of the project is around $25 million ($13.5 million funded by the World Bank). The cost per fiber kilometre was around $20,000	Plan targets: 500 Mbps international capacity available; $2,000 per E1; 15k Internet subs and 10% density. All targets exceeded.; After implementation of the BBS in 2014, the growth of International Internet bandwidth was very impressive; during 2010-2015, the highest within EAC countries at a growth rate of more than 160% a year; Cash flow positive in 2014 after six years of negative cash flow

Lessons Learned

- There is a tradeoff to the PPP design between (i) a collaborative approach and a complex design with major benefits (efficient leverage of public funds), and (ii) a simplified approach and design with more limited benefits but lower implementation risks (for instance, the outsourcing of the management of the network)
- Once established, the JV benefited from private sector participation in terms of management, expertise, efficiency, etc
- Minimized duplication of network
- As operators are by definition competing and as such do not want to be in a level playing field, their incentives to work together for success may be low
- Runs risk of being not truly open access for operators and ISPs which are not shareholders of BBS
- Ultimately insolvent and has been effectively taken over by the state
- There is an opportunity now to re-establish BBS or its assets are a more firm commercial basis

Cross Border | **National Backbone** | Middle/Last Mile

Gabon NFON

National fiber backbone run by Axione under concession

URL: http://www.axione.fr/en

Narrative

HQ: Libreville, Gabon

State of Gabon built the national backbone, which was financed by the World Bank in 2012.

Private network operator (Axione) – a member of the French Bouygues group, which has significant telecom and other infrastructure assets in Europe – won an international tender to ensure professional commercialization of the 1,000 km+ fiber optic network, providing regional and international capacity and linking provincial capitals.

Significantly, this is not a long-term concession, but rather the operating contract is for a medium term of seven years. Support is ongoing, and the government of Gabon continues its involvement in the financing by covering CAPEX, while the network operator covers only OPEX. As of 2017, the operation of the landing station is successful, but the backbone linking over 20 cities and villages is still in test phase. Services offered will include backbone transport, dark fiber leases, co-location, and transit services to mobile operators and ISPs, provided on an open access basis.

GoG retained ownership of assets and the network operator is responsible for commercializing the assets. Services offered – backbone transport, dark fiber leases, co-location and transit services to MNOs and ISPs. Effectively competing with partially privatized Gabon Telecom.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Six ISPs active in the market. Gabon Telecom dominates the market at about 73% market share. The Axione-led entity operates the ACE cable landing	Gabon's HDI puts it at 109 out of 188 countries and territories. It has a GNI per capita of 19,044 in PPP USD	Active and Passive Layer Open Access Network (A-PLOA)	Regulatory Regime: Maturing	Market Segment: wholesale only national and international connectivity. Management: Private wholesale operator hired to run network. Pays GoG % of sales. Revenue: traditional revenues supplemented by 100% capex subsidy	GoG retained ownership of assets and is responsible for CAPEX; network operator responsible for OPEX. World Bank financed network construction with $58 million loan and expansion with a follow on $23 million loan.	Shared wholesale network, but no significant cross-sectoral synergies

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
1,140 km installed fiber optic network built. Number of localities served with broadband internet access increased from 3 to 24	International bandwidth 1.2 Gbps in 2010 to 10.29 in mid-2017	Number of Internet service subscribers increased from 14 per 100 people in 2010 to 102 in mid-2017	Retail price per Mbps decreased from $ 218 per month to 22 $ between 2010 and 2017. Average price per month of E1 link from capital city to Europe dropped from $10,500 to $390 from 2010 to 2017	$58 million for both national backbone and international connectivity	There have been delays in disbursements, which began in 2012, which has caused delays in the commercialization of national capacity (expected in 2018), but impact on international capacity has already been very beneficial to wholesale and resale prices

Lessons Learned

- PPP used to break monopoly of Gabon Telecom in international capacity
- PPP used to create open access national backbone to support competitors to Gabon Telecom, has spawned new significant players
- World Bank assistance used to implement competitive PPP approach to select private entity to run the facilities on behalf of government

Cross Border | **National Backbone** | Middle/Last Mile

Gambia ECOWAN

Gambian national fiber optic network

URL: http://www.gamtel.gm

Narrative

HQ: Banjul, Gambia

The Gambian national fiber optic network component of the Regional Backbone Infrastructure and eGovernance Platform Program of the Economic Community of West African States ("ECOWAN") was funded in 2010. It is a government support build-out carried out by the state-owned vertically integrated incumbent Gamtel. ECOWAN implemented by state-owned enterprise Gamtel; no private sector representation.

After completion of the network construction, the operation of the network remained in Gamtel's hands. Beyond its deteriorating financial health (Gamtel has been struggling financially for some years now), Gamtel has arguably been proven organizationally incapable of delivering low cost, reliable and non-discriminatory backbone transmission services. Due to high prices and low service quality, some operators are continuing to rely on or even moving back to usage of their microwave networks instead of the ECOWAN. The ECOWAN, which should bring the capacity from ACE submarine landing station across the country, is therefore highly underutilized.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Mobile market highly competitive. Gamtel is dominant in provision of national transmission services and competes with other service providers downstream	The Gambia is one of the most densely populated countries in Africa. It is also one of the poorest countries in the world and ranks near the bottom of the United Nations Human Development Index, 173rd out of 188 countries	In theory, an open access network, but as Gamtel behaves as a typical vertically integrated service provider	Policy indecision about what to do with Gamtel; regulatory delays and questionable capability to enforce open access policy	Market Segment: nominally open access, but Gamtel is driven by vertical integration interests; Management: state-run through State-owned Enterprise. Revenue: subsidized loan for the network build; government leniency on other repayment obligations	ECOWAN financed through IDB loan taken on by government. No partnership or risk-sharing. Gamtel's financial fragility raises questions regarding the stability of the funding of both the national backbone, and the Gambian Submarine Cable company	No significant use of power, transport or water utilities

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Existing backbone consisted of 534 km of fiber optic cable. With the ECOWAN project, 817 km of fiber cable was installed from Banjul to Basse in the North Bank, and 26 districts from Banjul to Fatoto in the South Bank of the country	Increases in bandwidth attributable to ACE international cable landing, not to ECOWAN	Low utilization due to high prices	Decreases in bandwidth attributable to ACE international cable landing, not to ECOWAN	US$18.5million on national backbone. US$22k per kilometer	Technical criteria met. Commercial launch delayed by a year. Fixed broadband targets have been missed and impact on prices in the market has been insignificant

Lessons Learned

- Role of SOE and government's objectives for SOE can be detrimental and in the long-term counterproductive
- Project prioritized salvaging Gamtel business, rather than sector's overall health
- Missed opportunity to restructure the incumbent
- Missed opportunity to utilize private sector
- Go-it-alone strategy in fragile state puts public sector finances at risk unnecessarily

Cross Border | **National Backbone** | Middle/Last Mile

Lithuania RAIN

Rural Area Information Technology Broadband Network

URL: ec.europa.eu/information_society/newsroom/cf/dae/document.cfm?doc_id=4988

Narrative

HQ: Vilnius, Lithuania

The Rural Area Information Technology Broadband Network (RAIN) was comprised of two core phases. In the first phase (2005 –2008) 3357 km of fiber optical lines were installed; 509 network nodes were installed; 467 districts were connected to 51 municipalities. In the second phase (2009-2015) another 5800 km of fiber installed connecting 982 rural townships connected to the core network.

The RAIN is owned and managed as a division of the State Ministry of Transport and Communications, but it is maintained by private sector entities selected via public tenders.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	Markets are competitive, except, by definition, in grey and white areas where RAIN focuses	Lithuania's HDI puts it as 37 out of 188 countries and territories. Gross national income (GNI) per capita (2011 PPP$) is 26,006 USD	Active and Passive Layer Open Access Network (A-PLOA)	Advanced. EU member state, so has a well developed regulatory framework	Segment: core-network to rural areas. Management: State-owned and managed. Revenue: Traditional revenue model: prices are set at a level that ensures that retail broadband services in the targeted areas can be provided at a price similar to retail levels in urban areas	State assistance comes in the form of ERDF (European Regional Development Fund) and the Lithuanian national budget	No synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	About 10,000 km built and of 3,000 km leased fiber-optic cable lines, which connect all of the country's rural elderships	N/A	N/A	N/A	N/A	N/A

Lessons Learned

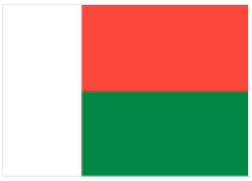
- Good example of using a new entity to end vertical monopoly of incumbent
- Successful positioning as dominant open access network that does not compete with customers for end-users
- Market risk of not having private sector players involvement; not clear how well it will perform in the face of a challenge from the private sector

Cross Border | **National Backbone** | Middle/Last Mile

Axian

Privatized national fixed line operator providing carrier neutral tower infrastructure

URL: http://www.axian-group.com



Narrative

HQ: Antananarivo, Madagascar

Not to be confused with the French Axiane, Axian is a local Malagasy corporation. With interests in financial services, real estate, energy as well as telecoms.

Axian acquired the state-owned national fixed line incumbent, Telma, in 2004, which has built out 8,800 km of fiber-optic cables nationwide over the last ten years. It also owns Towerco of Madagascar (TOM), which provides passive infrastructure to mobile operators on non-discriminatory basis. in addition to rolling out fiber and mobile access networks.

Telma and TOM as well as Camusat, and Orange, have won subsidies through competitive tenders to build out towers in rural areas that are to made available open access conditions, with non-discriminatory and low-cost pricing.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	Mobile market highly competitive. Telma's market share of subscribers is around 25-30% behind Airtel and Orange. Telma is dominant player in fixed infrastructure	Madagascar's HDI puts it as 158 out of 188 countries and territories. It has a GNI per capita of 1,320 in PPP USD	For tower infrastructure with TOM	Maturing	Market Segment; Vertically integrated fixed network Management: private company Revenue: traditional. Very little subsidy and limited to TOM's rural tower deployments	N/A	There are some synergies with Axian energy interests (power), but chief sharing via Towerco of Madagascar which provides infrastructure

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	Telma: 8,800 km of fiber-optic cables nationwide over the last ten years. Upgrade of the metropolitan network to provide fixed broadband access TOM: installed 45% of all telecom towers in Madagascar, 60% of which are powered by either wind or solar	International bandwidth increased from 200 Mbps in 2007 to over 31 Gbps in 2015	Internet subscriber penetration increased from 0.23 in 2007 to 13.4 in 2015	Price of wholesale international E1 capacity link decreased from $10,000 in 2007 to $442/month in 2015; Retail price of a 1 Mbps connection dropped from $400 in 2007 to $58 in 2015	N/A	Plans not published but annual reports suggest robust achievements. World Bank funding of rural development disbursed on time and towers deployed on time

Lessons Learned

- Axian has demonstrated that a company can have diverse enough interests (about one-third of its revenues are originate from its telecoms business) to offer infrastructure on non-discriminatory terms despite being involved in both upstream and downstream markets
- Privatization of Telma and liberalization of the market provided the foundation for a robust multi-player, competitive market
- State support has been limited to support of rural development
- Focus has been on creating national infrastructure extension for mobile networks rather than fixed networks

Cross Border | **National Backbone** | Middle/Last Mile

Peru RNDFO

Peru's north-to-south national backbone (RNDFO)

URL: http://www.mtc.gob.pe/version_ingles/backbone/index.html

Narrative

HQ: Lima, Peru

In 2014, the government of Peru awarded a concession to design, build, and operate a north-to-south national backbone (RDNFO) to Azteca totaling 13,500 km of fiber. A year later, the government began issuing a number of regional and access network concessions to complement the RDNFO. To date, the government has issued 15 out of the 21 projected regional concessions, totaling around additional 19,500 km of fiber. These concessions were to offer wholesale open access services to mobile operators and ISPs.

However, at the same time, mobile operators were building out their own national backbone networks, as might be expected in avibrant Latin American market like Peru. For example, Viettel, the fourth entrant into the mobile market which launched services in 2014, had deployed over 21,000 km of fiber by 2017. Claro and Telefonica have also aggressively expanded their networks.

The result: a crash in prices for network service and a highly underutilized network.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Highly competitive mobile industry: Telefonica Movistar (55% market share), America Movil's Claro (30%), then Entel Peru, Vietnamese Bitel and Virgin Mobile. In the market for fixed broadband, Telefónica del Peru's Movistar is the market leader	Peru's HDI puts it at 87 out of 188 countries and territories. Gross national income (GNI) per capita (2011 PPP$) is 12,480 USD	Active and Passive Layer Open Access Network (A-PLOA)	Mature regulatory regime	Market Segment: national and regional wholesale backbone; Management: Build-operate-transfer. 20 years (for the national backbone) or 15 years (for the regional backbone); Revenue: traditional supplemented by capex subsidies	Build and operate risk borne by operators. State limited risk to capex subsidy	Aerial fiber over high tension power lines

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
13,500 km, connecting Lima with 22 regional capitals and 180 provincial capitals	Over 2014-2017 MNOs increased their fiber holdings 6-fold. This is in addition to the RDNFO projects	Around 1%. Actual capacity demand for 2016 was about 18% of projections at the time of the award	Sharp drop of average leased lines prices ~60% between 2013-2017. Leased line prices in 2013: low – $106 / average – $234 ; in 2017: low – $4.18 / average – $91.19	$1.8 billion; $23k per fiber kilometer for national backbone	Very quick roll-out: 3 years

Lessons Learned

- In theory, best practice PPP was followed with the private sector providing a DBO role to create carrier-neutral capacity
- Inaccurate assessment of national backbone market conditions at design stage and the deployment of backbone capacity by private providers have impacted expected demand for RDNFO capacity
- This suggests that policy could have benefited from an incremental approach to wait and see if the private sector would solve the problem on its own
- Long administrative processes to reassess conditions imposed on RDNFO in light of changing market conditions may undermine long term viability of the business case

Cross Border | **National Backbone** | Middle/Last Mile

Phillipines NBNs

Competing national fiber-backbone infrastructure

URL: N/A

Narrative

HQ: N/A

The Philippines is one of the few developing countries in the world with competing national fiber-backbone infrastructure: PLDT's Domestic Fiber Optic Network (DFON) and Globe Telecom's Fiber Optic Backbone Network (FOBN) and the National Grid Corporation of the Philippine's (NGCP) national private telecommunication network.

The government's priority is therefore focused at the middle and last mile level. However, it is therefore considering how to best facilitate these backbone networks to support programs to roll-out middle and last mile networks in unserved and underserved areas. This includes 1) identifying areas that are yet to be served with the domestic backbone routes but will eventually serve as the primary nodes for serving under-served areas and 2) linking the national backbones to avoid the need to duplicate network roll-out to these challenging areas.

The country's plan for selecting business models for these areas reflect good practice.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Competing national fiber-backbone infrastructure, but gaps in certain areas of the country. Five major tel-ecommunications fixed network operators. PLDT dominates the fixed broadband market (60% market share)	The Gross National Income per capita is (GNI) is PPP USD 3,540. The Philippines' Human Development Index (HDI) ranking it 116 out of 188 countries in 2015 accord-ing to the 2016 Human Development Report of UN Development Programme	To date the arrangements for access have been com-mercial terms (2LCA). New government sponsored builds will be open access	The government, through the NBP, will provide coordinated policy for limited intervention to support availability, accessibility, and affordability of broadband internet services to Filipinos	Segments: nodes in under-served areas for extension of existing national backbone networks; subsea cable landings Management: PPP or consortium Revenue: traditional plus limited subsidy to achieve affordability for end user	Exploiting use of existing commercial installed infrastruc-ture; will consider government build and operation, PPP or subsidized investment options on a case-by-case basis	Avoid duplication, i.e., expand use of existing infrastructure.; One of existing national backbones utilizes facilities of the national power grid.; government plans to allow fiber roll-out along rail and roadway rights of way

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Extensive networks throughout the country, except in the south (Mindinao and Palawan). Diverse submarine landings (currently 7, soon to be 9), but in the hands of two operators	N/A	With the National Broadband Network, Philippines plan to provide at least 10 Mbps connec-tion to all households by 2020	N/A	The government earmarked USD 1.5 billion) for 2017 to 2020 in the Philippine Integrated Infrastructure - PhII, (which consists of international submarine cable landing stations, national government backbone, and the last mile access network) implementation	Government plans yet to be realized but they consist of investing in a carrier neutral subsea landing facilities via a PPP or consortium arrangement

Lessons Learned

- Philippines government plan put primacy on policy and regulatory reforms to facilitate private sector-led infrastructure deployment
- Analyzed markets to limit public sector investment to underserved areas
- Included a demand stimulation component, including an access device subsidy scheme for broadband users

Cross Border | **National Backbone** | Middle/Last Mile

Rwanda NBFON

High-capacity national optic fiber backbone in Rwanda

URL: https://www.ktrn.rw

Narrative

HQ: Kigali, Rwanda

As part of its National Information Communication Infrastructure plan for 2005-2010, Rwanda set out to deploy a high-capacity national optic fiber backbone throughout the country.

It did so by contracting Korea Telecom to supply a network comprising 2,300 km of fiber to link 317 institutions (97 in Kigali and 220 outside the capital) across all 30 districts of the country, as well as connecting at all nine of Rwanda's borders.

KT Rwanda Networks also has been granted a monopoly on 4G LTE wholesale in the country and has been increasing its presence in retail markets. Not surprisingly there have been complaints, however, that KT Rwanda Networks is not acting as the carrier neutral entity it was set up to be and its 4G monopoly is unjustified.

Local Rwandan mobile operators are favoring the upgrade of their own 3.75G networks rather than use KT's monopoly 4G network.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	Competition found throughout the value chain: from access services to national backbone and cross-border connectivity. The RBFON has played a critical role in connecting land-locked Rwanda with Tanzania	Rwanda's HDI puts it at 159 out of 188 countries and territories. It has a GNI per capita of 1,617 in PPP USD	A-PLOA, but increasingly vertically integrated; monopoly on 4G	Maturing	Segment: National wholesale networks Management: Government contracted with telecoms companies and utility to roll-out network, then transferred to private sector for management, only to be transferred to JV between KT and State Revenue: Traditional + Government as anchor client	The government owns the infrastructure and provides the private partner an equity stake in the joint venture. Government financed with equity participation of three mobile operators (MTN, Tigo and Airtel)	In addition to building own infrastructure, Rwanda NBFON rolled out fiber along with national electricity, water and sanitation networks to expand backbone coverage and redundancy to insulate the market from common cable cuts

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	The National Optic Fibre backbone (2.500 km) connects all districts in towns as well as districts in remote and rural areas. Separate project funded by the World Bank created a Virtual Landing Point (VLP) and capacity purchases for subsea cable access	Number of broadband (internet) subscribers increased from 726 in 2008 to 2,515,689 in 2015 and as compared to the target of 4,500. Volume of international traffic increased from 235 Mbps in 2008 to 11,684 Mbps in 2015	The backbone of NBFON is heavily utilized; however, the take up of 4G wholesale service has been negligible. KT Rwanda claims to have coverage of over 95% of the population, but at the end of 2017 very few subscribers	The wholesale price of international capacity link from Rwanda to European hubs dropped from $10,000/Mbps in 2008, to $125/Mbps in 2015	Investment of $22 million in national backbone, which implies unit investment of under $10k per fiber km.	In 2007, a government programme was adopted for the construction of national optic fiber backbone which was completed in 2010

Lessons Learned

- Successful mix of public procurement of network from private sector and transfer of operations to (ultimately) private majority joint venture
- Successful positioning as dominant open access network
- Minimized duplication of network
- Question of whether new JV is undermining pro-competitive mission: extending into retail space and not clear that a wholesale 4G monopoly was necessary

Cross Border | **National Backbone** | Middle/Last Mile

ADIE

Senegal's national government fiber optic network

URL: https://www.adie.sn/

Narrative

HQ: Dakar, Senegal

Government launched a vendor-financed national fiber optic project to provide services for public administration including government buildings, ministries, facilities. The network is operated and maintained by the government's own ICT agency, which is arguably inadequately resourced.

The result has been poor maintenance, underutilization of the network, and excessive subsidies to keep the entity afloat. The government is now seeking ways to introduce private sector expertise and possible private sector investment to transform the network into a financially sustainable initiative.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	ADIE owns and operates the second largest fiber optic network in Senegal, after Sonatel, the privatized incumbent operator. Three mobile operators: Sonatel/Orange – which has a quasi-dominant market position, Sentel/Tigo, and Sudatel/Expresso; and one independent ISP	Senegal's HDI puts it at 162 out of 188 countries and territories. It has a GNI per capita of 2,250 in PPP USD	Aspirations to be open access wholesale network but poor management has meant that the network cannot be effectively used	Regulatory and policy framework require and overhaul to facilitate more competition in the sector	Market Segment: government network Management: State Agency for IT (ADIE) is responsible for operating the network. Revenue: traditional	State-owned. not 100% financed with vendor financing, at least one of the tranches was financed by China Exim Bank	No synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	More than 4,000 km of fiber optic network was built in 3 phases starting in 2000. More than 700 government sites connected (buildings, ministries, facilities)	Negligible additional bandwidth to market	Underutilized	Negligible impact on market prices	No balance sheet	No financial accounts or business plan. With World Bank intervention, the hope is to raise Internet penetration rate from 60-70% and increase the number of facilities-based Internet providers from one to 6 over three years

Lessons Learned

- Never designed to be a fully functioning telco, rather a big government network
- Despite ambitions to operate as a national backbone, does not operate as a commercial entity
- GoS ICT agency is poorly resourced; as a consequence the network is poorly maintained and financially unsustainable
- Limited participation of the private sector and lack of a robust business case has lead to poor performance
- GoS is currently seeking ways to introduce private sector expertise and possible private sector investment to transform network

Cross Border | National Backbone | Middle/Last Mile

Simbanet VLS

National backbone in Malawi

URL: URL: http://www.simbanet.net/

Narrative

HQ: Lilongwe, Malawi

The government of Malawi ran a competitive tender for a national backbone design build and operate 10-year contract. Simbanet deployed 900 km of fiber and a "virtual landing station" within the land-locked nation. This virtual landing station includes the meet-me and NOC facilities one would expect at subsea cable landing station but are located in Malawi.

SimbaNET contracts for connectivity to the actual cable landing stations via Tanzania and Zambia to the TEAMS, EASSy, SEACOM and WACS subsea cables.

To improve the business case, the government offered an offtake arrangement guaranteeing a critical level of sales to the new entity. Simbanet is required to offer services on an open access basis.

A critical role was played by the World Bank in developing the concept and implementation.

Attributes & Success Criteria

Attributes	**Market Structure**	**Economic Context**	**Carrier Neutrality**	**Regulatory & Policy Efficacy**	**Business Model**	**Financing & Risk-Sharing**	**Infrastructure Sharing**
	Malawi has two major mobile network operators (MNOs): Bharti Airtel and Telecom Networks Malawi (TNM). Apart from Simbanet, MTL and ESCOM (state-owned power company) provide wholesale transmission capacity. There are 15 licensed ISPs	Malawi's HDI puts it at 170 out of 188 countries and territories. It has a GNI per capita of 1,073 in PPP USD	Expected and encouraged to sell to other operators on a non-discriminatory basis	Maturing	Segment: national backbone and international capacity; Management: private DBO. The GoM, represented by the PPPC awarded a 10 year contract. Revenue: Traditional + Government of Malawi acts as an anchor customer for supply of internet bandwidth from Simbanet	Simbanet will be investing to construct a national backbone; The GoM then purchases the network along with complementary international capacity with a loan from the World Bank	No synergies with power, transport and water utilities

Success Criteria	**Geographic Reach of Network**	**Increased Bandwidth / Volume**	**Take-up: Utilization of Network Relative to Legacy**	**Prices Relative to Legacy, Affordability**	**Investment and Unit Investment (per fiber km)**	**Performance to Plan**
	Simbanet has constructed over 900 km of fiber optic infrastructure spanning from Lillongwe to Mchinji and Lilongwe to Songwe River	International Internet bandwidth increased from 180 Mbps at the end of 2008 to 4210 Mbps in 2015	N/A	Price of international capacity dropped from $36,000 per STM-1 to $13,600. Price of national traffic has dropped substantially from the current $1,500 to $300 for an E1	The total value of the contract is around $14.5 million funded by the World Bank. The cost per kilometer was around $16k.	Plan details not public

Lessons Learned

- Design, build and operate approach to PPP offered through a competitive tender has proven successful
- Good example of using a new entity to end vertical monopoly of incumbent
- Successful positioning as dominant open access network
- Simbanet was awarded a license to operate in the wholesale and retail markets, so may cause problems down the road
- Missed opportunity to include power transmission assets (ESCOM)?

Cross Border | **National Backbone** | Middle/Last Mile

Southern Telecom

Telecommunications subsidiary of power utility Southern Company

URL: http://www.southern-telecom.com/

Narrative

HQ: Atlanta, United States

Southern Telecom is the telecommunications subsidiary of Southern Company, a public service holding company which owns electric utility operating subsidiaries serving consumers in the states of Alabama, Florida, Georgia and Mississippi. It was founded to commercialize excess dark fiber on the transmission grids of Southern's electric utility running subsidiaries.

Southern Telecom's fiber network holds 1,300 route miles, including fiber routes on the transmission grid of other electric utilities which Southern Telecom has acquired through fiber swaps, and it provides long-haul and metropolitan dark fiber connecting Atlanta with other smaller cities throughout the southeastern United States.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	High competition, several telecom provides on the market in the states of Alabama, Florida, Georgia and Mississippi	USA's HDI puts it at 10 out of 188 countries and territories. It has a GNI per capita of 53,245 in PPP USD	Carrier-neutral, commercial access	Regulatory Regime: Mature	Market Segment: wholesale broadband connectivity Management: privately owned and operated Revenue: traditional wholesale pricing	Through the partnerships with major telecom network operators, ST was able to develop an internal backbone connecting all its major facilities in four states with a zero capital budget	Multiple partnerships with major telecom network operators for joint build-outs and shared use of fiber optic cables on the electric transmission lines of Southern Company's operating subsidiaries

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	Its fiber network has over 1,300 route miles of backbone between the larger metropolitan areas in Alabama, Florida and Georgia, plus numerous spurs from the backbone to smaller cities	4G/LTE ?	N/A	N/A	N/A	Company plans to upgrade its network to 4G/LTE over its entire coverage area in three stages, with completion expected by mid-2018

Lessons Learned

- Government simply had to authorize power utilities to provide telecommunications service and private sector exploited the opportunity to the benefit of the market

Cross Border | National Backbone | **Middle/Last Mile**

4Afrika

Affordable access through TV white space

URL: https://www.microsoft.com/africa/4afrika/

Narrative

HQ: Redmond, WA, USA

The 4Afrika project was launched by Microsoft in 2013, with the stated aims of assisting in the development of affordable access, skills and innovation on the African continent.

As part of the 4Afrika initiative Microsoft has launched 15 TV white space (TVWS) connectivity pilots across many countries in Africa, including Kenya, South Africa, Namibia, Tanzania and Ghana.

The project has spurred several other programs including a telemedicine service, diagnosis applications, and more around government participation and agriculture.

Ultimately, as a business model, traditional financial self-sustainability of these initiatives may not possible.

Main regulatory issue is about spectrum: regulators may be hesitant to allow TVWS for commercial use as there are questions about whether this is the most appropriate way to use spectrum.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	4Afrika targets white markets (where there is no broadband service provision). There is no direct competition	It has a GNI per capita of 3,382 in PPP USD	4Afrika is not a wholesale play	Regulatory Regime: Maturing	Market segment: last mile wireless network and retail service provider. Management: private sector, Community-based. Revenue: usage based	Initial capital put up by Microsoft, USAID, angel investor Jim Forster, and Paul G. Allen's Vulcan, Inc. To date this is a CSR initiative. Not intended to be a profit maker	There are no sharing arrangements in place

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	It has launched 15 TV white spaces connectivity pilots. 4Afrika projects support non-commercial Internet access to primary care centers, schools through partnerships with local organizations	N/A	These are areas which have had negligible broadband coverage. This is access provided to previously unserved areas	$0.50 for 24 hours (300 MB cap), $1 per week (500 MB cap), $3 for one month (2 GB), or $10 for a three-month package (8 GB), and device charging. After the data thresholds are reached, connectivity throughput is slowed. (See Closing the Access Gap, USAID, 2017)	$75 million investment in Africa in order to provide affordable access to technology – great accelerator for African competitiveness. No public information is available on the costs of the network	Plans have not been made public

Lessons Learned

- The model allows for simplified delivery in which community inhabitants have the capability to deploy and maintain facilities, software and hardware with minimal training
- The major advantage of this type of technology is that the frequencies used, in the range of 450 to 800 MHz, allow non-line-of-sight transmission (NLOS), with low power, over relatively long distances, typically 15 km. This spectrum provides deep coverage for long-distant Internet connectivity to under-served communities over hills and through foliage
- May be a risky deployment: 1) given the secondary status of such TVWS use, in some cases there no guarantee of protection or availability exists if licensed TV stations decide to use this spectrum to broadcast their programming; and 2) regulatory status of spectrum may change

Cross Border | National Backbone | Middle/Last Mile

AirJaldi (in partnership with Facebook)

Low-cost, environmental-friendly and durable broadband for rural India

URL: https://airjaldi.com/

Narrative

HQ: Himachal Pradesh, India

AirJaldi is the trading name for Rural Broadband Pvt. Ltd., which is licensed to operate all over India. It was incorporated in India in 2009 with the aim of creating sustainable broadband Internet networks and solutions for rural areas. AirJaldi was started as a not-for-profit enterprise, but has made an effort to shift to a more commercial base to expand operations. AirJaldi continues to operate AirJaldi.org, which performs open-source applied research, capacity building, and knowledge sharing through classes and conferences, on a non-profit basis.

AirJaldi purchases bandwidth from Internet Service Providers like Airtel and distributes it to a local Network Operation Center (NOC). From the NOC, connectivity is extended through wireless relays to its customers. Distances between relays range between a few hundred meters to 50 km. The wireless relays are solar powered and mounted on small poles. Its customers connect to relays through Customer Premise Equipment (CPEs), which are small and powerful routers. Each relay is built to reach specific customers but at the same time, each customer is also potentially a relay to other clients.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	AirJaldi targets emerging (white and grey) markets. There is no direct competition, however it indirectly competes with other broadband providers	India's HDI puts it as 131 out of 188 countries and territories. It has a GNI per capita of 5,663 in PPP USD	AirJaldi offers retail broadband Internet service and network solutions to rural areas	Regulatory Regime: Maturing	Market segment: last mile wireless network and retail service provider. Management: private sector owned and operated. Revenue: subscription and usage	The company is privately funded and in 2017 reported no debt. Operates sustainably from from the revenues collected	No significant synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	AirJaldi has 10 networks in 6 Indian states covering more than 24,000 km^2	N/A	N/A	Between 0.3-4 USD depending on usage limit (200 Mb-20 GB) and subscription term (1-30 days)	N/A	N/A

Lessons Learned

- The WIFI relay network allows each station to operate as an access link and a transmission link to other stations
- Relays are fully solar powered and are mounted on small poles, reducing operating cost
- Continuous power supply particularly during the monsoon season is a challenge. Good battery backups are required.
- Middle-mile relay WIFI can limit scalability

Cross Border | National Backbone | **Middle/Last Mile**

Aquila

Short-term initiative by Facebook to provide internet to hard to reach areas

URL: URL: https://www.facebook.com/notes/mark-zuckerberg/the-technology-behind-aquila/10153916136506634/

Narrative

HQ: Menlo Park, CA, USA

Aquila proposed to prove the concept of using aircraft or drones to offer a fixed backhaul service for Internet connectivity from the stratosphere. The project sought to demonstrate the viability of deploying high altitude platform stations to bridge the "backhaul gap" and provide connectivity to base stations and other access points serving suburban and rural communities. Once backhaul connectivity was delivered to the base station or access point, last-mile connectivity to the end user would then be offered by a mobile provider and/or wireless ISP using licensed or unlicensed spectrum.

Each drone was designed to remain airborne for 90 days using solar power during the day and stored battery power at night and cover a radius of around 50 kilometers.

In June 2018, Facebook announced that it was no longer designing and building aircraft for project Aquila, and that it would instead focus on working with other companies developing high-altitude platform station technologies. These include Airbus, Softbank, and Lockheed Martin, among others, which are entering the high altitude platform stations space and advancing different types of business models to support backhaul connectivity to expand Internet access.

Attributes & Success Criteria

Attributes	**Market Structure**	**Economic Context**	**Carrier Neutrality**	**Regulatory & Policy Efficacy**	**Business Model**	**Financing & Risk-Sharing**	**Infrastructure Sharing**
	Proof of concept project to provide global middle mile, spanning a range of suburban and rural markets across various countries. Actual coverage not announced.	Mainly intended for countries which are in the rank between low human development and medium development according to the United Nations Human Development Index.	Not clear. Likely would have been made available to any service provider.	Global project, relying on spectrum designated for high altitude platform stations	Market segment: provision of backhaul to mobile providers or other ISPs to support their retail services. Management: privately owned and operated. Revenue: not clear.	Privately funded	No significant synergies with Power, Transport and Water Utilities

Success Criteria	**Geographic Reach of Network**	**Increased Bandwidth / Volume**	**Take-up: Utilization of Network Relative to Legacy**	**Prices Relative to Legacy, Affordability**	**Investment and Unit Investment (per fiber km)**	**Performance to Plan**
	Actual coverage was not announced	Not launched	Not launched	Not known	Not known	Designing and building aircraft discontinued to support other companies developing technologies for high altitude platform stations

Lessons Learned

- The objective was to develop technology and prove viability of high altitude platform stations as a solution to bridge backhaul gaps limiting extension of broadband services.
- Since the launch of Aquila a diverse group of players have entered the arena for high altitude platform stations, including technology providers, aerospace companies, and satellite companies, among others, which could lead to attractive business cases and models in the future.

Cross Border | National Backbone | **Middle/Last Mile**

Australia NBN

Providing superfast broadband to all Australians

URL: https://www.nbnco.com.au/

Narrative

HQ: Australia

Created in 2009 the NBN, together with phone and Internet providers is intended to establish Australia as a more connected, more competitive and more innovative nation.

The Government's Statement of Expectations asserts that NBN is to provide wholesale download speeds of at least 25 Mbps to all premises, and at least 50 Mbps speeds to 90 per cent of premises.

Over three million households and businesses are currently connected to the NBN, which is available to more than 6.1 million premises and is due for completion in 2020.

Involved the highly controversial creation of a massive state-owned and managed entity. The incumbent privately run fixed network operator, Telstra, was not required to separate retail and wholesale operations, or transfer assets to the NBN. Instead it agreed to become a reseller of NBN services and lease dark fiber, exchange space and ducts to the NBN.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	National broadband network, as such is operating in the full range of markets — from highly competitive to total absence of competition	Australia is ranked at 2nd place on the HDI of 188 countries and territories. Gross national income (GNI) per capita (2016) $49,927	NBNco offers wholesale to any ISP in Australia on an open access basis	Mature regime. In addition to being a state-owned and managed entity. Various regulators influence operations, e.g., ACCC determined T&C s of access	Market Segment: wholesale open access Management: state entity Revenue: standard	State-owned equity; and state loan of nearly $15 billion	Shared wholesale access network. Also the Co-Development Program was established to leverage synergies between NBN's planned construction and third-party construction projects

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	Nationwide, Australia	Speeds up to 100 Mbps are available in Australia	3.5 million premises connected out of around 7 million are passed, which is far below planned	Prices are high, take-up is low. Expensive higher speed packages, but discounts of up to 27% are expected to be introduced in 2018	Capex of $A5.8 billion (US$4.6 billion) by the end of 2017. With 5.7 million premises passed that results in ~US$800 per premise	As originally foreseen, the plan should have been completed by now. Service speeds are lower than promised. Many issues: Speed (only a quarter of those who connected to the NBN via FTTN would be able to access download speeds of 100 Mbps). Just 44 per cent of NBN users said the network had met their expectations, and more than half of it's users experienced connection and speed problems

Lessons Learned

- Public ownership can lead to political battles and technology choice influenced by non-economic factors
- Single, centralized project put too much risk in one entity
- Complexity of project suggested a multi-player, decentralized approach would be preferable

Cross Border | National Backbone | **Middle/Last Mile**

Avanti ECO

Solar-powered Internet connectivity for rural Africa

URL: https://www.avantiplc.com/eco/

HQ: London, UK

Narrative

Initiative to roll out high-throughput satellite service to rural communities in Africa. The business model benefits from an initial contribution from the European Space Agency and links communities, service providers and private and/or public partners to ensure on-going affordability through subsidy.

The project was launched in 2016 as a response to the fact that most African governments have limited budget or resources to deliver broadband to the population.

ECO delivers a robust and high performing Wi-Fi hotspot service to end users at low prices. The ECO App enables users to buy and trade broadband credits so that everyone can use the Wi-Fi services.

ECO has been successfully piloted in several projects and is now ready for scale.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Avanti ECO targets emerging white markets. There is no direct competition, however it indirectly competes with other broadband providers	It has a GNI per capita of 3,383 in PPP USD	Avanti ECO is not a whole-sale play	Regulatory Regime: Maturing	Market segment: last mile wireless network and retail service provider. Management: Avanti Eco also partners with service providers and delivers installation and maintenance in return for a revenue share. Revenue: usage and private and/or public CSR partner contributions to ensure on-going affordability through subsidy	European Space Agency (ESA) to contribute €10.7 million. The business model is start up equity	No infrastructure sharing. No synergies with power, transport and water utilities

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Affordable satellite broadband connectivity to 1,400 community sites across Sub-Saharan Africa	Too early to say	ESA is funding the project for the next 5 years, aiming to reach 500,000 communities in Africa	N/A	Avanti has invested $1.2 billion in a network that incorporates satellites, ground stations, data centers and a fiber ring	ECO aims to deliver sustainable broadband to every rural school in Africa and to provide broadband Internet connectivity at very low cost to millions across Africa. In next five years aim is 500,000 communities

Lessons Learned

- Low cost power through solar cells
- Easy-to-use ECO app and purchase broadband ECO credits to connect to the Avanti Community Wi-Fi hotspot
- Carrier class Wi-Fi to connect a school and users in the surrounding community to the Internet
- The model allows for simplified delivery in which local staff has the capability to deploy and maintain facilities, software and hardware with minimal training
- Yet unclear whether benefits (benefits package photography, impact report, ECO partner status and data analytics about usage in school and amongst community users, sponsorship brand message to be carried on the App and seen by community users) will secure adequate contributions for on-going operation

Cross Border | National Backbone | **Middle/Last Mile**

Burlington Telecom

An example of how revenue-bonds can be used to finance rural broadband

URL: https://www.nbnco.com.au/

Narrative

HQ: Burlington, VT, USA

Burlington Telecom (BT) is a local fixed municipal network offering television, telephone and internet services. The company runs its communications offerings on a citywide fiber-optic network. It is a 100% municipality-owned fiber optic network.

BT built a modified "homerun" fiber network, which meant less shared capacity among customers.

Launched in 2001, Burlington Telecom was initially portrayed as a model for municipality fixed network development. While ostensibly cash-flow positive, BT was drawing on state funds to cover an increasing debt service and capex. By 2010, the firm was basically insolvent.

The network was privatized in 2017 through competitive bidding. Burlington Telecom was acquired by Schurz Communications for $30.8 million.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
BT competes with Fairpoint and Comcast who offer similar product set in television, telephone and internet services	U.S. HDI puts it at 10 out of 188 countries and territories. It has a GNI per capita of 53,245 in PPP USD	Offers retail broadband using its own citywide fiber-optic network	Regulatory Regime: Mature	Market segment: vertically integrated - Burlington Telecom built its own infrastructure and offered retail services. Management: city owned and operated Revenue: traditional product and bundle pricing	Financed through capital lease, which grew from $2.6 million to $33.5 million over several years. Also borrowed $17 million from the state. Due to financial struggles, privatized in 2017, with the municipality retaining a minority holding	No significant synergies with power, transport and water utilities

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Burlington, Vermont, USA	Speeds up to 1 Gbps	Low at 1,800 subscribers in 2007, 5 years after launch of service. Now at somewhat over 4,000, still not as high as planned	Pricing was competitive, but appeal was for individual services rather than bundle, so ARPU was low. Now, at between $57/month for 5 Mbps to $190/month for 1 Gbps, while in other U.S. cities 1 Gbps costs $70/month	Projected to cost $21 million, however discontinued due to lack of funds	Meant to service 4,500 to 5,000 subscribers profitably. This figure was never met and had to draw on state funds to remain solvent. Experienced significant delays in completion of network

Lessons Learned

- Being a third entrant in the local fixed network market can prove a challenge to a business case, particularly when incumbents have deep pockets
- As a small organization, BT found it more costly to contract for content services, paid more per Mbps for transit services
- Early mover in fiber. Ten years ago consumers less likely to value superfast broadband to pay the premium that would have kept BT afloat
- There is evidence that BT was run too much like a civil service, rather than a commercial enterprise
- Although a business failure as a municipal network, BT had a positive competitive impact on the market and was reborn on a sounder financial basis with privatization

Cross Border | National Backbone | **Middle/Last Mile**

Chorus

Ultra Fast Broadband (UFB) network deployment in New Zealand

URL: https://www.chorus.co.nz/

Narrative

HQ: New Zealand

The new Telecommunications Act of New Zealand was approved in 2001 which provided the legal basis for the structural separation of Telecom New Zealand. Faced with the threat of such an action, Telecom New Zealand voluntarily split itself into the retail (Spark) and wholesale infrastructure (Chorus), which was finalized in 2011.

The government planned investment of $NZ1.5bn for Ultra Fast Broadband (UFB) network deployment. Crown Fibre Holdings (CFH) was established to manage the government's investment. Local wholesale open access concessions were offered by tender to build fibre infrastructure meeting the goals of the UFB strategy. Chorus was awarded 24 of the 33 candidate areas for deployment. The deployment prioritized schools, hospitals, health service providers and businesses.

The wholesale prices are determined by the Commerce Commission. In December 2015 the Commission announced its final decisions on the wholesale prices Chorus could charge Internet providers for its broadband services over local lines.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	National access market competitive. Chorus competes with vertically-integrated service providers. Share of the fixed broadband market: 72% of all New Zealand homes	New Zealand's HDI ranks it 30th out of 188. GNI per capita in USD PPP is 37,860	Subject to four open access undertakings for copper, fiber and Rural Broadband Initiative services that obliges the provision of services on a non-discriminatory or equivalent basis; also has specific capacity availability obligations	Regulatory Regime: Mature	Market Segment: Providing wholesale core and access network services to retail providers (in 2017 customer base around 100 retail service providers . Management: publicly traded private company Revenue: traditional wholesale pricing model	Excluding government investment for access network build-out, which are competed for through tenders. Chorus has a debt to equity ratio of about 1.6. Two-thirds of the debt in euro-denominated bonds, one third in NZ bonds	Shared wholesale network. No infrastructure sharing. No synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	Chorus operates a national network. Chorus was awarded local areas, including Auckland and Wellington, for fiber rollout covering 830,900 premises	Average fixed broadband download speed has increased from 3.9 Mbps in 2011/12 to 14.7 Mbps in 2016/17.; Data used per fixed line connection has increased from 20 GB per month in 2011/12 to about 120 GB in 2016/17. Number of government-sponsored fiber lines has increased from 1k in 2011/12 to 413k in 2016/17	New Zealand has had one of the highest broadband subscriptions growth rates among OECD countries in the recent years	Prices by speed of connection have remained relatively stable over the period	Chorus and other local fiber companies have received over half billion USD each year since 2012/13	Number of New Zealand homes with broadband connections is 87%; with fiber connections. This gave New Zealand a ranking of 15th out of the OECD countries for fixed broadband penetration, ahead of the U.S. at 16th and Australia at 21st. Fibre connections have grown from around zero when Chorus was created to 500 thousand. About one third of the way to government's goal

Lessons Learned

- Structural separation forged two new businesses, which have performed better for shareholders and New Zealand structural separation fundamentally changed the dynamic of both Chorus and Spark. At an economic level, it delivered greater management and board focus on each business, while improving financial flexibility for both entities
- Fundamental shift in behaviour – Spark and Chorus. Changes to incentives and behaviour. Both more customer focused. Chorus incentivized to provide open access network
- Competitive tenders for deployment in rural areas keeps costs in control and incentivizes operational efficiency

Cross Border | National Backbone | **Middle/Last Mile**

Concero

Affordable connectivity infrastructure for the communities in remote areas

URL: http://www.conceroconnect.net/

Narrative

HQ: Park City, UT, U.S.

Concero Connect is a "Low-Profit" Limited Liability Company – founded to promote a social mission of bringing broadband to underserved areas around the globe. First project was launched in 2011 in a village in Mexico.

It is exploiting Motorized Earth Station Antennas (MESAs) to track inclined orbit satellites for providing access in rural areas. The earth stations are solar-powered near a community site, e.g., a post-office and school, where content and applications are cached. Connectivity can then be extended via point-to-point or point-to-multipoint connectivity.

Concero provides a set of e-services over the system, which are free to users or available for minimal subscription fee. Concero's financial ambition is to recover the costs of the operation (terrestrial system and satellite connectivity) through share of revenues paid for financial transactions (money transfers) of subscriber.

Capex, debt service and other non-operations expense are to be covered by donation.

Attributes & Success Criteria

Attributes	**Market Structure**	**Economic Context**	**Carrier Neutrality**	**Regulatory & Policy Efficacy**	**Business Model**	**Financing & Risk-Sharing**	**Infrastructure Sharing**
	Targeting under-served areas where there is little or no alternative service	Mainly covers countries which are in the rank between low human development and medium development according to the United Nations Human Development Index	Concero is not a wholesale play	Regulatory Regime: Maturing	Market segment: last mile wireless network and retail service provider. Management: privatesector Revenue: various -revenue share of money transfer fees; subscription and/ or funding from aid organizations	Privately funded	No infrastructure sharing. No synergies with power, transport and water utilities

Success Criteria	**Geographic Reach of Network**	**Increased Bandwidth / Volume**	**Take-up: Utilization of Network Relative to Legacy**	**Prices Relative to Legacy, Affordability**	**Investment and Unit Investment (per fiber km)**	**Performance to Plan**
	Solution could be used anywhere, however the focus is on communities in the remote areas	N/A	N/A	Free to user, small fee added to money transfer transaction fee	Unknown – also varies according to the needs of the community	N/A

Lessons Learned

- Business model is "opportunistic" in the sense that revenue and funding depends on the sponsors and community involved
- Costs contained by limiting service and content availability. Content is locally cached and broadcast to local servers only periodically
- Low cost technology and low-levels of subsidy can bring service to unserved communities

Cross Border | National Backbone | **Middle/Last Mile**

CSquared

High-quality broadband metro access to Africa

URL: http://www.csquared.com/

Narrative

HQ: Nairobi, Kenya

Following initiative from Google's Project Link, CSquared is building wholesale-only carrier-neutral and open-access fiber networks in Uganda and Ghana and recently announced entry into Liberia.

Build out:
1 of 3 metro areas (central Accra) to be deployed in Ghana
1 of 2 metro areas (central Kampala) being served in Uganda.

Picking opportunities where link between mobile and ISP networks and subsea cables are weak.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
CSquared is serving mobile operators and ISPs in competitive markets in Ghana, Uganda and soon in Liberia. Fixed networks in these countries are underdeveloped or non-existent	The network mainly covers countries that rank between low and medium in UN Development Index	Carrier neutral, wholesale fiber and last-mile Wi-Fi access to all ISPs and MNOs	Regulatory Regime: Maturing	Market Segment: wholesale open access metro fiber Management: private sector owned and operated Revenue: traditional	Total investment by the partners in new markets is around $100 million	Shared wholesale network. No synergies with power, transport and water utilities

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
CSquared has built more than 800 km of fiber in Kampala and Entebbe, Uganda; and more than 840 km (out of 1000 km expected) of fiber in the Ghanaian cities of Accra, Tema, and Kumasi	N/A	In both Ghana and Uganda, more than 25 ISPs and Mobile Network Operators (MNOs) now use these metro fiber networks to offer broadband services and 4G data to end users	Lower prices than competition. Flat pricing with connection costs	Chorus and other local fiber companies have received over half billion USD each year since 2012/13	Plans not made public, but plans to use these markets as launching pad for more markets in Sub-Saharan African markets. Effectiveness in deployment is expected to benefit from participation of IFC, Convergence Partners and Mitsui

Lessons Learned

- Private sector was able to make use of opening of markets to expand to meet demand of retail service providers
- Filling a gap in metro network, shared networks – avoids duplicating network
- May not be replicable model outside urban areas without some state support

Cross Border | National Backbone | **Middle/Last Mile**

Cyphy Works

Military spinoff adapted for civilian use

URL: https://www.cyphyworks.com/

Narrative

HQ: Danvers, MA, U.S.

Cyphy Works is a Massachusetts-based company that specializes in the development of drone technologies.

The Cyphy Persistence Aerial Reconnaissance and Communications platform (PARC) is a tethered drone that hovers at up to 400 ft though this is expected to increase as regulation relaxes. The tether carries power and connectivity to the drone which is equipped with a 4G LTE antennae. Each device can hover at up to 1000 ft and provide a coverage area of around half a square mile and can be linked to other drones as repeaters to provide larger coverage footprints.

To date the Cyphy PARC drones have been used in military applications including reconnaissance and providing secure communications. The commercial telecommunications applications of the technology are being explored now and are being built using the technology to provide coverage or capacity for short periods of time – a few hours to a few days.

Most likely application substitute for Cell on Wheels, or emergency deployments before service restored.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	Global last mile access product spanning a range of markets across various countries	U.S. HDI puts it as 10 out of 188 countries and territories. It has a GNI per capita of 53,245 in PPP USD	Cyphy is unlikely to be wholesale play	Regulatory Regime: may operate in a variety of regulatory environments. Must contend with aviation as well as telecommunications regulations	Market segment: most likely to be leased to retail service providers for niche last mile access situations. Management: Privately owned business. Revenue: TBD	In expanding its product offering the company has raised an additional $7 million of funding from number of venture capital companies including Motorola Solutions and United Parcel Service	No synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	CyPhy provides their solution globally	Only recently commercially launched	Only recently commercially launched	For last mile temporary coverage much cheaper than other current solutions	Only recently commercially launched	Only recently commercially launched

Lessons Learned

- Business model is a work-in-progress
- Can be applied in most geographies and topologies; advantageous line-of-sight and coverage characteristics
- Quick assembly and launch
- Limited period of uninterrupted coverage: measured in days and weeks
- Limited bandwidth

Cross Border | National Backbone | **Middle/Last Mile**

EE Helikite

Short-term solution that can be used to add capacity or replace downed network

URL: https://www.ft.com/content/9c16b23c-f80f-11e6-9516-2d969e0d3b65

Narrative

HQ: London, United Kingdom

EE, a mobile operator owned by British Telecom, announced the Helikite drone in 2017 to fill in wireless coverage holes when its 4G network goes down or needs more capacity. The drones are developed to cover rural areas where it has been difficult to build traditional mobile network infrastructure.

The balloons hover at 150 feet and can provide coverage over a 4 km wide area. The balloons rely on a satellite signal powered by Avanti.

The initial idea behind the Helikite was providing permanent coverage in rural areas; however, regulatory challenges may prolong it. Currently, EE expects that the aerostat helikites would be used for areas that need an urgent capacity boost or for search and rescue missions.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
The mobile market in the U.K. has four major network operators that account for around 80% of the market. MVNOs, most notably Virgin, account for the rest	U.K. HDI puts it as 16 out of 188 countries and territories. It has a GNI per capita of 37,931 in PPP USD	EE Helikite is not a wholesale play	Regulatory Regime: Mature	Market Segment: EE will offer retail services through its last mile Helikite connectivity. Management: EE is a subsidiary of British telecom. Revenue: as Helikite is a replacement solution to existing infrastructure unlikely to impact the traditional means by which EE earns revenue	Privately financed	No synergies with power, transport and water utilities

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Function of the three applications for which Helikite if foreseen: 1) coverage in emergency situations where the regular infrastructure has been negatively impacted through disasters or similar; 2) coverage to remote areas that only require coverage on a sporadic basis, for example festivals, some sporting events and so forth; and 3) capacity for events where the regular networks are overloaded, e.g. major sporting matches or concerts.	Only being trialed at this stage	Only being trialed at this stage	Only being trialed at this stage	Only being trialed at this stage	Only being trialed at this stage

Lessons Learned

- Can be applied in most geographies and topologies; advantageous line-of-sight and coverage characteristics
- Quick assembly and launch
- Limited period of uninterrupted coverage: up to three months
- Limited bandwidth

Cross Border | National Backbone | **Middle/Last Mile**

Endaga

Open-source "community cellular network" undergoing testing phase

URL: http://endaga.com

Narrative

HQ: Berkeley, CA, USA

Endaga is not a service provider per se, but rather supplies equipment to enable the roll out of service provision in communities cut off from cellular connectivity, road and grid access. Endaga was launched out of University of California at Berkeley's Technology and Infrastructure for Emerging Regions research group in 2014. The group built a micro-station, a small box (called CCN1 – named for "community cellular network."), which could be attached to a tree or structure in a remote village.

The box uses OpenBTS, an open-source application that substitutes Internet Protocol and a software radio for telecom cellular protocols and hardware. CCN1 communicates with cell phones in the field using standard cell stacks and frequencies, it converts the signals to Voice over Internet Protocol (VoIP).

The service provider must arrange for backhaul via a satellite link or long-distance Wi-Fi.

The box runs on dedicated 2G frequencies to provide coverage in the surrounding area.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	A solution for rural communities where no coverage is present. Locally-owned, small-scale, independent cellular networks, run by and for rural communities	N/A	The solution is not designed for carrier neutrality as only one operator of the network is feasible	Rolled out in areas where regulatory regimes are maturing	Market segment: Endaga enables a last mile network and retail service provision. Management: privately owned and operated. Revenue: payment for Endaga's software and hardware came out of user revenue	Endaga was founded receiving funding (US$1.2 million) from local venture capitalists (VCs) and angel investors from the San Francisco Bay Area	It reuses the village infrastructure including the existing power and any existing network backhaul

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	Rural environments where mobile operators struggle to provide affordable network coverage	N/A	High as no other alternative is possible. Also, mobile phones are generally affordable to a large segment of the 1 billion non-connected population	Enables affordable due to low cost of set-up and operation. Local operators set their own tariffs	The cost of cell equipment has plummeted and what used to cost $100,000 to build a base station is $5,000-$10,000 today	N/A

Lessons Learned

- Endaga solution is well suited for unserved areas or disaster hit zones and any other environment that requires quick and easy coverage set-up
- Frequencies used are often already allocated to other service providers, thus making Endaga in theory an illegal service
- Negotiating the business model with mobile operators proved challenging, and described as the most problematic aspect of the model
- Low cost technology and low-levels of subsidy can bring service to unserved communities

Cross Border | National Backbone | **Middle/Last Mile**

EstWin

An example of a successful collaboration between government institutions

URL: https://www.elasa.ee/

Narrative

HQ: Tallinn, Estonia

EstWin is a fiber Middle Mile project established in Estonia in 2009 with the aim of reaching rural communities that were marked as "white areas" under EU broadband availability categorization. These are rural areas where there was no optical network available at the time of the evaluation nor the network was to be available in foreseeable future based on normal commercial investment terms by the local operators. The network aims to bring fiber within 1.5 km distance to 98% of all residential buildings, companies, and public authorities.

The project is run by a consortium of private companies the Estonian Broadband Development Foundation (ELASA) on whose board sits a representative of the Ministry of Economic Affairs and Communications. The founding members of ELASA are Elion, Elisa, Eltel, EMT, Ericsson, Levira, Televõrgu and Tele2 – representing the biggest telecom operators in the country. EstWin is funded inter alia from European Structural and Investment Funds (ESIF). EstWin is a non-profit organization with transparent and published financial information, providing equal access to its passive fiber infrastructure to all licensed service providers.

ELASA was criticized by the Competition Authority for skewing development in a manner favorable to existing service provider networks.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
In 2013 there were over 200 operators offering electronic communications services, including three vertically integrated MNOs. EstWin, however, is targeting white areas	Estonia's HDI puts it at 30 out of 188 countries and territories. It has a GNI per capita of 26,362 in PPP USD	EstWin offers fiber wholesale to all ISPs	Regulatory Regime: Mature	Market segment: Open access passive fiber infrastructure Management: governance is a PPP structure with a consortium of existing service providers as well as Ministry of Economic Affairs and Communications. Construction and maintenance carried out by private sector Revenue: traditional lease arrangements	Estimated €70 million by end of implementation. Share of public funding is 85% versus private funding of 15%	Multiple fiber architecture where at least 5 operators can provide their services in parallel. There have been also projects reported to facilitate civil works synergies

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Rural areas in Estonia, to eliminate digital divide between cities and rural areas. The network will comprise 5,825 km of fiber and 2,308 total network connections including 566 local government buildings coverage	N/A	N/A	The cheapest price for fixed broadband (standalone offer, 12-30 Mbps or above) in Estonia is €14.04, compared to the EU average of €21.33. Dark fiber price is USD/km/month including VAT	As of 2017 the ELASA web site reports total cost of €66 million out of which €57 million is received EU support and €9 million is the self-financing element	Close to 4100 km of middle mile optical network has been built, with more than 1,400 access points in network nodes (out of targeted almost 6,000 km and 1,400 connection points by 2018)

Lessons Learned

- Example of private consortium model applied to middle mile project
- Outsourced operation of network to a single entity appears to work well
- However, governance issues have arisen with respect to construction:
  - Delays in initial roll out: 2015 targets were not met on time, disputes have arising over some use of remaining funds
  - The competition authority has raised a question of whether governance of project with such a scale of state funding should be more closely supervised by state
- Possible example of incumbent operators using development fund more in their interest than of the market overall

Cross Border | National Backbone | **Middle/Last Mile**

Even Telecom

Construction company serving the telecommunications industry in Mexico

URL: http://www.eventelecom.com.mx/

Narrative

HQ: Monterrey, Mexico

Even Telecom S.A. de C.V. offers turnkey solutions for telecommunications networks and maintenance of fixed and mobile telephony infrastructure. Headquartered in Monterrey, Mexico, Even Telecom was founded in 2013 as an integrated operator of telecommunications infrastructure. The group offers a portfolio of diversified services including tower and fiber construction, installation, operation and maintenance.

Even Telecom builds and operates telecom towers, deploys fiber optics and renders maintenance and other services to carriers and tower operators. This includes the acquisition of land, management of the permitting process, site audits, and the dismantling and disposal of obsolete infrastructure in addition to the construction, servicing, and maintenance of towers, fiber, Distributed Antenna Systems (DAS), Outdoor DAS, small cells, and other telecommunications equipment and infrastructure.

Current clients include all main Mexican operators and carriers.

Attributes & Success Criteria

Attributes	**Market Structure**	**Economic Context**	**Carrier Neutrality**	**Regulatory & Policy Efficacy**	**Business Model**	**Financing & Risk-Sharing**	**Infrastructure Sharing**
	Even Telecom is divided into four different companies: Even Telecom (in charge of construction); Neutral Networks (manages the assets); NH Solutions (JV for IDAS & ODAS) and Dicotel (construction and operation of towers in Rural Areas)	Mexico's HDI puts it as 77 out of 188 countries and territories. Gross national income (GNI) per capita (2011 PPP$) is 16,383 USD	Even Telecom offers their solution to any operator that requires infrastructure in Mexico	Regime: Mature	Market Segment: Passive and Active Mobile infrastructure Management: Privately owned and operated Revenue: payment schemes depend on how clients want to pay: "Both Opex and Capex models are offered"	Financing comes from a variety of sources, including investments from private equity funds, such as Southern Cross Group	Even Telecom develops and acquires shareable infrastructure such as towers, fiber, and indoor DAS
Success Criteria	**Geographic Reach of Network**	**Increased Bandwidth / Volume**	**Take-up: Utilization of Network Relative to Legacy**	**Prices Relative to Legacy, Affordability**		**Investment and Unit Investment (per fiber km)**	**Performance to Plan**
	Even Telecom is focused on the Mexican market and offers operators access to infrastructure. Main clients include carriers and wholesale networks	N/A	N/A	N/A		N/A	N/A

Lessons Learned

- Service providers have found it cost effective to outsource many aspects of infrastructure deployment and operation
- Standard TowerCo model of building and leasing space on passive mobile infrastructure can be improved upon – up and down the value chain:
  - Up, e.g., acquisition of land and management of permitting
  - Down, e.g., full turnkey infrastructure solutions

Cross Border | National Backbone | **Middle/Last Mile**

Fairwaves

Open-source solution for mobile operators in low-income areas

URL: https://fairwaves.co/

Narrative

HQ: London, United Kingdom

Fairwaves was founded in 2011. It manufactures and provides equipment required to build mobile networks. The equipment to build all the functions of a mobile network are integrated into a single, self-contained cellular base station powered from off-grid energy sources such as solar. Scaling and integration with operator networks is made possible via local and cloud-based UmCORE servers.

The solution is tailored mainly for small mobile operators in low-income areas. Fairwaves claims that their solution requires 5-times less investment than building a traditional mobile network in addition to shorter deployment time.

The Fairwaves approach significantly reduces the financial and technical barriers to deploying cellular networks, while ensuring that during their operation backhaul costs are minimized thanks to local call routing and use of effective voice compression algorithms.

Fairwaves claims to provide everything needed to build a mobile network which would be profitable even at $2/month revenue per user and that it can scale to a national network.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
A solution for rural communities where no coverage is present. Locally-owned, small-scale, independent cellular networks, run by and for rural communities	Fairwaves targets low-medium HDI countries	The solution is not designed for carrier neutrality as only one operator of the network is feasible	No specific regulatory or policy developments that apply specifically to the organization. However, the organization is subject to the domestic policies and regulatory frameworks where it operates	Fairwaves enables a last mile network and retail service provision. Management: privately owned and operated. Revenue: Fairwaves sells their hardware to local mobile operators. Their business model might also include revenue share, however it is not publicly reported	Fairwaves seeks funding through crowdfunding campaign and have already received funding from multiple investors in exchange for share of capital	Solar energy where applicable

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Fairwaves is currently active through partnerships in Mexico, Palau and Mayotte	N/A	N/A	airwaves solution is very affordable and allows mobile operators to be profitable even with ARPU of $2. Effectively mobile operators can then offer lower rates to end-users	N/A	N/A

Lessons Learned

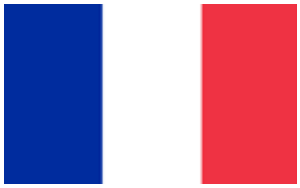
- Technology is still in something of a pilot stage, not clear how successful it will be
- Technology provided by telecom vendors such as Fairwaves can significantly reduce the network build-out costs for mobile operators
- Low cost technology and crowdfunding may bring service to unserved communities

Cross Border | National Backbone | **Middle/Last Mile**

Axione Limousin

Broadband connectivity for the Limousin Region in France

URL: http://www.axione-limousin.fr



Narrative

HQ: Limoges, France

The Limousin is a very rural region of France, where the search for adequate broadband connectivity began as early as 1996. Not content with the options available from the incumbent or new entrants, the regional authorities ultimately formed a public consortium called DORSAL to define the scope and scale of the deployment, secure the appropriate financing and arrange for overall project management for deployment.

In a first phase, after securing €204 million in financing, a 24- year concession was awarded by competitive tender to a local ICT company called Axione Limousin in 2005. Through this concession, Axione was mandated to design, build and operate a broadband core and middle mile wholesale network, available to all French service providers on a non-discriminatory basis. This deployment was referred to as the first-generation network.

In parallel, another consortium, the SPL Aquitaine, was created and given the mandate to design and build public fiber access networks, which were then transferred through concession to Axione, to commercialize and operate. This was then referred to as the second-generation network. One key success factor of the project was the harmonization between the first and second-generation networks.

The region has also encouraged private investment and allows service providers to deploy their own infrastructure in the most populated areas of the region.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	There are number of broadband providers in France. However, this project only targets a specific rural region of France	France's HDI puts it at 21 out of 188 countries and territories. Gross national income (GNI) per capita (2011 PPP$) is 38,085 USD	Wholesale broadband network offered to all ISPs.	Regulatory Regime: Mature	Market Segment: active and passive wholesale infrastructure services on an open access basis Management: private DBO concessioned off to private sector Revenue: traditional supplemented by state capex subsidy	The network is financed by the state budget and EU funds	Shared access network. No significant synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	Backbone network of 1200 km, covering 269 villages in the Limousin Region (rural area)	N/A	N/A	N/A	150,000 homes and offices for a total cost of €280 million. An average cost per connection reaching €1,900. The overall project, including both phases, is expected to reach €800 million	150,000 homes and offices connected

Lessons Learned

- Smooth harmonization between the implementation of "first-generation" and "second-generation" network was key to the project's success
- Offering wholesale broadband network on "non-discriminatory" basis to all ISPs increases competition and provides better pricing for customers
- Leveraging state and regional funds was crucial in securing financing for CAPEX of the backhaul
- More creative revenue generation must be undertaken: may include: down payments, predominant government contracting and subsidy

Cross Border | National Backbone | **Middle/Last Mile**

Länder projects, Germany

Federal program financing "profitability" and "investment" gaps

URL: N/A

Narrative

HQ: N/A

In 2008 Germany initiated its first broadband subsidy schemes to foster the provision of broadband services in underserved areas.

Universal service-type subsidy scheme implemented by the Federal Government of Germany and distributed to the Länder (States) and municipalities.

Funding was directed at developing wholesale open access networks delivering at minimum 1 Mbps service to premises.

Limited total amount per project to half a million euros, but could be complemented with EU funds.

Allocation process was as follows: 1) municipality drafts tender describing the network required; and 2) selection among bids specifying "profitability gap" to be met by subsidy.

Operators are not restricted to wholesale only play, but if not, must offer terms to competitors to allow them to replicate retail offers.

In subsequent years more funding was added to such subsidy schemes and the speed requirements were raised.

Attributes & Success Criteria

Attributes	**Market Structure**	**Economic Context**	**Carrier Neutrality**	**Regulatory & Policy Efficacy**	**Business Model**	**Financing & Risk-Sharing**	**Infrastructure Sharing**
	Number of ISPs with Deutsche Telecom having 40% market share nationally (based on subscribers), but the number of independent local fixed operators has increased significantly	Germany's HDI puts it at 4 out of 188 countries and territories. It has a GNI per capita of 45,000 in PPP USD	The selected operator was obliged to provide wholesale access to the subsidized infrastructure to all operators	Regulatory Regime: Mature	Market segment: vertically integrated or wholesale only open access Management: networks are privately owned and operated Revenue: standard sources complemented by subsidy	Private equity and debt complemented by funds to cover the "profitability gap"	Municipality utilities have been very active in this space. Some of these cases also benefit from the use of ducts infrastructure constructed by the municipality

Success Criteria	**Geographic Reach of Network**	**Increased Bandwidth / Volume**	**Take-up: Utilization of Network Relative to Legacy**	**Prices Relative to Legacy, Affordability**	**Investment and Unit Investment (per fiber km)**	**Performance to Plan**
	Focused on the areas in Germany that have missing or insufficient Internet offer in rural areas	N/A	N/A	N/A	The annual budget was estimated as €47 million for 2008-2010. Total aid budget was around €141 million	N/A

Lessons Learned

- Most effectively administered through competitive tender or as fixed figure. Ongoing subsidy may incentivize sub-optimal behavior
- Government financing can incentivize private operators to deploy services in rural areas if "profitability" or "investment" gaps are covered
- Program has been a boon to cross-sectoral infrastructure sharing. The number of municipal utilities (Stadtwerke) and of their spin-off subsidiary companies, that provide telecommunications services is reported to have grown steadily over the last several years, either solely as wholesale facilities and service providers to telecoms service providers or as vertically integrated retail service providers.

Cross Border | National Backbone | **Middle/Last Mile**

iProvo – North America

A short-lived community attempt to provide wholesale broadband services

URL: https://fiber.google.com/cities/provo/

Narrative

HQ: Mountain View, CA, USA

iProvo was set up in 2004 as a fiber optic network under the administration of the Telecommunications Division of Provo City's Energy Department. Funded by a bond issue of $39.5million, the wholesale FTTH network was planned to be completed by 2006 and cash flow positive by 2008.

It has struggle to meet its financial objectives. In the first year it attracted only one retail partner, HomeNet Communications, which was not able to attract enough customers and went bankrupt. Other retail partners were not able to offer sizable discounts over competitors.

Although largely completed on time, in 2006 and 2007, iProvo was still posting losses and requiring loans from the city.

In 2008, Provo sold the network to Broadweave Networks, for $40 million. Broadweave was then acquired by Veracity Networks who ended up pulling out of the deal.

In 2014 it was announced that iProvo was being sold to Google for a dollar. At the same time, the city of Provo still oweds the debt for a $39 million bond that was used to funding iProvo's construction.

Attributes & Success Criteria

Attributes	**Market Structure**	**Economic Context**	**Carrier Neutrality**	**Regulatory & Policy Efficacy**	**Business Model**	**Financing & Risk-Sharing**	**Infrastructure Sharing**
	There are several companies in Provo, Utah offering fiber optic network	USA's HDI puts it as 10 out of 188 countries and territories. It has a GNI per capita of 53,245 in PPP USD	Wholesale open access model	Regulatory Regime: Mature	The broadband network was offered wholesale for all ISPs operating in the area. Management: Design and build out-sourced to private sector, but operation remained in city hands	Financing came from a city revenue bond, complemented by smaller loans from the city	No synergies with power, transport and water utilities

Success Criteria	**Geographic Reach of Network**	**Increased Bandwidth / Volume**	**Take-up: Utilization of Network Relative to Legacy**	**Prices Relative to Legacy, Affordability**	**Investment and Unit Investment (per fiber km)**	**Performance to Plan**
	32,000 homes passed in Provo, Utah, USA	After acquisition of iProvo by Google, the speeds up to 1Gbps are offered	At its peak subscriptions were at 11,000, but churn was high	Expensive	USD 39million for entire municipal fiber network	Completed on time within 2 years in 2006 and constructed within budget. But financially a failure, because of inadequate revenues.

Lessons Learned

- Design and build aspect successful (carried out by private sector), over business case was overly optimistic
- There is evidence that iProvo was run too much like a civil service, rather than a commercial enterprise
- Although a business failure as a municipal network, iProvo has a chance to be reborn on a sounder financial basis with privatization

Cross Border | National Backbone | **Middle/Last Mile**

Project Isizwe

Free Wi-Fi for low-income communities across South Africa

URL: http://www.projectisizwe.org/

Narrative

HQ: Pretoria, South Africa

Project Isizwe is a South African based non-profit Wi-Fi service provider, established in 2013, which aims to bring free Wi-Fi connectivity to public spaces in low income communities across South Africa.

Isizwe works with municipalities, who pay a set fee for the service for a fixed period of time, including all bandwidth and maintenance. The municipalities also provide mounting assets, power, and backhaul for the deployments. Project Isizwe's non-profit structure helps keep costs down given that there is no markup in the price of services. Isizwe also works to utilize local installers and ensure that maintenance is performed with local workers.

Project Isizwe has partnered with telecommunications company Hero Telecoms to provide the hardware, installation, support and maintenance for all sites at prices lower than retail, and Neotel has provided additional bandwidth at no cost as part of their Corporate Social Responsibility program.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	Isizwe targets emerging (white and grey) markets. It indirectly competes with other Wi-Fi service providers	South Africa's HDI puts it at 119 out of 188 countries and territories. It has a GNI per capita of 12,087 in PPP USD	Project Isizwe is not a wholesale play	Project Isizwe partners with public entities, and as such must follow standard procurement processes. The actual Wi-Fi service operates in unlicensed bands	Market Segment: last mile network and retail service providers. Management: privately owned and operated. Revenue: Government subsidy	Funded through partnerships with local and municipal governments	No synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	1076 Free Internet Zones in South Africa	N/A	3.8 million unique users	Each user is allocated 500 MB per day (15 GB per month) free, at download speeds of 15 Mbps. On net content is provided with unlimited access	Cost of a typical municipal deployment (capacity for 150,000 devices for 12 months) is about R 3 million ($240 thousand)	Isizwe currently has six live projects, three pilot projects, and four planned projects across South Africa

Lessons Learned

- Low cost technology and low-levels of subsidy can bring service to underserved communities.
- Business model used by Project Isizwe involves free service to end user and instead relies on government subsidy; Not clear how the approach might be made commercially viable; Funding is clearly a barrier to expansion.

Cross Border | National Backbone | **Middle/Last Mile**

Kalo

Mobile satellite internet service enabled by innovative antenna

URL: https://www.kymetacorp.com/kymeta-products/#kalo

HQ: DC U.S. and Luxembourg

Narrative

Kalo is a satellite broadband data service announced in early 2017 as a collaboration between Kymeta antenna venture and the satellite operator Intelsat. Kalo's service is tailored for moving objects such as cars and boats due to its innovative antenna design that allows high speed satellite communications on the move.

The company has received a total investment of nearly $260 million across five disclosed funding rounds with $73.5 million announced in 2017 and $62 million announced in 2016. Investors are high profile private funds including Bill Gates, Lux Capital and Liberty Global.

The service is marketed as bringing connectivity to buses, trains, ships, mobile emergency-response teams, remote construction sites and rural areas. The company takes advantage of metamaterials, specially constructed electronic matrices that can bend electromagnetic waves to pick up satellite signals coming from any direction. In addition the mTenna technology uses software to electronically point and steer toward a satellite; this means the terminal will auto-commission and auto-provision, allowing for rapid setup and installation.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
As a global product it is not aimed at particular territory. It competes with various other satellite broadband offerings	N/A	The solution is not designed for carrier neutrality	Not clear how the terminal will be sold in various countries, therefore the regulatory aspects are also unknown. Initial trials were conducted in the United States	Market segment: last-mile niche connectivity to service providers Private company Management: privately owned and operated. Revenue: selling satellite ground terminals in collaboration with satellite connectivity provider (at present Intelsat)	Received a total investment of nearly $260 million across five disclosed funding rounds. Investors are high profile private funds including Bill Gates, and Lux Capital	No synergies with power, transport and water utilities

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Available globally	N/A	N/A	Not mass market rural connectivity product. Not affordable for normal households. Current price is $25k for antenna with monthly charges from $29 for 1 Gb to $899 for 80 Gb of data	N/A	N/A

Lessons Learned

- Business model still somewhat of a work-in-progress
- Current products are more aimed at the vertical sectors and not affordable for a typical rural direct-to-household broadband connectivity. A possibility is to use this as a backhaul solution combined with Wi-Fi or other wireless downstream connectivity
- Good speeds can be achieved when clear shot is available to Intelsat's satellites but when signal is blocked by buildings and trees the speeds are much lower or the signal is lost. Therefore independent customer tests are required to verify any real conditions performance

Cross Border | National Backbone | **Middle/Last Mile**

LeoSAT

Low-earth-orbit satellite constellation as a B2B service

URL: http://leosat.com/

Narrative

HQ: Washington, DC, U.S.

LeoSat Enterprises was established in 2013 in Washington, DC, as a satellite constellation project with an aim to develop a new low-earth-orbit (LEO) satellite constellation providing a global, enterprise grade, high-speed and secure data network.

LeoSat is currently working with Thales Alenia Space to manufacture and launch a constellation of up to 108 Ka-band communications satellites. The high-throughput satellites (HTS) will be interconnected through laser links, effectively creating an optical backbone in space which is about 1.5 times faster than terrestrial fiber backbones. Once operational, the constellation will provide a highly secure communications infrastructure for business operations in the telecom backhaul, energy, maritime, government and international business markets.

It plans to provide wholesale services to regional service providers that have large installed base in large geographic areas and services companies specialized in certain markets.

The total estimated cost of the project is $3.5 to $3.6 billion. So far LeoSat has undergone a few investment rounds, however the total funding is unknown. LeoSat aims to start operations in 2019, claiming to be the first commercially available project of such scope, with full worldwide service by 2021.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	As a global product it is not aimed at particular territory. It competes with various other satellite broadband offerings	N/A	LeoSat will offer wholesale services to service providers and services companies specialized in certain markets	Likely to rely on local service providers to ensure compliance with most local regulation, but will require own licensing and spectrum allocations as well	Market segment: Wholesale to distributors and value-added resellers (VARs) for them to resell LeoSat services to their customers. Management: privately owned and operated. Revenue: not clear, may follow standard satellite pricing approach	LeoSat was targeting $100 million in Phase A funding in 2016 and $175 million in 2017. One of the confirmed investors is SKY Perfect JSAT Group, however the investment amount is unknown	No synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	Available globally	N/A	N/A	N/A	The total estimated cost of the project is $3.5 to $3.6 billion	Said to be "on-track". Project started in Oct 2016 and planned to be completed in 2021. Until now, LeoSAT has attracted investment and secured few partnerships

Lessons Learned

- Business model still a work in progress
- Satellite over-crowding and satellite debris/decommissioning might be issue going forward - OneWeb has raised debates about interference with existing deployed satellites and creating more space debris. This is expected to be an issue once more satellite providers deploy their satellites, however it is not yet known what might be the consequences

Cross Border | National Backbone | **Middle/Last Mile**

LeverettNet

Fiber-optic-To-The-Home broadband network owned by the town of Leverett

URL: https://broadband.masstech.org/building-networks/last-mile/program-unserved-towns/leverettnet

Narrative

HQ: Leverett, MA, USA

In May 2011, the Leverett Select Board submitted an application to the state of Massachusetts for a grant to support broadband planning and deployment in Leverett. Massachusetts has set aside it own funds and oversaw federal monies as well for broadband deployment.

LeverettNet is a Fiber-optic-To-The-Home (FTTH) broadband network owned by the Town of Leverett, Massachusetts. LeverettNet is operated under the telecom authority of the Leverett Municipal Light Plant (LMLP), which contracts with third parties for network construction, internet services provision, and maintenance functions. Service provider pays LMLP a fee out of subscriber revenue to defray network O&M costs.

LeverettNet provides symmetrical (equal upload and download) 1-Gigabit-per-second (1 Gbps) Active Ethernet (dedicated fiber links) connectivity between each subscriber location and the Internet Point of Presence. LeverettNet connects from the Point of Presence to the Internet Service Provider (ISP) at 2-Gigabits-per-second (2 Gbps), via the Massachusetts Broadband Institute "middle mile" network, a project of the Massachusetts Technology Collaborative.

Attributes & Success Criteria

Attributes	**Market Structure**	**Economic Context**	**Carrier Neutrality**	**Regulatory & Policy Efficacy**	**Business Model**	**Financing & Risk-Sharing**	**Infrastructure Sharing**
	LeverettNet is a broadband service brought by Massachusetts Broadband Institute to all residents in Massachusetts and it does not have direct market competition	U.S. HDI puts it at 10 out of 188 countries and territories. It has a GNI per capita of 53,245 in PPP USD	LeverettNet provides the access to its network only to Otelco	Regulatory Regime: Mature	Market Segment: vertically integrated last-mile network and service provision. Management: DBO outsourced to different private entities with oversight provided by Leverett Municipal Light Plant (LMLP) Revenue: traditional telephone, TV and internet pricing, but prices are regulated by MLP	Capex financed through mostly general obligation bond; state provided a subsidy for network design and part of build cost; subscriber revenue covers O&M and depreciation	Synergies with overhead infrastructure of Power Utility and incumbent telco

Success Criteria	**Geographic Reach of Network**	**Increased Bandwidth / Volume**	**Take-up: Utilization of Network Relative to Legacy**	**Prices Relative to Legacy, Affordability**	**Investment and Unit Investment (per fiber km)**	**Performance to Plan**
	Town of Leverett, Massachusetts, United States	Speeds up to 1 Gbps	Around 700 subscribers, which is a very high percentage of Leverett households	Very affordable with 1 Gbps prices one of the cheapest in the U.S. at $74/month (including LMLP charge for network operator and maintenance of $50.5/month)	$3.7 million for the city-wide network coverage	Construction started in 2013 and was completed in 2015 in line with the plan

Lessons Learned

- Small rural community of no interest to large incumbents was able to organize PPP vehicle for deployment
- Lower return expectations overcome by government subsidy
- Diversified risk across a number of private actors

Cross Border | National Backbone | **Middle/Last Mile**

Microsoft Airband

Connecting rural areas through TV white space and other technologies

URL: https://www.microsoft.com/en-us/affordable-access-initiative/default.aspx

Narrative

HQ: Washington, DC, U.S.

The Microsoft Airband Initiative was launched in 2017 as a partnership-based program that aims to connect rural areas in the United States and around the world, focusing mostly on the use of TV white spaces. The project involves both commercial partnerships and grants to early-stage Internet access and energy access start-ups.

Microsoft's strategy involves investing upfront capital needed for projects to expand broadband coverage, and then seeking a revenue share from operators to recoup the investment. The initiative also involves digital skills training and technology licensing; Microsoft aims to stimulate market investments to reach underserved communities through royalty free access to patents and source code to help enable connectivity in rural areas.

Microsoft does note that ultimately a mix of technologies will offer the most cost effective solutions for connecting rural populations around the world, however, the Airband Initiative focuses on the use of TV white spaces (TVWS), which Microsoft identifies as the best approach for reaching the majority of underserved populations in the United States.

Microsoft is working to preserve this spectrum for rural applications.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Microsoft Airband targets white markets by partnering with local operators	Microsoft Airband targets low-medium HDI countries as well as rural areas in more developed countries, such as the United States	The solution is not designed for carrier neutrality, but rather for a single service provider	Varies by jurisdiction. Long term use of TVWS can be uncertain in countries undergoing the transition to digital television	Market Segment: does not directly provide telecommunications services, instead partnering with operators to help expand services. Management: deploying and operating local network may be a private company or community Revenue: ultimately may seek revenue share from internet operators to recover costs	Airband initiative is funded by Microsoft	Microsoft partners with companies seeking to provide electricity connectivity in rural areas as a precursor to Internet connectivity

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Airband is currently active through partnerships in U.S., South America, Africa and Asia	N/A	The Airband Initiative is designed to provide connectivity in areas where alternative options are not currently available	Varies by Project	Using a mix of technologies (mainly TVWS) Microsoft believes it can reduce the cost of connecting rural populations by 50-80% compared to only fixed wireless or an only fiber approach	Microsoft previously deployed more than 20 TVWS projects worldwide serving 185,000 users and launched the Airband initiative with the goal of setting up 12 new projects within one year. The goal of the Airband Initiative is to connect 2 million people in rural America by 2022. In addition to rural areas in the United States, Microsoft supports projects across South America, Africa, Asia, and in the United Kingdom

Lessons Learned

- Low cost technology and low-levels of subsidy can bring service to underserved communities
- Success dependent on resolution of spectrum controversy surrounding proposals to re-farm TVWS spectrum in view of:
  - The move to digital TV (and indeed IPTV) means that less spectrum needs to be reserved for TV broadcasting
  - The drive by Mobile Network Operators and vendors proposing to re-allocate this spectrum for mobile services

Cross Border | National Backbone | **Middle/Last Mile**

O3b Networks

Middle-earth-orbit satellite service for operators in remote and low-income areas

URL: https://www.ses.com/networks/

Narrative

HQ: Luxembourg

O3b (short for "Other 3 Billion") was set up in 2007 as a satellite constellation project that aims to provide Internet access to remote and low-income areas.

The technology is based on deploying Middle Earth Orbit (MEO) satellites operating in Ka-band and using steerable spot beams to deliver connectivity to target customers. The satellite-earth gateway connectivity is delivered by number of earth based installation and the satellites feature handover functionality.

The constellation currently has 16 satellites in orbit, but due to some problems only nine are used operationally. Eight more satellites are to be launched in 2018 and 2019. Seven next generation Boeing mPower satellites are planned to be deployed in 2021.

The proposition is not currently (nor is planned in the future) aimed at individual households (unlike OneWeb) but more as a backhaul solution that needs last mile access to deliver the service to the end users. The last mile solution ranges from wireless access (such as Wi-Fi) installations, to mobile cells to Google's balloons.

Since the set-up, O3b Networks has raised an estimated $1.7 billion and has been acquired by SES, a world-leading satellite operator with over 50 satellites in Geostationary Earth Orbit (GEO). The integration of the two platforms will enable software-defined routing to direct traffic between the two platforms (mPower MEO satellites and SES' GEO satellites)

Attributes & Success Criteria

Attributes	**Market Structure**	**Economic Context**	**Carrier Neutrality**	**Regulatory & Policy Efficacy**	**Business Model**	**Financing & Risk-Sharing**	**Infrastructure Sharing**
	As a global product it competes with various other satellite broadband offerings as well as submarine cable deployments to remote locations	O3b Networks targets low-medium HDI countries	O3b Networks offers wholesale service to ISPs and MNOs	N/A	Market segment: offer wholesale services to ISPs and MNOs on commercial terms Management: privately owned and operated Revenue: traditional satellite pricing	O3b has raised approximately $1.7 billion from many investors since 2007. In 2016 SES took over majority ownership of O3b Networks	No synergies with power, transport and water utilities
Success Criteria	**Geographic Reach of Network**	**Increased Bandwidth / Volume**	**Take-up: Utilization of Network Relative to Legacy**	**Prices Relative to Legacy, Affordability**		**Investment and Unit Investment (per fiber km)**	**Performance to Plan**
	Available globally. The services are provided over integrated MEO and GEO platform	N/A	N/A	N/A		N/A	Delays in launch of initial satellites (planned 2010 actual first deployment 2013)

Lessons Learned

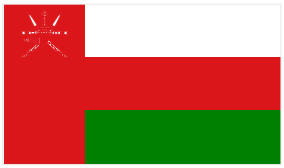
- Satellite installation deployments are prone to delays and technology glitches. O3b initial launch had suffered initial three year delay. Additionally some of the initial satellites had technical issues and needed to be put into a standby mode and replaced by other satellites after the issue was fixed (adding delays)
- Slow customer acquisition: O3b has been able to only acquire a handful of customers across the ten years of existence providing backhaul services to number of isolated communities in Nigeria, Pakistan, Cook Islands and French Guiana connectivity for some U.S. government agencies and cruise ships
- The scalability of the solution to larger number of customers once the constellation is extended and integrated with the rest of the SES network is yet to be determined

Cross Border | National Backbone | **Middle/Last Mile**

Oman Broadband

National Broadband Provider

URL: https://www.omanbroadband.om/



Narrative

HQ: Muscat, Oman

Oman Broadband Company (OBC) is the national broadband network recently created by the Sultanate of Oman.

Its remit is to install broadband infrastructure, providing equal and open access to telecommunication service providers on a wholesale basis.

One important aspect of the OBC initiative is infrastructure sharing. The first phases of the network were deployed by the waste water utility. Going forward OBC will share trenching with other utilities such as water and power companies for access network installation, but also to share fiber already provided on long haul routes for SCADA applications.

The next generation broadband infrastructure network, largely based on optical fiber, will deliver an exponentially faster and broader online experience, bringing benefits to society and the business sector with an enhanced delivery of communication services, cost savings, increased competitiveness and improved sustainability.

To date the company has installed fiber infrastructure which passes more than 200,000 homes, predominantly in Muscat, and has some 40,000 connected end-users.

Attributes & Success Criteria

Attributes	**Market Structure**	**Economic Context**	**Carrier Neutrality**	**Regulatory & Policy Efficacy**	**Business Model**	**Financing & Risk-Sharing**	**Infrastructure Sharing**
	Currently a duopoly for mobile services with Omantel and Ooredoo, and three licensed operators for fixed services, including Omantel, Ooredoo and Awasr	Oman is ranked 53rd on the HDI out of 188 countries and territories. Gross national income (GNI) per capita (2011 PPP$) is 34,402 USD.	OBC providing infrastructure on a carrier neutral basis to Omantel, Ooredoo and Awasr	Regime: mature. There is consensus on national broadband strategy and OBC's role	Market segment: Open access passive infrastructure Management: State owned and operated. Revenue: Traditional monthly pricing	100% state-owned and initially state funded. However recently financing for further expansion has been obtained from private channels	Shared access network. OBC rolling out fiber in duct laid by Haya Water, in the new sewer infrastructure. OBC has arrangements with other utilities as well

Success Criteria	**Geographic Reach of Network**	**Increased Bandwidth / Volume**	**Take-up: Utilization of Network Relative to Legacy**	**Prices Relative to Legacy, Affordability**	**Investment and Unit Investment (per fiber km)**	**Performance to Plan**
	National backbone interlinking all major centers of population with some 4000 km of fiber cable	Latest fiber services are offered at 1 Gbps, compared with previous ADSL services at about 10 Mbps	High due to lack of infrastructure competition and expected to be close to 70%	20 Mbps fibre service offered at 23 OMR per month	No over-run investment	Strong performance to date with high take-up

Lessons Learned

- The cross-sector infrastructure sharing initiative harmonizes infrastructure laying on a more cost effective basis, and in addition allows a national backbone network to be provided quickly and for minimum cost
- OBC initiative has greatly benefited from consensus on policy and OBC role
- Open access passive infrastructure model quickly demonstrated its value by allowing third entrant (Awasr) to quickly enter the market which reduced prices and more choice
- Business model may be challenged as OBC moves from being simple utility serving Muscat to providing more complex services nationwide

Cross Border | National Backbone | **Middle/Last Mile**

OneWeb

Low-earth-orbit satellite constellation for operators, households and businesses

URL: http://www.oneweb.world/

Narrative | **HQ: Arlington, VA, U.S.**

OneWeb was founded in 2012 as a satellite constellation project that aims to provide Internet connectivity globally through retail and wholesale services.

OneWeb has an initial goal to "connect every unconnected school" by 2022, and "bridge the digital divide" by 2027 by providing better and cheaper coverage for existing networks and new-found connectivity in remote areas. It is expected to start operation in 2019.

OneWeb had acquired the satellite spectrum that was formerly owned by SkyBridge and is planning to initially deploy 900 plus satellites at 1200 km altitude that will use Ku-band and Ka-band spectrum. The on-ground deployment has plan for 50 to 60 Satellite Network Portals (SNPs) beaming Internet to satellites, which provides coverage for OneWeb's operational area. To manufacture these low-cost, ultra- high performing satellites at high-volumes the company has established OneWeb Satellites as a joint venture between OneWeb and Airbus.

OneWeb will provide its retail service to households and businesses, and wholesale service to operators. OneWeb will provide wholesale services to Softbank under an off-take agreement.

Attributes & Success Criteria

Attributes	**Market Structure**	**Economic Context**	**Carrier Neutrality**	**Regulatory & Policy Efficacy**	**Business Model**	**Financing & Risk-Sharing**	**Infrastructure Sharing**
	As a global product it is not aimed at particular territory. It competes with various other satellite broadband offerings	OneWeb targets low-medium HDI countries	OneWeb will provide both retail and wholesale services on a commercial basis	OneWeb will rely on the in-country ISPs and MNOs to gain licenses from the local regulators, but will require spectrum from local regulators	Market Segment: offering both retail and wholesale services Management: privately owned and operated Revenue: traditional satellite portfolio	OneWeb has raised in total $1.7 billion. Investors include Airbus, Qualcomm, Virgin, Coca Cola and Japan's SoftBank	No synergies with power, transport and water utilities

Success Criteria	**Geographic Reach of Network**	**Increased Bandwidth / Volume**	**Take-up: Utilization of Network Relative to Legacy**	**Prices Relative to Legacy, Affordability**	**Investment and Unit Investment (per fiber km)**	**Performance to Plan**
	Available globally.	N/A	N/A	No specific information is available on intended pricing levels	N/A	Delays are expected as plans may be over-optimistic

Lessons Learned

- No lessons learned as yet as service is not launched
- Satellite over-crowding and satellite debris/decommissioning might be issue going forward. OneWeb has raised debates about interference with existing deployed satellites and creating more space debris. This is expected to be an issue once more satellite providers deploy their satellites, however it is not yet known what might be the consequences
- Trial to provide insight into the performance. Service launch in 2019 with Alaska Communications as a reseller will be the first commercial and operational trial of the technology

Cross Border | National Backbone | **Middle/Last Mile**

OpenNet/Netlink

Global pioneer delivering the fastest and most affordable broadband nationwide

URL: http://www.netlinktrust.com

Narrative

HQ: Singapore

In 2005 Singapore published its 10 year ICT plan under Intelligent Nation 2015 (IN2015) which, among other projects, called for the establishment of a single national fiber infrastructure with assets separated from the incumbent. The implementation task was given to the regulator, Infocom Development Agency (IDA) which ran an open international tender process for selection and awarding a single NetCo license for passive infrastructure and a single Opco license for active telecom operation under a 3 tier telecom framework that included the Retail Service Providers (RSPs) as a top layer that provides much of the service innovation. OpenNet won the Netco license in September 2008.

NetLink acquired OpenNet in 2013 as part of a consolidation process to acquire the fiber network – effectively Singtel buying out its four partners for a combined amount of $95 million. IDA approved the transaction with certain caveats relating to the monitoring of the operations, the role of Singtel as main subcontractor and mandating SingTel to divest the majority of its ownership in NetLink by 2018.

As per the agreement Singtel sold 75% of its shares through an IPO in July 2017 with a value at $1.7 billion, thus completing its divestment move.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	Monopoly serving an OpCo and competitive retail service providers	Singapore's HDI puts it at 5 out of 188 countries and territories. It has a GNI per capita of 78,162 in PPP USD	Open-access, providing wholesale services	Regulatory Regime: Mature	Market segment: passive fixed infrastructure. Management: publicly traded, privately owned and operated. Revenue: traditional revenue sources	Private Public Partnership (PPP) Investment with government providing $500 million grant funding and private consortium investment of circa $70 million	All consortium members contributed its infrastructure for use as part of the deal. No significant synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	Total 1.5 million residential homes passed to date (2017)	Passive Network Infrastructure, all-fiber network to the homes and businesses and capable of supporting more than 1 Gbps	88% of residential market (households) as of end of 2016 (2nd highest in the world). As of 30th September 2017 the company reported 1.5 million home passed and 1.1 million home connected across Singapore confirming the strong business case fundamentals of the NetCo business	Singapore was the first country to offer 1 Gbps on a nationwide basis, with prices that are amongst the most affordable in the world, according to the International Telecommunication Union (ITU). 1 Gbps, below S$50 (US$38)	N/A	Deployment of the network (home passed) mostly on time (Next Gen NBN reached nationwide coverage in 2013), but delays in connections and activations had significant reputation and financial damage. Demand was observed stronger than planned

Lessons Learned

- Population density and the fact that network built on existing asset base allowed for fast deployment and high penetration in relative short time
- Competition for private sector role in building and operating network ensured reasonable cost of the endeavor and acquisition of required expertise

Cross Border | National Backbone | **Middle/Last Mile**

Poa! Internet

Low-cost Wi-Fi for the rural communities in Africa

URL: http://www.poa.co.ke

Narrative

HQ: Nairobi, Kenya

Poa! Internet service was launched in 2016 and provides wireless broadband to low income and rural communities across East Africa, offering individuals and small businesses highly affordable Internet access.

It competes with established service providers using mesh Wi-Fi network allowing coverage much larger than a single access point.

Poa! Places its hotspots in community centers, e.g., schools, mosques, churches and youth centers. It therefore attracts community involvement through siting infrastructure on community assets.

Poa! pioneered innovative pricing which offers users the ability to buy access at very low cost and allow payment through the use of a mobile phone.

Poa! more recently has expanded from public Wi-Fi service to home connections via private Wi-Fi router.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	Competes with several companies offering broadband access in Kenya including: AccessKenya, Safaricom, Wananchi Group, etc	Kenya's HDI puts it at 146 out of 188 countries and territories. It has a GNI per capita of 2,881 in PPP USD	Poa! Internet offers retail services	Regulatory Regime: Maturing	Market Segment: last mile wireless network and retail service provider. Management: Private Revenue: sells voucher-based unlimited Wi-Fi internet access for fixed time period	Private equity and debt	Poa! Internet has partnered with Liquid Telecom and is using its infrastructure

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	The network now uses 120 access points, covering an area that is home to around 1 million low income residents in Kenya	N/A	Customer base: 21,000 subscribers	Pricing is reportedly 40% cheaper than network operators, free content and free online services and tools. Poa!'s service provides unlimited internet plans to the surrounding residents, offering them access from K Sh 10 ($0.10) per hour or K Sh 50 ($0.50) per day, instead of the traditional data bundle pricing that charges per Megabyte (MB).	Wireless access points cost "a few hundred dollars"	Revenue growth of over 400% since the beginning of 2017

Lessons Learned

- Success due to the relatively low cost of Wi-Fi equipment, the availability of spectrum and the large number of Wi-Fi enabled devices
- Poa! Internet innovation has been in it's price structure. Rather than selling based on usage, it sells unlimited usage for a fixed amount of time
- Scalability will depend on resolving a number of issues, e.g., very dependent on backhaul from operators - often not available

Cross Border | National Backbone | **Middle/Last Mile**

Poland Rural Networks

Government initiative auctioning offers to build rural NGA

URL: N/A

Narrative

HQ: N/A

Poland has used EU funds for deployment of middle mile network projects and hundreds of access network projects. Between 2007 and 2013, €1.4 billion was used to build 60,000 kilometers of networks, including 24,000 kilometres of new optical networks. About 280,000 households gained Internet access, including 200,000 in FTTx technology. Poland is planning to utilize roughly the same amount again between 2014 and 2020 in its Digital Poland program.

Government uses auctions to grant funds. It develops selection criteria and contest procedure in a manner which minimizes the subsidy and maximizes private capital.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	These programs focus on white areas	Poland's HDI puts it at 36 out of 188 countries and territories. Gross national income (GNI) per capita (2011 PPP$) is 24,117 USD	The selected operator was obliged to provide wholesale access to the subsidized infrastructure to all operators	Regulatory Regime: Mature	Market segment: vertically integrated or wholesale only access open Management: networks are privately owned and operated Revenue: standard sources complemented by subsidy	Estimated investments in broadband infrastructure are approximately €1.03 billion, to be accompanied by possible investments from private investors, estimated at €4 billion	No significant synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	White areas across the nation	Broadband with speeds of at least 30 Mbps. Highest speed available in Poland is 1 Gbps. In 2016, a 16% increase in fiber was recorded. Compared to the previous inventory, there were more than 46,000 new fiber nodes, which means an increase of 43%	The take-up of the new infrastructure is unknown; however, Poland has one of the lowest fixed broadband take-up rates in EU	Fixed broadband prices in Poland are affordable with lower prices than the EU average	N/A	N/A

Lessons Learned

- For these areas additional revenue source necessary, may include: down payments, predominant government contracting and subsidy
- Areas chosen so as not to crowd out private investments

Cross Border | National Backbone | **Middle/Last Mile**

Project Loon

Series of balloons that act like mobile towers

URL: https://x.company/loon/

Narrative

HQ: Mountain View, CA, U.S.

Project Loon is a research and development project being developed by Google with the mission of providing Internet access to rural and isolated areas.

Project Loon is trying to solve this problem by using series of balloons that will act like mobile towers. Each balloon will cover an area of over 5000 square kilometers.

For backhaul, the balloons will form chains of up to five balloons with the last linking to a ground based tower with each chain in the link being up to 40 kilometers long. Under initial planning this means that ground towers could be up to 1000 kilometers apart with expectation to grow to 10,000 kilometers which compares to maybe 40 km for a ground based network.

Attributes & Success Criteria

Attributes	**Market Structure**	**Economic Context**	**Carrier Neutrality**	**Regulatory & Policy Efficacy**	**Business Model**	**Financing & Risk-Sharing**	**Infrastructure Sharing**
	It is a global product, however likely to be focused most on white market in Africa. It competes with satellite and drone broadband providers	Project Loon will target low HDI countries	Project Loon will provide wholesale services to local operators	N/A	Market segment: as yet unclear; likely will be last mile wireless network leased to retail service providers. Management: privately owned and operated. Revenue: as yet unclear, but perhaps Project Loon will undertake revenue share with local operators to provide backhaul and termination	Fully funded by Alphabet (Google)	No significant synergies with power, transport and water utilities

Success Criteria	**Geographic Reach of Network**	**Increased Bandwidth / Volume**	**Take-up: Utilization of Network Relative to Legacy**	**Prices Relative to Legacy, Affordability**	**Investment and Unit Investment (per fiber km)**	**Performance to Plan**
	So far, Project Loon has been tested in Puerto Rico and Peru	Not launched as yet	Not launched as yet	Not yet known	Each balloon costs in the "tens of thousands of dollars"	There is no plan in place, however technically development seems to be progressing well – balloon flight times and location accuracy are improving quickly

Lessons Learned

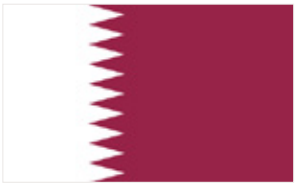
- Technology is still at a stage where commercial viability and appropriate market niche are still unclear
- The investment, timeframe and risk of the project mean that only a company with the resources of Google is in a position to undertake such a project
- Currently each balloon can stay aloft for about 6 months, so current anticipation is that these will be for temporary installations

Cross Border | National Backbone | **Middle/Last Mile**

Qatar Broadband

Deployment of a passive dark fiber network infrastructure in Qatar

URL: http://www.qnbn.com/



Narrative

HQ: Doha, Qatar

Qnbn focuses on the deployment of a passive dark fiber network infrastructure, providing equal and open access to telecommunication service providers, on a wholesale basis, and owners and operators of private networks, on a retail basis, thereby enabling end users to efficiently leverage high speed fiber in Qatar.

Qnbn's mission is to become a competitive provider of high-speed fiber to Qatar's communication service providers and closed user groups, on an open and non-discriminatory basis, striving to maximize coverage across the nation.

The infrastructure is for use by any telecom provider in Qatar, but would most benefit Vodafone, as Ooredoo has already laid much of its own network. Ooredoo aggressively reacted to Qnbn's creation and rolled out a fiber network in advance of Qnbn.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Qnbn competes with the vertical integrated Ooredoo and Vodafone	Qatar is ranked 33rd out of 188 countries and territories on the HDI. Gross national income (GNI) per capita (2011 PPP$) is 129,916 USD	Qnbn is carrier neutral, offering a open access passive infrastructure	Regulatory Regime: mature; but policy-making bodies disagreed about role of Qnbn in national broadband strategy	Market Segment: Wholesale passive infrastructure. Management: government owned and operated Revenue: traditional wholesale pricing structure	Qatar planned to invest $550 million to accelerate the rollout of a nationwide high-speed open and accessible broadband fiber to the home network	Qnbn was aiming to use Ooredoo, then Vodafone Qatar ducts, however the agreement has not been reached. No significant synergies with power, transport and water utilities

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Nationwide	Speeds of 100 Mbps	N/A	N/A	N/A	Since 2012, Qnbn has been working to install a fiber network across Qatar and expected to complete construction within three years. Qnbn had pledged that 95 percent of Qatar's homes and 100 percent of businesses should be able to use fiber by 2015. However, progress has been slow and so far has covered only part of planned area. Indeed, focus of organization has had to change to that of an enterprise and government customer base

Lessons Learned

- Lack of a coherent vision of broadband policy at highest levels of government undermines the initiative
- Poor governance led to poor execution
- Implementation requires a competition risk mitigation strategy

Cross Border | National Backbone | **Middle/Last Mile**

Red Compartida

National Mobile Wholesale Broadband Network

URL: http://altanredes.com/en/

Narrative

HQ: Mexico City, Mexico

In 2014, the Mexican government passed wide-ranging telecommunications reforms that included instruction to the Mexican telecommunications regulator to establish a wholesale-only wireless network or "Red Compartida" — a "carrier's carrier" that will sell mobile-network capacity to all newcomers.

The initiative's aims are 1) optimizing the usage of assigned spectrum (700 MHz band); 2) cost reductions and 3) coverage increase in regions without services.

The bid was awarded in 2016 to a consortium called ALTAN – which includes Axtel, Megacable, Morgan Stanley Infrastructure, the International Finance Corporation (IFC) and Canadian and Chinese investors. Under the terms of the Public-Private Partnership (PPP), the Mexican government is providing the radio spectrum and the use of the developed fiber network by the Federal Electricity Commission (CFE) while ALTAN will assume the commercial risks of the project.

ALTAN aims to offer incumbent MNOs additional coverage or capacity as well as serve other operators (MVNO, fixed operators).

ALTAN's concession requires that access to its network be offered on non-discriminatory terms. The goal of the wholesale, open access network is to facilitate market entry, and enhance competition and choice for consumers.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	America Movil controls 70% of the broadband market. Other competitors Movistar and AT&T own and operate their own mobile networks. Red Compartida will not compete at the retail level, but will compete with MNOs at the wholesale level	Mexico's HDI puts it at 77 out of 188 countries and territories. It has a GNI per capita of 16,383 in PPP USD	Red Compartida will offer wholesale services on an open access basis	Regulatory Regime: Mature. The Red Compartida project is grounded in the Mexican Constitution	Segment: Mobile Infrastructure available on an open access basis. Management: Private sector operator hired to exploit infrastructure and pays annual fees to GoM made up of i) spectrum fee (estimated at around US$21.5million per year) ii) 1% of revenue	Private sector consortium finances infrastructure as part of a PPP with GoM	Red Compartida is a shared wholesale model. Altan is building its network based on shared facilities (fiber, towers), CFE fiber and national roaming. The final network will expand to over 10,000 radio sites

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	Access to ~ 80,000 km+ of backbone terrestrial fiber and 90 MHz of nationwide spectrum in 700 MHz band. Also 35,000+ government sites nationwide are available for network deployment	Altan has committed to deploy a network that will grow to provide services nationwide using all-IP network and 4G-LTE technology reaching 92.2% of the Mexican population	N/A	Expected to reduce costs	$7 billion project to create and operate a wholesale shared nationwide 4G network	As of March 22, 2018 the network had covered 32.2% of the population, slightly ahead of the scheduled 30%. The network must cover 50% of the population by 2021 and 92.2% by 2024. Altan expects to roll out 5G as the technology develops

Lessons Learned

- Too early to draw lessons
- Aspirations for Red Compartida are to increase the telecommunication services coverage; promote more choice and competitive prices in telecom services; optimize the use of the assigned spectrum (700 MHz band); reduce costs and increase coverage in regions that lack access to these services
- The aim is to achieve these objectives through the wholesale open access model operating in parallel with incumbent MNOs, and extend service to underserved areas. Viability of the Red Compartida will pivot on Altan's ability to attract sufficient wholesale clients to its network

Cross Border | National Backbone | **Middle/Last Mile**

Rhizomatica

Cooperative that deploys locally owned, independent, mobile telephony networks

URL: https://www.rhizomatica.org/

Narrative

HQ: N/A

Founded in 2009, Rhizomatica is enabling communities in Mexico to own and operate GSM networks. The company deployed the country's first independent GSM network in 2014, using open source technology.

The main focus area of Rhizomatica are rural locations that are not served by existing mobile networks. Once infrastructure is purchased and installed, the network is fully owned and operated by the community as a cooperative. Users are able to make local calls and send SMS messages. Where Internet access is available, users can also make long distance and international VoIP calls (VOIP calling avoids outpayments to other service providers).

Rhizomatica focuses not only on the deployment of infrastructure in rural communities, but also works to train community members to maintain and operate telecommunications equipment. The organization endeavors to set up networks at a cost that will allow communities to recoup their investment within a reasonable time frame. This is typically done through charging users a monthly subscription fee. Rhizomatica also advocates for regulatory reform at the national and international level to promote community based telecommunications networks.

Attributes & Success Criteria

Attributes	**Market Structure**	**Economic Context**	**Carrier Neutrality**	**Regulatory & Policy Efficacy**	**Business Model**	**Financing & Risk-Sharing**	**Infrastructure Sharing**
	Rhizomatica is a regional telecommunications cooperative that enables communities in Mexico to own and operate GSM networks	Mexico's HDI puts it at 77 out of 188 countries and territories. Gross national income (GNI) per capita (2011 PPP$) is 16,383 USD	The solution is not designed for carrier neutrality as only one operator of the network is feasible	Rhizomatica operates under special authority granted for indigenous communities to use spectrum in areas not served by national concession holders	Rhizomatica enables a last mile network and retail service provision. Management: privately owned and operated on a non-profit basis Revenue: Rhizomatica receives up-front payment for installation, service provider charge, standard access and usage approach, but kept low	Basic financing came from private foundation (Shuttleworth) which was complemented with some funding from government of Mexico. Community must find funding for initial installation	No synergies with power, transport and water utilities

Success Criteria	**Geographic Reach of Network**	**Increased Bandwidth / Volume**	**Take-up: Utilization of Network Relative to Legacy**	**Prices Relative to Legacy, Affordability**	**Investment and Unit Investment (per fiber km)**	**Performance to Plan**
	Rhizomatica has deployed networks in 16 villages	N/A	N/A	Prices are low compared to national operators; monthly subscriptions for local calls can cost around 30 pesos (US$1.5), while international VoIP calls are about 1% the cost of international calls on local landlines. Enough to cover the O&M	Communities pay the equivalent of (US$6-10k) up front for installation of infrastructure, which they then own and operate. Communities retain any profit from operation of the network	N/A

Lessons Learned

- Low-cost technology and low levels of subsidy can bring service to unserved communities
- Rhizomatica was able to deploy networks after successfully arguing for authorization to use spectrum in areas not served by existing licensees. Without this regulatory flexibility, or access to open source telecommunications equipment, the deployment of these community owned networks would not be possible
- The project aims to keep money within local communities: any profit is retained by the community

Cross Border | National Backbone | Middle/Last Mile

RO-NET

Government initiatives delivering fast broadband in rural areas in Romania
URL: http://ec.europa.eu/regional_policy/en/projects/romania/ro-net-building-broadband-internet-access-to-boost-the-economy

Narrative

HQ: N/A

RO-NET project is an initiative that started in 2014 with the aim of supporting the deployment of a backhaul network in white areas of Romania where broadband is currently not available and where there are no plans for broadband rollout by market players over the next three years.

The project is defined as Design, Build and Operate (DBO) model where financial assistance is applicable to the design and deployment of new backhaul infrastructure and no aid is to be granted for the operation of the network. Network leased to concessionaire for 18 years.

Selection was based on open tender process divided into 7 lots with contracts awarded to the applicants presenting the most economically advantageous offer (i.e., least financial subsidy required) among other parameters for selection. The process awarded Romtelecom and Cosmote to implement the new network. The two companies are indirectly controlled by German group Deutsche Telekom.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	Developed market with six fixed telecom operators and four mobile operators. However, RO-NET itself is operating in white areas previously unserved	Romania's HDI puts it at 50 out of 188 countries and territories. Gross national income (GNI) per capita (2011 PPP$) is 19.428 USD	Wholesale services and access to subsidized networks to other operators in open, transparent and non-discriminatory manner for at least seven years	Regulatory Regime: Mature	Market segment: wholesale open access model Management: DBO model, Lease variant Revenue: traditional pricing structure for wholesales service	From approximately €84 million 82% is funded from European Regional Development Fund (ERDF) (€68.5 million) and the remainder from the state budget (€15.5 million) for design and deployment (not for operation)	Defined by process and administered by regulator. About 33% will be built on existing infrastructure. No significant synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	The target market is 9 million rural inhabitants representing 47.2% of the population that live in rural areas characterized with low household density levels. At the start of the project the Romanian authorities identified 783 rural localities divided into 7 regional projects	N/A	N/A	Affordable, ensured by the pricing being regulated. Service pricing for wholesale access will be based on the prices already set by ANCOM	$7 billion project to create and operate a wholesale shared nationwide 4G network	Issues were encountered during implementation. By end of 2015 works were completed only for 99 localities out of 783 planned. Further delays were reported due to payment issues

Lessons Learned

- Process of infrastructure sharing resulted in 33% re-use of existing physical infrastructure
- Simplifying authorization procedures may speed up implementation
- Tenders were won by dominant entities so with conflict of interest in maintaining carrier neutral facilities
- Additional long-term uncertainty created: not clear what will be market dynamics between the period that open access requirement lifted and end of concession

Cross Border | National Backbone | **Middle/Last Mile**

Rune Rural Networks

Privately-led initiative with intention to avoid subsidy

URL: https://www.ruralnetwork.eu/

Narrative

HQ: Komen, Slovenia

The RUNE project is organized through two Special Purpose Vehicles (one for Slovenia - Rune-SI d.o.o. and one for Croatia - Rune-Adria d.o.o.). Both SPVs are established and currently owned 100% by the project promotors (private companies). Equity partners will enter through subsequent capital increase. Following the capital increase, the project promoters will retain a minority share, and the external equity investors will get the majority (75%). Project promotors will retain management, however, but equity investors will benefit from priority financial return: repayment priority is first debt, then return to external equity, then project promotors.

Rune is building networks close to areas considered a market failure by national and EU authorities. In this respect, RUNE complements existing programs such as the European Regional Development Fund. By extending the area of commercial viability to rural and underserved areas, Rune will be able to obtain profits in excess of the rate of return set by regulators for white areas, and allowing for better use of state funds, for deeply rural areas.

RUNE is intending to building middle mile and cross-border connections among its local networks as well to lower cost of access to service provider clients.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Focused on white areas (areas in which currently no NGA broadband infrastructure is in place or planned to be developed in the next three years), in Slovenia Croatia and (later) Northeast Italy	The HDI ranking of Slovenia and Croatia HDI is 25 and 45, respectively, out of 188 countries. GNI per capita (2016 PPP$) is 32,360 and 22,880 USD respectively.Croatia is EU's most recent member	RUNE will offer long term whole-sale leasing agreements	Regulatory Regime: EU; Mature	Market segment: Business model involves leasing active wholesale product to operators. Management is to re-main in hands of project promoters	Initial capital put forward by project promoters. Subsequent capital increase is planned for private inves-tors. Requires 25% premise commitment before staring deployment	N/A

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Currently targeting around 4,700 villages comprising around 350,000 premises (household and business-es) in Slovenia and Croatia	N/A	The program is yet to start	Target pricing is €16.6 for Slovenia and €12 in Croatia, which is approximately 1/3 of the triple play retail ARPU	Targeting €228 million in funding	N/A

Lessons Learned

- Identification and application only to grey and white zones
- Challenging the notion that rural, white zones FTTH deployment only possible with state aid
- "Aggregating" local networks for ease of access to service providers through national node
- Offering risk trade-off to investors: less involvement in strategic decision-making (which stays in the hands of initial investors), but priority claim on return
- Improving business case by avoiding "deep rural" areas of with fewer than 8 inhabitants/sq. mile
- Moderating financial risk by requiring 25% of premise contracted before beginning deployment

Cross Border | National Backbone | Middle/Last Mile

SugarNet

Hybrid wireless broadband solution for rural areas

URL: https://www.sugarnet.co.uk

Narrative

HQ: London, United Kingdom

In the past few years a number of U.K. broadband ISP start-ups have utilized fixed wireless technology to overcome the rural connectivity gap created by the lack of suitable fixed infrastructure available through the incumbent BT. Both the Oxfordshire start-up SugarNet and their acquirer Voneus use a hybrid fiber-wireless broadband solution that extends high speed broadband to target communities. It offers packages of 20-50 Mbps symmetrical for under US$50 per month (<£35).

The business model is based on cooperation with local broadband activists or community action groups in rural areas. Voneus solicits expressions of interest from a minimum number of households in a community. Once community involvement secured it creates a back-haul connection to its core fiber network. Installation costs to Voneus are defrayed by the U.K. government's program of Better Broadband vouchers, which qualifying individual customers receive gratis and then give to Voneus. There are no installation costs to individuals.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
There are number of ISPs in England and Wales. However, SugarNet only targets rural locations with slow internet speeds	U.K. HDI puts it at 16 out of 188 countries and territories. It has a GNI per capita of 37,932 in PPP USD	N/A	Regulatory Regime: Mature	Market Segment: last mile network with retail service provision Management: The company is privately owned and operated Revenue: traditional pricing, but consumers may be able to use state provided vouchers. No installation cost, but upfront commitment required by community served	The company finances its operations from the revenues gathered. SugarNet was acquired by other rural broadband provided Voneus	No synergies with power, transport and water utilities

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Rural areas in England and Wales	N/A	N/A	Affordable	N/A	N/A

Lessons Learned

- State actively encourages market entry through subsidy to consumers
- Service provider lowers market risk by getting community to pre-commit to take-up
- Fixed Wireless Technologies with microwave backhaul have been providing more adequate solution for the rural connectivity problem as the cost will always be lower than deploying fiber over long distance

Cross Border | National Backbone | **Middle/Last Mile**

Tanzania Tri-Party

Shared mobile rural infrastructure via national roaming

URL: N/A

Narrative

HQ: N/A

GSMA supported rural connectivity project, the first of its kind in Africa, is a tri-party collaborative project that brings together three of Tanzania's biggest operators (Tigo, Vodacom, Airtel), in a bid to provide 3G connectivity to selected rural locations. Six 3G pilot sites (2 from each operator) were activated in 2017.

In these pilots, one operator built and owned the site, but the shared active equipment and spectrum allowed customers from competitor operators to "roam" on the site.

Network sharing via limited roaming model revealed significant benefits on both supply and demand side. On the supply side, roaming has allowed operators to cut down their costs significantly allowing for the deployment in unserved rural areas. From an adoption perspective roaming has boosted adoption level as it introduced more choice and better availability of products including SIM cards.

Attributes & Success Criteria

Attributes	**Market Structure**	**Economic Context**	**Carrier Neutrality**	**Regulatory & Policy Efficacy**	**Business Model**	**Financing & Risk-Sharing**	**Infrastructure Sharing**
	Areas this initiative addresses are underserved	Tanzania is ranked 152nd on the HDI out of 188 countries and territories. Gross national income (GNI) per capita (2016) $2,467 USD	Shared infra-structure among joint venture participants, but not open to others	Regulatory Regime: Maturing	Market segment: shared active infrastructure allowing "roaming" Management: collaboration of private entities; Revenue: revenue model of service provider unchanged	Shared cost approach to deployment. Each operator bore the cost of its site	Shared mobile network infrastructure in re-mote communities. No significant synergies with power, transport and water utilities

Success Criteria	**Geographic Reach of Network**	**Increased Bandwidth / Volume**	**Take-up: Utilization of Network Relative to Legacy**	**Prices Relative to Legacy, Affordability**	**Investment and Unit Investment (per fiber km)**	**Performance to Plan**
	Rural network national roaming was enabled on all sites with addressable market of 43,000 mobile customers benefiting from competitive offering at retail level from all three oper-ators utilizing single infrastructure deployment	N/A	N/A	N/A	N/A	N/A

Lessons Learned

- Despite a successful outcome, the investment case given fiscal constraints appears difficult and a barrier for further rural mobile broadband coverage expansion
- Over a short period, the sites showed steadily increasing revenue levels despite a drop in ARPU with revenues per site estimated to reach $62,000 per year - sufficient to ensure site viability from an operational cost perspective. However, CAPEX and tax levels render rural sites unprofitable.
- The savings generated by the sharing agreement are not sufficient to compensate for the whole investment unless some other solutions are consid-ered such as - government financial support in the form of grant or equity partnerships, implementation of low cost access solutions, lower taxes for selected sites, zero rated long-term debt.
- GSMA concluded that the provision of correctly allocated subsidies can significantly help mobile operators to scale the current national roaming agreement

Cross Border | National Backbone | **Middle/Last Mile**

TENET
Tertiary Education and Research Network of South Africa

TENET

Organizational home of and vehicle for collaborative internetworking by universities, science councils and associated support institutions

URL: https://www.tenet.ac.za/

Narrative

HQ: South Africa

Created in 2000 by the public universities of South Africa, TENET's main purpose is to secure Internet and Information Technology services for South African universities and associated research and support institutions. It is a non-profit company that does not provide service to commercial entities.

TENET operates the SANReN network, which is comprised of a national backbone, several metropolitan rings, and dedicated long-haul circuits to reach particular research installations. The network has national and international points of presence, connected using a combination of dark and managed fiber links at speeds of up to 100 Gbps. TENET also provides access circuits for many campuses which include optical fiber, ADSL lines, and low-speed rented access circuits.

TENET has applied a TVWS solution to connect remote campuses and other institutions.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
TENET targets higher education institutions. There is no direct competition, however it indirectly competes with other internet providers	South Africa's HDI puts it at 119 out of 188 countries and territories. It has a GNI per capita of 12,087 in PPP USD	N/A	TENET holds licenses from ICASA to operate and build electronic communications networks and to provide services to third parties	Market segment: vertically integrated service provider for public institutions Management: owned and operated by consortium of public institutions Revenue: traditional pricing structure for consortium members	TENET is completely self-financing but in general does not build its own infrastructure. Participating members finance costs	There are no sharing arrangements in place. No synergies with power, transport and water utilities

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
TENET provides Internet and related services to 170 campuses of 55 institutions. 10 Gbps national backbone connecting all major centers of the population, with Internet peering provided at all major national peering points and in London and Amsterdam	N/A	N/A	In aggregate, participating institutions were charged R 112 million (US$9.1 million) in 2012	N/A	N/A

Lessons Learned

- Able to exploit new TVWS technology to extend network to remote areas within private network
- Low-cost enables TENET to recover the full cost of service delivery through existing service charges to institutions comprising consortium

Cross Border | National Backbone | **Middle/Last Mile**

TOP-IX

IXP expands into middle-mile connectivity anticipating expansion in rural access

URL: https://www.top-ix.org/en/

Narrative

HQ: Turin, Italy

TOP-IX is a non-profit consortium, running the internet exchange point in the Piedmont region of Italy. TOP-IX is planning to build a backhaul network that will support the access network development strategy in Italy's national ultra-fast broadband policy. TOP-IX shareholders include public institutions, universities, telecom operators and service providers (e.g., Colt, BT, WIND, FastWeb, Eutelsat and Clouditalia). Current networks include 1000 km of backhaul in the region.

Seeking to exploit the upstream opportunities created by public and private sector push for more broadband in less developed regions as well as other trends spreading demand for broadband to industrial zones and rural areas (e.g., IoT). TOP-IX sees benefit of ending own reliance on leased (IRU-based) network with own build.

Focusing on complementary roll-out strategy in co-ordination with Open Fiber, the newly funded vehicle for the achieving the national FTTH roll-out objectives.

Seeking an equity partner who will can contribute managerial, operational and commercial expertise and opportunity to exit after three to five years, and institutional investors interested in the longer-term.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Backhaul market increasing competitive with fixed incumbent (TIM) and mobile networks providing own infrastructure and potential new investment from Open Fiber	Italy's HDI puts it at 26 out of 188 countries and territories. It has a GNI per capita of 38,230 in PPP USD	Carrier neutral active DWDM backhaul and associated colocation	Regulatory Regime: EU, Mature	Market segment: carrier neutral active DWDM backhaul and associated colocation Management: complement own capabilities with short-term investor with appropriate launch expertise	Seeking to complement own financing with short-term project investor and long-term institutional investors	Network shared among many service providers

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Rollout of 60 nodes across the less developed areas of Italy's Piedmont region. There are plans to scale up the project to alpine France, and to the Italian regions of Valle d'Aosta, Liguria and Lombardy	N/A	N/A	N/A	€12 million investment in backhaul	Plan is to be cash-flow positive by end of year 3, achieve payback in year 7 with an IRR of 12%

Lessons Learned

- Example of virtuous circle of access and middle mile investments
- Private sector finding commercial attractive solution to infrastructure issue (by attracting long term financing and equity partners), where other countries (e.g., Estonia and Romania) have relied on public sector
- Private sector management can be coupled with a cooperative, multi-stakeholder structure, but is likely to require a commercial SPV for the implementation and scale-up

Cross Border | National Backbone | **Middle/Last Mile**

Vanu

Wireless infrastructure solutions for commercial carriers and government customers

URL: http://www.vanu.com

Narrative

HQ: Lexington, MA, U.S.

The company was founded in 1998 and is based in Lexington, Massachusetts with two offices in India located in Gurgaon and Bangalore as well an office in Kigali, Rwanda.

Vanu, Inc. provides wireless infrastructure solutions for commercial carriers and government customers, in particular the CompactRAN, an outdoor base station to cover outdoor areas, such as rural areas in developing markets, spot fill-in on highways, or in rugged terrain areas. The low power consumption, small size and remote tools allow service providers to significant reduce the opex and capex required to serve rural locations. There is also no wired telecom infrastructure needed for the core of the network.

Vanu was a first mover in the network in a box space. It developed the first Radio Access Network (RAN) product to simultaneously support multiple cellular radio standards on the same platform. Vanu's software RAN solutions are developed through the use of Software Defined Radio (SDR).

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Rural areas, which technology focuses more on Wi-Fi or TV white space. In Africa alone, it is found in Rwanda, Mauritania, Ghana and the Democratic Republic of Congo	VANU operates in countries that rank between low and medium on the UN's HDI	The solution is not designed for carrier neutrality as only one operator of the network is feasible	There are no specific regulatory or policy developments that apply specifically to the organization. It is subject to the domestic policies and regulatory frameworks where it operates	Vanu's technology enables a last mile network and retail service provision. Management: privately owned and operated. Revenue: software and hardware is paid for by service provider	Self-financing model	The small form factor allows for simplified mounting on poles and alternative structures, eliminates the need to place equipment on the ground, and greatly simplifies tower construction requirements. Solar powered and wind powered to provide coverage where there is no power grid

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Vanu's technology has been used around the world, particularly in rural areas. In Africa alone, it is found in Rwanda, Mauritania, Ghana and the Democratic Republic of Congo	N/A	N/A	N/A	N/A	N/A

Lessons Learned

- Low cost technology and low-levels of subsidy can bring service to unserved communities

Cross Border | National Backbone | **Middle/Last Mile**

VAST Network

Open-access Wi-Fi network infrastructure

URL: http://www.vast.network

Narrative

HQ: Johannesburg, South Africa

VAST Networks is Africa's first open access Wi-Fi infrastructure provider and largest mobile data reseller across three GSM networks. The company was publicly launched in 2015 through the joining of the Wi-Fi assets of two market players: MultiChoice-owned Internet service provider (ISP) MWeb, and Internet Solutions.

Its ambition is to create a ubiquitous network that any service provider or organization can use to offer a Wi-Fi product that consumers can access on the same basis everywhere they go.

VAST initially set up Wi-Fi infrastructure in shopping centers and offices across South Africa, serving the country's middle and upper class. In 2016 it brought technology of exactly the same quality to townships for the first time.
Currently one Wi-Fi hotspot for every 6,160 South Africans.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
VAST Network is ultimately competing with the vertically integrated MNOs that are its clients as ubiquitous WI-FI is a competitor for their service	South Africa's HDI puts it at 119 out of 188 countries and territories. It has a GNI per capita of 12,087 in PPP USD	VAST Network offers wholesale services to other operators on a "commercial access" basis	Regulatory Regime: Maturing	Market segment: wholesales WIFI hot-spots Management: privately owned and operated Revenue: sells data to mobile operators and ISPs and also offers infrastructure as a service	VAST Network is funded with private equity and debt	No significant synergies with power, transport and water utilities

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
VAST networks deploy, and develop a Wi-Fi network across 2,200 locations in South Africa (2017)	N/A	Already, more than 1.5 million township residents benefit from affordable access to a quality Internet service that rivals some of the more affluent suburbs in South Africa	N/A	Wi-Fi equipment for each access location is required, for which the cost is unknown	N/A

Lessons Learned

- Unclear whether ubiquitous WI-FI network is that their service providers will pay for
- Value of the firm may simply be its contractual arrangements with hot-spot venues

Cross Border | National Backbone | **Middle/Last Mile**

Village Telco

Low cost Wi-Fi Mesh networks for villages

URL: https://villagetelco.org/

Narrative

HQ: Cape Town, South Africa

Village Telco, established in 2009, aims to provide very low cost Wi-Fi Mesh networks for villages through the selling of "Mesh Potato" CPE.

A Village Telco Entrepreneur Server can easily be added by a local organization or entrepreneur, which will connect the local Mesh Network to the other telecommunications providers and allow for billing, network management, etc.

The network is designed to be self-installed by users with relatively limited technical knowledge. To date there have been eight publicized deployments around the world; three in South Africa and one each in Nigeria, Colombia, Puerto Rico, Timor-Leste and Brazil. The different deployment have often been for a different reasons – to provide NGOs with an inexpensive network in Timor-Leste to entrepreneurs providing data services in poorly served areas of South Africa.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	Vendor last mile access product available to all countries. Targeting grey and white markets	Rural areas with low and medium HDI	The local provider will determine local carrier neutrality. Neutrality for back-haul will depend on where services are launched	Service providers operating with maturing regulatory regimes The technology uses the 2.4 Ghz band though which is generally unlicensed	Market segment: Village Telco enables a last mile network and retail service provision. Management: privately owned and operated. Revenue: Requires the community to buy and install the equipment themselves	Funded through selling equipment – Village Telco is a vendor. Individual operators will have their own funding arrangements	No synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	Markets include South Africa, Colombia, Brazil, Puerto Rico, Nigeria, and Timor-Leste. Targeting mainly rural areas	N/A	Estimated to be in the tens of thousands	Inexpensive compared to other solutions	Unit investment cost is unknown, however solution might require significant local investment	N/A

Lessons Learned

- Whilst not designed to be full substitute for mobile networks Village Telco is designed to allow users to move a significant amount of their traffic onto a locally owned network and reduce the associated telecommunications costs. With the inclusion of data services the network can scale to reduce dependency on telecommunications providers
- Low cost technology and low levels of subsidy can bring service to unserved communities

Cross Border | National Backbone | **Middle/Last Mile**

ViRural

Compact carrier-grade outdoor base stations

URL: https://virural.com/

HQ: Dover, DE, United States

Narrative

ViRural, established in 2014, offers compact carrier-grade outdoor base stations, a wide variety of media for backhaul (primarily satellite), remote monitoring and software upgrades, local content caching and a solar power energy source in Africa.

Users use their existing devices, calling plans, and services to simply roam on the ViRural Africa network while remaining a customer of their current provider. Virural does not sell SIM cards, maintain subscribers or own spectrum. Approach described as an "upside down MVNO".

ViRural produces low cost package of 15-foot mast, small-cell base station, satellite or microwave dish for backhaul link, as well as solar panels with back-up batteries to power the network. It is a network extension initiative carried out in partnership with existing service providers. ViRural takes a share of end-user revenues.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
ViRural targets emerging (white and grey) markets. There is no direct competition, however it indirectly competes with verti-cally-integrated service providers	Sub-Saharan Africa has a GNI per capita of 3,383 in PPP USD	ViRural offers wholesale servic-es on shareable network	Service providers operating in areas with maturing regulatory regime; some markets do not allow active mobile infrastructure sharing	Market segment: ViRural enables a last mile network and retail service provision. Management: privately owned and operated. Revenue: Share of end-user revenues; offers service to end-users for powering devices; offers WI-FI services to the community	The company is a service provider so it finances its operations from the revenues gathered	Shareable network over which end-us-ers for multiple net-works could roam. No synergies with power, transport and water utilities

Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
ViRural is an initiative that is focused on Africa, with focus on the rural parts. Targeting villages with adult populations greater than 2,000	N/A	N/A	N/A	Site cost reportedly at US$70,000-80,000	Plans to expand to 20,000 villages in rural Nigeria over the next several years

Lessons Learned

- Innovative mobile wholesale model: existing cell phones, calling plans and services remain unchanged to the end user with service provider using ViRural's technology
- Low operating cost and shared infrastructure may improve business case of MNOs to bring service to unserved communities
- Part of strategy dependent on regulatory policy on active infrastructure sharing. Shareable nature will reduce to supplying single operator if active sharing not possible

Cross Border | National Backbone | **Middle/Last Mile**

Vodafone Instant Network

Easy transportation, rapid activation and smart connectivity

URL: http://www.vodafone.com/content/foundation/instant-network-emergency.html

Narrative

HQ: London, United Kingdom

The Vodafone Foundation Instant Network is an initiative to enable rapid restoration of mobile coverage and extension in the case of emergency. It is a portable solution that weighs 100 kilograms and can be transported on commercial flights in just four suitcases of less than 32 kilograms each.

It can be activated in just 40 minutes as a standalone network and can support free local voice and SMS, as well as remote connectivity (GSM radio through satellite backhaul to a core network).

The instant network is not positioned as a commercial offering or solution, but a humanitarian undertaking for emergencies to restore and provide free, vital communications and technical support to aid agencies, victims and refugees in remote areas.

Attributes & Success Criteria

	Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
Attributes	A niche service aimed directly at providing communications access to remote or challenging areas free of charge in emergencies	U.K. HDI puts it at 16 out of 188 countries and territories. Gross national income (GNI) per capita (2011 PPP$) is 37,931 USD.	N/A	No reported challenges	Market segment: N/A Management: operated by Vodafone Revenue: no revenue, humanitarian aid	A Vodafone Foundation philanthropic program, providing the technology and volunteers	No synergies with power, transport and water utilities

	Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
Success Criteria	Emergency Response service with global reach.Instant Network Schools – targeted to marginalized communities where Vodafone operates	The Instant Network provides 2G and 3G connectivity with inbuilt wireless capability and secure connectivity via firewall and VPN	To date, Vodafone has delivered 11 emergency response missions in the past 5 years, supporting natural disasters	There is no charge for this service	N/A	The initiative has scaled and delivered against the Foundation's intended aim of providing connectivity during times of crisis or need

Lessons Learned

- Technological progress has enabled quickly deployable infrastructure for humanitarian relief:
  - Equipment is light enough to travel in the back of a car or on commercial flights
  - Includes Instant Charge to provide free mobile charging to communities in areas with no power
  - Instant Classroom is currently benefiting thousands of children and teenagers in schools in refugee camps across Sub-Saharan Africa

Cross Border | National Backbone | **Middle/Last Mile**

WrightGrid

Solar-powered Wi-Fi and charging stations

URL: http://www.wrightgrid.com

HQ: Somerville, MA, U.S.

Narrative

Established in 2013, WrightGrid specializes in designing and manufacturing independent power platforms in areas of the world that have unreliable power.

The WrightGrid Model Z is powered by a single solar panel and operates as a cell phone charging and Wi-Fi station, which provides a sustainable source of energy and is equally applicable at educational campuses, outdoor festivals, trade shows, resort destinations and off-grid locations. The WrightGrid power platforms can provide secure charging for up to 10 devices and allow for on-station advertising.

Stations are purchased by distribution partners and are deployed to the field. Stations generate revenue from phone users seeking to charge their devices, advertising on the outer shell and via the Wi-Fi splash screen/landing page and taking a small percent fee per mobile money transaction. WrightGrid makes a 50% gross margin on the sale of each station, as well as passive income via revenue share with the distribution partner, in exchange for exclusivity.

Attributes & Success Criteria

Attributes

Market Structure	Economic Context	Carrier Neutrality	Regulatory & Policy Efficacy	Business Model	Financing & Risk-Sharing	Infrastructure Sharing
WrightGrid targets emerging (white and grey) markets. There is no direct competition, however it indirectly competes with other Wi-Fi providers	Subsaharan Africa has an average GNI per capita of 3,383 in PPP USD	N/A	Regulatory Regime: Maturing	Market segment: Wrightgrid can enable a last mile network solution Management: privately owned and operated. Revenue: Device charging and WI-FI Stations are sold to communities and service providers	N/A	No synergies with power, transport and water utilities

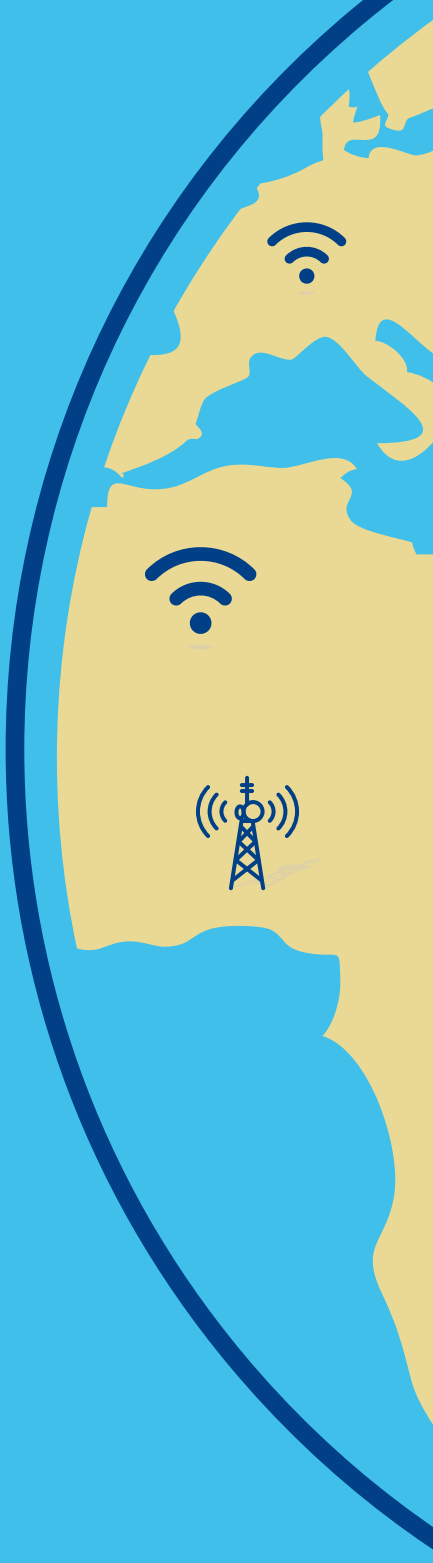
Success Criteria

Geographic Reach of Network	Increased Bandwidth / Volume	Take-up: Utilization of Network Relative to Legacy	Prices Relative to Legacy, Affordability	Investment and Unit Investment (per fiber km)	Performance to Plan
The company operates in Sub-Saharan Africa, focusing on rural villages where access to internet does not exist or is very limited	N/A	N/A	N/A	N/A	N/A

Lessons Learned

- Has benefits for non-telecoms retailers as customers are attracted and stay longer at location for access to wireless Internet and phone charging
- Other business may also help pay for the stations through advertising on the WiFi hotspot

Notes



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