Rural Connectivity Options for Microfinance Institutions

A Technical Note

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Introduction

The objective of this paper is to inform chief information officers or senior information technology managers at rural microfinance institutions (MFIs) about the technology options that may be available to them so that they can assess and engage with potential connectivity solution suppliers. This paper also reviews possible limitations of connectivity solutions as they relate to an MFI's requirements, so that MFI managers can ask the appropriate questions when engaging a connectivity solution supplier.

This paper focuses on commercially deployed access bearer technologies that can be used to connect an MFI device or application to its intended use. This connection is generally referred to as the "last mile" and is primarily the link between the remote site or device and the core network, which may be a local telephone exchange or a service provider point of presence.[1]

We first review the main reasons why MFIs may require connectivity in rural areas. The various uses or applications have different technical requirements, and the various technologies have different characteristics. To help assess the "fit" of technologies to the uses, we describe a reduced set of key attributes that can be used as a basis for comparison. We then profile the various connectivity technologies that might be used, with reference to the defined attributes. In the final section, we summarize the performance of the various technologies against the likely applications MFIs may use in rural environments.

Uses of connectivity: MFI application requirements

MFIs primarily require connectivity to enable a set of applications such as those described below. Although it is assumed that these require data connectivity, the possibility of using voice connectivity (perhaps via the same handheld device) is not excluded.

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[1] "Last mile" should be distinguished from the term "backhaul," which generally refers to the link between the core network and the "edge" of the network, usually the element in the carrier's access network (shared facility) nearest to the customer.

Authorizing transactions in real time

An agent needs to be able to undertake transactions in real time. One should to be able to *(a)* take no more than a few seconds to initiate a service and (*b*) interact on a basis that is viewed as immediate (irrespective of the process). This correlates with a short setup time and an immediate interaction time. A delay of more than a few seconds in any activity would be deemed unacceptable.

The type of solution that may be envisaged here would involve a handheld device operating as a point of sale (POS) terminal; a mobile device used for mobile banking transactions; or, possibly in conjunction with several other devices, the handheld may be purely a conduit to capture and send customer data from the field. The latter could also include voice connectivity to an interactive voice response (IVR) unit to handle customer data or financial transactions. In many cases, it may be necessary to run a client application that uses the access network to communicate to the MFI transaction handling or database systems.

Synchronizing data collected in the field

A remote loan officer must be able to synchronize a handheld device (in which loan application and collection data have been captured). This does not necessarily require an "always on" capability, but it does mean that the loan officer should be able to synchronize via wireless or wireline means and transact data within a matter of minutes.

The solution capability here is fundamentally simpler than in the previous case. A basic data transaction capability is required, with appropriate security and application to authorize and acknowledge the synchronization. Obviously when used to synchronize from an offline mode, one may have multiple data "sets" to synchronize, but the required bandwidth is not likely to be large.

Interface to the core banking system

Branch integration with head office backend systems must be possible in both an always-on, automatic, and real-time synchronized manner and an offline periodic manner or automatic synchronized manner. A branch solution is likely to involve a far greater number of transactions: it may be viable to implement wireline (also known as fixed) network infrastructure that is able to support real-time and high-volume transactions, and the branch is more than likely to support PC- or tablet-based solutions with appropriate automatic teller machine or POS devices. The connectivity requirement would be similar whether the core banking system is held at head office or is hosted by a third-party application service provider (ASP).

Help Desk

Support of voice services, whether via direct customer care agent, IVR, or deposit of voicemail, is done in real time. Real-time data support might be via Web access frequently asked questions, an avatar, or an online customer care agent using instant messaging. These require real-time interactive responses but low data volumes. The help desk function might also include nonreal time (IVR and data) support for both MFI personnel and MFI customers. Nonreal-time support can involve call back or use of chat, voicemail, or electronic mail to correspond with the person making the request. Basic connectivity and access to such services are all that is required.

Key technical attributes of connectivity services

The key attributes associated with an access technology relevant to a service can be summarized as follows.

Bandwidth

Bandwidth is the speed at which one can upload (UL) and download (DL) information and is typically measured in bits per second (bps). It may be quoted as specific to UL and DL, or it may be symmetrical. Kbps and Mbps refer to thousands and millions of bps, respectively. This measure is relevant for both voice and data communication. Typically, voice (including voice over Internet Protocol [VoIP]) communication requires 8 Kbps to 64 Kbps (symmetrical), depending on the type of CODEC used.[2] Data communication can generally use any speed; however, it is usually only for data connectivity that a given speed would be quoted by a service provider and is thus a parameter to which an individual might subscribe. Evidently each technology has a finite upper limit to what data rate it can provide.[3]

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[2] A CODEC is a device or program capable of encoding and decoding an analog-to-digital signal. Voice is analog and hence, to be conveyed as a (digital) bit stream, it needs to be converted via a CODEC. There are many CODECs available, some of which are standardized (PCM G711 is the typical CODEC used in PSTN systems), and some of which are proprietary. The CODEC has a profound impact on the quality of voice via packet delay (latency and jitter), and the cost of the solution via the amount of bandwidth it requires (G711 uses 64 Kpbs whereas VCELP GSM half rate requires only 5.6 Kbps). In cellular networks, the type of CODEC used is critical to the capacity of the system—optimizing the quality of voice while minimizing the amount of bandwidth required has a profound impact on the capacity and hence cost of the radio network.

[3] Customers often subscribe to a specific service package that comprises bandwidth (possibly with specific service level agreements and contention ratios—described later) and a DL or UL capacity limit (typically in Mbytes or GBytes of data that are available to a user within a specific time frame for a specific price). This is a purely commercial arrangement and is primarily a tactic used by operators to constrain the amount of data a user may consume, and thereby reduce the possibility of exceeding the available capacity of the system (or entities within the system).

Capacity

Capacity is a measure of how many customers a given entity can support. Different entities, or network elements, have different measures. Typically these may include (*a*) the absolute number of customers, (*b*) the total bandwidth, (*c*) the absolute number of traffic channels, or (*d*) "erlangs" of traffic (a specific number of traffic channels with a specific grade of service [GoS]). Capacity is a term and consideration used specifically by engineers within service providers and would not be something quoted to a customer. The available capacity in the network does, however, directly affect the ability to meet the quality of service—referred to later—and the perceived experience of the end user.

Coverage

Coverage is a measure of how well the population targeted by the service is able to use the service. It is mostly relevant to wireless access technologies and is usually expressed by an operator in the form of percent of population in a given area able to access the service or percent of the geographic area in a given country where the service is available. In wireline network terminology, the key measure for coverage would be the number of **points of presence**, either in terms of absolute customer connections or absolute intercarrier connections.

Mobility

A wireless access technology can be mobile in that it allows a user to move with a device within a defined coverage area without loss of service (i.e., voice or data session continuity is maintained during the movement). The defined coverage area comprises a large number of smaller coverage areas, or cells, between which the network allows the user to "hand off" a voice or data session. A nomadic wireless access technology allows one to initiate and maintain voice or data session continuity within different coverage areas or cells but with temporary loss of service when moving between coverage areas.[4]

[4] It is now possible for a service provider to offer the capability of achieving mobility *across* different access technologies with devices that support multiple wireless access technologies, which may be mobile or nomadic.

Latency

Latency is the time it takes for a packet of information sent from one entity, or user, to arrive at another entity, or user.[5] Clearly, low latency is best. Voice services are particularly susceptible to severe degradation with high latency. For example, one drawback of several satellite-based technologies is a significant delay that results in an echo effect. Latency is particularly significant in the context of VoIP and packet-based technologies wherein interaction time is important.

A closely related parameter is **jitter**: the variability in latency. Jitter results in out-of-sequence packets of information. This is not relevant in circuit-switched-based systems (referred to later), but in packet-based systems it can result in unusable voice or data that an application will need to resequence to enable it to be used for the intended purpose.

An important measure related to quality of voice calls is the **mean opinion score** (MOS). It is a qualitative measure specified by International Telecommunications Union (ITU) Recommendation P.800, which defines a method to derive an opinion of voice quality by human listeners, ranging from 1 to 5. Any measure above 4 is deemed acceptable for voice. A typical public-switched telephone network (PSTN) connection is rated at 4.3.[6]

Quality of service

Quality of service can be broken into several core components. **Availability** is the actual in-service time expressed as a percentage of the total possible in-service time; the latter generally excludes planned maintenance windows and such. **Reliability** of a system is expressed in different ways by different manufacturers and operators and can use measures such as mean time between failure (expressed in years). **GOS** is a percentage measure specified by an operator that indicates the possible unavailability of a traffic channel because of congestion (i.e., insufficient channels, because of use or nonavailability, to handle all voice or data sessions). Statistical means are used to plan the quantity of traffic channels required in a given system; however, the higher the GoS, the higher the deployment cost.[7] The **contention ratio** is

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[5] It should be noted that references to latency are focused on latency in the network and not latency end to end incorporating whatever applications or servers are implementing the services at the client and server. These themselves can be quite significant and need to be addressed in an overall solution design.

[6] MOS is a useful evaluation measure, particularly when deploying VoIP. If MOS is below PSTN grade, then user experience is likely to be poor. If IVR systems, in particular, are being used in any transaction-based system, there are likely to be significant speech recognition problems, and poor user experience will render the system useless.

[7] A high GoS means that the probability of being unable to make a call is low. As such, GoS is typically expressed as a percentage; a GoS of 1 percent is typical.

used primarily in data networks to specify how many other potential simultaneous users of the bandwidth there are.[8]

These factors are not so much constraints of the access technologies themselves but are determined by the engineering of the solution and, as such, are driven by the cost model of the operator deploying the network. An operator can build a great deal of additional reliability into a system, for example, by replicating components and removing single points of failure. However, this is not always a cost-effective way of building and deploying a network, and so this very much depends on the operator.

Circuit switch vs. packet switch

Circuit-switch (CS) systems are those in which the physical path between the two endpoints used in a connection (voice or data) is allocated and reserved for the entire duration of that connection. A typical example is the plain old telephony system (POTS) network through which most voice calls are made today. Packet-switch (PS) systems are those in which relatively small units of data called packets are routed through a network based on the destination address contained within each packet. This allows the same physical path to be shared among many users. This is connectionless-based communication. A typical example is the Internet.

Today's telecommunications networks are primarily CS systems. Wireline networks are rapidly migrating to PS-based systems. PS systems generally are cheaper to deploy (because of the multiplexed use of the physical paths), but until recently, the latency and quality of service management capabilities were limited. It was difficult to prioritize delay-sensitive traffic, such as voice, over and above data—with obvious impacts to MOS. Thus the network evolution of a service provider may temper an MFI experience based on its impact on key attributes.

Because the core network infrastructure of wireline and wireless networks is essentially the same, operators that manage both systems find themselves working with a common, converged infrastructure. However, last mile or access technologies, whether for backhaul or end user, do not have such a commonality yet, and the vision of achieving an end-to-end PS (or all-Internet protocol [IP]) network is far from being realized.

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[8] The multiplex nature of the channel means that the effective bandwidth available to a user could be significantly reduced. For example, a typical contention ratio in an ADSL network might be 50:1. If there are 50 potential users, each subscribing to a DL service of 1 Mbps, yet the network has been engineered to provide only 10Mpbs, say, then simultaneous access by each of the 50 users would in fact yield a maximum DL of only 200 Kbps per user (20 percent of the required rate).

Spectrum use

Radio frequency spectrum is relevant to wireless technologies. Spectrum use is governed by ITU and by relevant national bodies within each country. ITU focuses on achieving standardization across the globe while national bodies attempt to both conform to that standardization and manage local spectrum use, including reuse, license fees, and carrier obligations. The key considerations in respect to spectrum are as follows.

Frequency. Low-frequency systems are able to achieve better geographic coverage than high-frequency systems. Low frequency tends to mean fewer base stations and antenna and lower capital and operational costs for an operator to achieve coverage. The corollary is that high frequency requires more infrastructure to achieve the same coverage, and thus higher cost, but it does provide much greater capacity. However, it is not strictly true to say that to achieve a given geographic coverage with a global system for mobile communications (GSM) 900MHz system would require half the base stations of a GSM1800 system. It should be noted that although the latter would require more infrastructure, it would also provide significantly more capacity.

Licensing. Licensed spectrum is allocated and managed by regulatory bodies. A service provider often will charge a fee to procure and manage a given frequency band. This usually means that there is a set of policies and active management of the spectrum, designed to ensure optimal use of spectrum and avoidance of customer impacting issues, such as interference. Unlicensed spectrum is defined by regulatory bodies but is not allocated to either a specific operator or use. Anyone can use unlicensed spectrum. A well-known frequency band is the industrial, scientific, and medical (ISM) band at 2.4 GHz, which has several generic use allocations. This spectrum is used by a wide range of radio-based technologies, and because it is unregulated, anyone can buy and use equipment that uses this frequency. This has significant implications for both the services and cost structures deployed with such equipment—most notably from interference.

Interference. Interference is specific to wireless-based technologies and can result in significant service degradation or failure of radio systems. There are many forms of interference, ranging from frequency (electromagnetic fields or otherwise) interference to climatic interference. These are a fact of life, and it is the job of the service provider's radio planning engineers to minimize such issues.[9]

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[9] New techniques using technologies such as smart antennae and mesh networks are being deployed to reduce the effects of interference and to improve system capacity and coverage. These will not be described in detail here.

Table 1: Summary technical requirements of MFI applications

	MFI applications				
				Customers' access to helpdesk	
Attributes	**Real-time data transactions**	**Synchronization (nonreal time) of data**	**Interface to head office IT (real & nonreal time data)**	**Data (real & nonreal time)**	**Voice (real time)**
Bandwidth	<100 Kbps	<100 Kbps	<1 Mbps	<100 Kbps	variable
Capacity	<50 Kbytes per transaction	<1 Mbytes per synchronization	<1 Gbytes per day	<100 Kbytes per user	variable
Coverage & mobility	nomadic, on location	nomadic, as required	fixed	nomadic	nomadic
Latency	<500 ms	<10s	<500 ms	<500 ms	<480 ms
Quality of service	50:1 contention Available>99.9%	50:1 contention Available>99.9%	50:1 contention Available>99.9%	50:1 contention Available>99.9%	GoS<1% Available>99.9%

Available Access Technologies

Figure 1 depicts the range of commercially available access technologies, according to the data rates they offer (bandwidth—typical DL rate) and the degree of mobility they provide. This section summarizes each technology in turn, including qualitative measures of how they rate in terms of the key attributes described in the previous section. The technologies are ordered roughly in decreasing order of coverage, starting with satellite technologies, which cover a broad swathe of the earth from a single satellite; then cellular technologies and other wide-area wireless technologies; then fixed networks; and finally short-range wireless access technologies, which have a range of less than 100 meters.

Figure 1: Access technologies, according to bandwidth and mobility

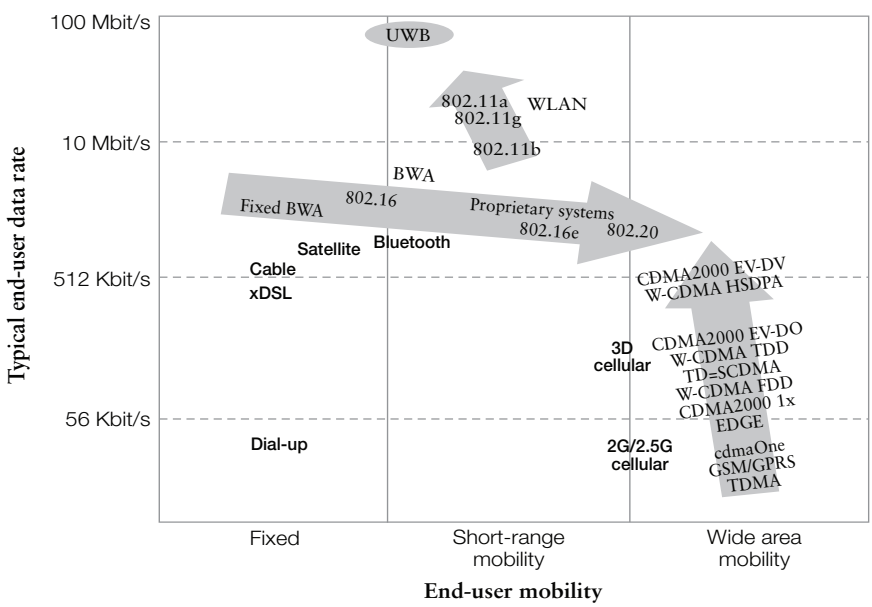

Table 2 at the end of this paper portrays the adequacy of each of the access technologies discussed against sample MFI applications, considering their fit against the attributes identified above. For the main technologies, these data and a summary evaluation are noted in the table after the discussion of each technology. In these tables, the term "viable" indicates that the technology being consideration is technically viable to support that application; any comment otherwise indicates some criteria that make this less than ideal.

Satellite

Satellite technology remains a key alternative to cable for providing telephone, television, and other multimedia services—both in terms of use by the end user, particularly in remote areas, and in terms of transferring data around the world. However, aside from broadcast, satellite technology is far more suitable to store and forward type applications, such as transfer of video, than for telephony use. This is primarily because latency is generally high, and thus, voice calls are prone to echo. Typical data support for end user services is no more than 64 Kbps. However, some newer satellites support general radio packet switched (GPRS) and broadband IP capabilities of up to 492 Kbps. Satellite technologies are inherently more expensive to deploy, and capacity is somewhat constrained, thus it is the most expensive per bit carriage. Satellites do provide the ultimate in mobility because the individual satellite footprint defines the coverage area. However, the high frequencies used by satellite systems ensure that environmental interference, particularly from trees and buildings, is more pronounced.

Geosynchronous earth orbit (GEO) satellites revolve around the earth at a constant speed once per day over the equator. Well-known examples of typical GEO satellites are those provided by Intelsat, Inmarsat, and Thuraya. The latter is very similar to Globalstar, in that it offers a dual mode (GSM-satellite) satellite phone; however, it is regional rather than global and does not need to hand off calls between satellites. The Inmarsat system can offer an IP data connection of up to 492 Kbps.

Very small aperture terminals (VSAT) are self-contained (and are usually but not always fixed) systems that use GEO satellites for communications. VSAT consists of two parts, a **transceiver** and dish—up to 2.4 m in diameter—which is in direct line of sight for communication with the satellite—and an interface to the **end user's** communications device—typically a PC. The satellite sends and receives signals from a ground station that acts as a hub for the system. Each end user is interconnected with the hub station via the satellite. The hub controls the entire operation of the network. For one end user to communicate with another, each transmission goes first

to the hub station, which then retransmits it via the satellite to the other end user's VSAT. These systems are a specific implementation of GEO technology and is primarily used by businesses that require a remote (and often temporary) connectivity to a central office. They can be used for voice, data, and video services. However, they are expensive both in initial outlay for the VSAT and use of service. They are typically carried in a vehicle and used by TV news crews.

Low earth orbit (LEO) satellites typically move in a circular orbit about 400 km above the earth's surface. LEO satellites are less expensive to position in space than geostationary satellites and, because they are closer to the ground, require lower signal strength. Iridium and Globalstar are two constellations that provide satellite communication (voice and low-speed data) services primarily to remote areas.

	Real-time data transactions	Nonreal-time data synchronization	Interface to head office IT systems	Customers' access to helpdesk	
				Data	Voice (real time)
Satellite	viable, long call setup	viable, borderline	viable, but not recommended	viable	viable, but not with VoIP
Satellite is better suited to end user requirements but should be regarded as a niche market for extremely rural or mountainous terrain where no other solution is viable. This is simply because of the very high relative cost of any voice or data transaction. It should not be considered for high bandwidth applications.					

Cellular technologies

We begin with a family of standards covered by the 3rd Generation Partnership Project (3GPP), an association of European and Asian standards organizations that are responsible for developing GSM-based technical specifications for mobile technology. We then cover the family of standards under 3GPP2, which is primarily an association of North American and Asia standards organizations that are responsible for developing competing Interim Standard (IS) 95-based (code division multiple access [CDMA]) technical specifications for mobile technology. The technologies described provide broadly equivalent coverage and mobility and differ primarily in their cost structures and availability and capability of devices.

Global system for mobile communications (GSM) is a European-originated standard that is the predominant digital mobile technology deployed today. GSM was originally developed specifically for CS voice communications (as well as limited low-speed fax and data services) with several supplementary services, including call forwarding, call barring, call transfer, conference calls, and short message service (SMS). SMS enables a user to send and receive text messages between mobile phones and is the forerunner of data services.

In addition to providing a range of supplementary services, GSM differentiates itself from previous and competing technologies in two key ways. First, it enables a user to roam between networks—a user can use the services of their home network in another, interconnected network. These services include both the original voice-based service and the supplementary and text-based services. Second, it offers in-built security—authentication and encryption. GSM devices use a smartcard, known as a subscriber identity module (SIM), that contains operator- and subscriber-specific data that enable users to be authenticated and sessions (voice or data) to be encrypted over the air. A key point is that only the link between the device and the base station is encrypted (i.e., not the end-to-end session).

GSM uses licensed spectrum and has been standardized to commonly operate in the 900 MHz, 1800 MHz, and 1900 MHz frequency bands. The latter band is primarily used in North America. In some parts of the world GSM is also operating in the 450 MHz and 850 MHz frequency bands, primarily as older analog mobile technologies are retired and the spectrum is released (or refarmed).

High-speed circuit switched data (HSCSD) is an evolution of the GSM standard that allows the network to use additional timeslots to provide a higher data rate—in theory, up to 115 Kbps. This technology has not been widely deployed.

GPRS, which was mentioned earlier in this paper, is a packet-based mobile data system that is, in theory, capable of providing up to 115 Kbps. Specific device support is required, as is hardware and software upgrades to the radio network and new infrastructure in the core network. It does, however, use existing licensed spectrum bands. GPRS was designed with Web and data-based applications in mind. Because it is a packet-based system and one without any adequate method to prioritize sessions among users, GPRS is susceptible to high latency and erratic bandwidth. GPRS was thus established with an always-on capability, meaning that a device could establish a context at switch-on, or at the push of a button, to reduce the effects of latency on device applications that would otherwise need to setup a session and then connect to a peer application or service. Despite being an always-on technology, few operators choose to charge for the connected time, and most charge by volume of data transferred (either UL or DL).[10]

Enhanced data rates for GSM evolution (EDGE) was originally designed to upgrade the bandwidth capability of both HSCSD and GPRS. Base station

[10] There are a variety of classes of GPRS device. These classes differ not only in their ability to support various data rates, but also in their ability to simultaneously support voice and data sessions. The latter is important if the device is being used to support access to a data-based application and the user wishes to speak with someone at the same time.

hardware and software has to be upgraded to support EDGE; however, the cost of doing so is significantly less than building a new 3G network. Specific device support is also required. EDGE is primarily deployed by operators who have no 3G spectrum or who have had perceived issues with the timing or availability of 3G technologies. In some cases, EDGE has been seen as a viable "cheap" alternative to 3G, where an operator has used 900 MHz to deploy GSM in rural areas and needs a data rate of 100–200 Kbps. EDGE theoretically supports data rates of up to 474 Kbps; EDGE evolution is expected to enhance this to approximately 1Mbps in the future. Although it has no further prioritization capability over GPRS, it does have significantly more bandwidth and capacity to share among users, providing for a better user experience.

	Real-time data transactions	Nonreal-time data synchronization	Interface to head office IT systems	Customers' access to helpdesk	
				Data	Voice (real time)
EDGE	viable	viable	viable	viable	not viable for VoIP
The primary driver for EDGE is its wider coverage (using 900 MHz spectrum, for example) and availability, which make it commercially more viable than less mature technologies. The potential drawback with EDGE is that, where MFI applications do require significant bandwidth and capacity, the ability of the cellular network to meet the availability requirement may be impacted by other users of the radio network. This can be overcome only by agreeing performance targets with the relevant service providers but may result in a price premium.					

3rd Generation Mobile (3G) Wideband CDMA (WCDMA) is the predominant 3G technology deployment in the world today.[11] It is primarily deployed in the 2100 MHz licensed spectrum band. However, in many jurisdictions, operators are now being allowed to deploy the technology using existing 900 MHz or 850 MHz spectrum—primarily to drive greater coverage. The higher bandwidth and capacity made available by WCDMA networks make possible a number of additional services, such as video calls, video streaming, mobile television, and simultaneous voice and data calls. Although the business model for these services has not been proven, and there is a strong dependency on the type and quality (read battery life) of devices, the opportunity for mobile to provide an increasing number of data-based services and applications is significant.

[11] According to ITU's definition, 3G technologies include WCDMA, CDMA2000 (the successor to 2G CDMA IS-95), time division–code division multiple access (TD–CDMA), and time division–synchronous code division multiple access (TD–SCDMA), EDGE, digital enhanced cordless telecommunications (DECT), and worldwide interoperability of microwave access (WiMAX). WCDMA is used in both the Japanese Freedom of Mobile Multimedia Access (FOMA) system and the European Universal Mobile Telecommunications System (UMTS), the latter being the predominant 3G technology deployment in the world today. CDMA2000, WiMAX, and EDGE are covered elsewhere in this paper. TD-SCDMA is being strongly promoted by China. The rest are presently niche market technologies.

WCDMA offers both CS-based voice services and PS-based data services. The PS-based data services provide typical data rates of up to 384 Kbps DL and 64 Kbps UL in WCDMA networks currently deployed. Upgrades to 14 Mbps (DL) via high-speed downlink packet access (HSDPA) and 11.5 Mbps (UL) with high-speed uplink packet access (HSUPA) are currently coming to market. HSDPA offers latency figures of approximately 120 ms, compared to 300 ms for WCDMA.

	Real-time data transactions	Nonreal-time data synchronization	Interface to head office IT systems	Customers' access to helpdesk	
				Data	Voice (real time)
WCDMA	viable	viable	viable	viable	viable for VoIP with HSDPA & HSUPA
In the near term WCDMA remains relatively immature and thus more expensive to deploy than competing technologies. High capacity and bandwidth capability, plus evolution of the standards, make it a viable future MFI application solution. Deployment of WCDMA using 900MHz or lower frequencies will significantly improve coverage and hence commercial viability of using this technology across all MFI applications.					

CDMA IS95 Revisions A and B (also known as CDMAOne) was pioneered by Qualcomm. IS95 is typically deployed in the 800 MHz or 1900 MHz frequency range but has been deployed in the 450 MHz, 900 MHz, and other ranges. It has both CS and PS capability, providing for voice services and data rates of up 14.4 Kbps for IS95-A and 115 Kbps for IS95-B. It thus compares favorably with GSM and GPRS. There is no SIM, so the ability of a user to change networks, change devices, and maintain services and numbering are a little more difficult to do (without operator intervention). Device variety is not as extensive as with GSM. Although CDMAOne supports SMS text capability, it has been historically poor in its support of supplementary services; to some extent this has been addressed by vendor-specific (IS41) intelligent network (IN) based solutions. Furthermore, CDMAOne has been slow to provide roaming in a standardized manner, which has impacted its ability to provide services for the traveler.

3G CDMA 2000 1xRTT, evolution–data/voice (EV–DV), and evolution–data optimized (EV–DO). 1xRTT is an evolution of IS95 that effectively doubles network capacity and provides a data rate capability of up to 144 Kbps. CDMA2000 EV–DV supports DL data rates up to 3.1 Mbit/s and UL data rates of up to 1.8 Mbit/s. It is compatible with CDMAOne networks; however, in 2005 Qualcomm indefinitely halted the development of EV–DV because of a lack of carrier interest. EV–DO was designed as an evolution that would support high data rates with very low latency and could be

deployed alongside a wireless carrier's voice services—meaning an overlay network build would be required. The network is entirely packet based—it was designed to be operated end-to-end as an IP-based network. Although it was not intended to support voice, with native quality-of-service support, it is feasible to support VoIP.[12]

	Real-time data transactions	Nonreal time data synchronization	Interface to head office IT systems	Customers' access to helpdesk	
				Data	Voice (real time)
CDMA2000 EV–DO	viable	viable	viable	viable	viable for VoIP with Rev A
CDMA2000 is more mature than WCDMA and generally operates at lower frequencies (e.g., 800 MHz), which should equate to a high commercially viable model for rural deployment. However, the lack of widespread deployment outside of North America means that the equipment is more expensive and there are questions regarding its longevity.					

For all the mobile technologies discussed here, the engineering of the mobile network is a critical factor in achieving the expected end-user experience and performance of a given application. The presence of mobile coverage in the relevant locality does not guarantee the MFI application will function as intended. Coverage providing voice services will certainly enable coverage of bearer technologies, such as SMS (and unstructured supplementary service data [USSD], for that matter), but this does not necessarily mean that one will have access to the required packet data technologies, such as GPRS or EDGE.[13]

Wide-area wireless technologies with limited mobility

Wireless local loop (WLL) is a generic term that is used to describe the delivery of POTS and Internet services in the last mile. The actual technology used can be any one of a number described in this document, such as LMDS, GSM, or CDMA; it will thus not be discussed further.

Local multipoint distribution service (LMDS) IEEE 802.16 is a line-of-sight broadband wireless access technology governed by IEEE 802.16 and conceived as a broadband, fixed wireless, point-to-multipoint technology to be used in the last mile. It is primarily being used as a backhaul technology

[12] There are two revisions of EV–DO: Rev A supports 3.1 Mbps DL and 1.8 Mbps UL, and Rev B is a multicarrier version of Rev A, which ultimately supports 4.9 Mbps DL per carrier (so one could theoretically achieve 14.7 Mbps DL, for example). It provides more flexibility for asymmetric services and is capable of supporting high-definition video. Rev A is currently deployed and supporting VoIP services.

[13] Some handheld devices can certainly show the presence of the capability, but they will not provide any indication of the bandwidth or the capacity available in that part of the network. This can be understood only via direct discourse with the operator—who could indicate how much bandwidth per user is ordinarily available.

and not as an end-user technology. LMDS commonly operates on microwave frequencies across 26 GHz and 29 GHz bands but can, in theory, use any spectrum in the 10–66 GHz range. Bandwidth and reliability depend on radio link length and modulation method used. In general, deployment links of up to 5 miles (8 km) from the base station are possible, but distance is typically limited to about 1.5 miles because of rain fading attenuation constraints. It has not enjoyed widespread success and is likely to be replaced with WiMAX.

Multichannel multipoint distribution service (MMDS) was originally produced to provide cable television services. MMDS uses a lower frequency than LMDS and has less capacity but a larger range. As with LMDS, MMDS does not address mobility or portability needs and thus does not necessarily offer the value to differentiate from wired broadband services. Moreover, the cost structure in most developed areas is likely to be higher than an equivalent wired service. MMDS spectrum is not approved for mobile services. As with LMDS, it has not enjoyed widespread success.

	Real-time data transactions	Nonreal time data synchronization	Interface to head office IT systems	Customers' access to helpdesk	
				Data	Voice (real time)
LMDS	not recommended with handheld	not recommended with handheld	viable	not recommended with handheld	not recommended
MMDS	not recommended with handheld	not recommended with handheld	viable	not recommended with handheld	not recommended
LMDS and MMDS should be considered as niche market solutions to provide branch connectivity only. They are not particularly successful as end-user technologies because the high bandwidth and high frequency nature of these technologies make them more expensive for end-user-related services. The likely obsolescence created by WiMAX would suggest that one should not even consider these; however, this is possibly a timing issue.					

Microwave generically refers to spectrum in the 300 Mhz to 300 GHz range (covering ultra-high frequency [UHF], super-high frequency [SHF], and extremely high frequency [EHF]). Most of the radio technologies described in this paper are actually microwave technologies. However, the context here is specific to the use of microwave radio to provide point-to-point links—these can be high bandwidth links (from 64 Kbps to tens of Mbps) of up to 100 km in length. Latency can be low but somewhat depends on climatic effects and interference. Before the advent of fiber optic, microwave radio links were used extensively to connect network elements and to interconnect networks. Microwave radio link technology is today primarily

used as a cost-effective backhaul capability to connect network entities. It is also typically used in a multiplexed consumer environment to connect a PBX or quantities of exchange lines at an enterprise premises to a telephone exchange.

	Real-time data transactions	Nonreal time data synchronization	Interface to head office IT systems	Customers' access to helpdesk	
				Data	Voice (real time)
Microwave	not recommended	not recommended	viable	not recommended	not recommended
Microwave remains a viable technology but needs to be assessed on a case-by-case requirement—both in terms of business case and performance (primarily because of the climatic effects and dependent on the distances of the radio links involved). The usage anticipated would be very much toward remote branch applications but could also be used to provide the backhaul for a shorter range access technology, such as WiFi, which could then be used for some of the handheld-device type applications. The latter may not be viable on its own, but in conjunction with a branch data requirement, the business case would be much improved.					

WiMax IEEE 802.16 is a long-range broadband data system that typically uses licensed spectrum to deliver a point-to-point connection to the Internet—linking an ISP with a network entity or an end user. Different 802.16 standards provide different types of access, from mobile (similar to data access via a cellphone) to fixed (an alternative to wired access, where the end user's wireless termination point is fixed). Commercial deployments today are in fixed broadband—rather than mobile—and are primarily being used to provide last mile connectivity, or backhaul, in areas where it has thus far been commercially not viable to provide such access. We expect mobility products to still be at least one year away from commercial deployment. Although primarily a wireless broadband data network, the advent of VoIP and native quality of service capabilities enable WiMax to offer quality voice services at relatively low cost (being an all-IP network). No supplementary services are presently specified.

Typical user data rates for WiMax suggest 10 Mbps DL and 5 Mbps UL are possible. Latency figures of 30 ms suggest significant performance improvements beyond currently deployed 3G technologies. The high spectral efficiency and use of multiple-in-multiple-out (MIMO) antennae technology mean that significant base station coverage and capacity can be provided at a much lower cost than other technologies available today. There is no uniform global licensed spectrum for WiMAX, although the WiMAX Forum has published three licensed spectrum profiles: 2.3 GHz, 2.5 GHz, and 3.5 GHz in an effort to decrease cost. Economies of scale dictate that the more WiMAX embedded devices (such as mobile phones and WiMAX-embedded laptops) are produced, the lower the unit cost. Similar

economy-of-scale benefits apply to the production of base stations. In the unlicensed band, 5.x GHz is the approved spectrum profile.

	Real-time data transactions	Nonreal time data synchronization	Interface to head office IT systems	Customers' access to helpdesk	
				Data	Voice (real time)
WiMAX	viable	viable	viable	viable	viable for VoIP
WiMAX is the most immature of these access technologies. However, the hype (bandwidth, capacity, coverage, latency, quality of service, and cost) and the adoption of WiMAX as a 3G cellular technology suggest a degree of longevity that may carry it through to a 4G cellular technology. Commercial deployments in fixed networks, to provide backhaul, show great promise (i.e., factual performance is close to the hype); however, the next 6–12 months will determine whether the same can be said of the cellular variants of WiMAX. WiMax is nonetheless likely to make WiFI, LMDS, and MMDS technologies obsolete.					

Wireline technologies

The **plain copper** network is the traditional medium for transporting both voice and data signals in the wireline CS environment. The copper network is widespread in the developed world and is thus a cheap and "sunk" cost over which one can deploy services. The main service running on copper cables has traditionally been POTS, which describes the voice-grade telephone service that remains the basic form of residential and small business service connected to the PSTN. It is the most reliable telephony-related service in existence and has an availability in excess of 99.999 percent. POTS uses a pair of wires from the telephone exchange to the end user—typically powered by -48V direct current (DC) at the exchange. Services include bidirectional (full duplex) voice path, with frequency range of 300–3400 Hz (human ear "tuned"); call-progress tones, such as dial tone and ringing tone; and subscriber dialing. Many additional calling features have evolved and become available to these POTS lines over time, including voicemail, calling line identification, call waiting, speed dialing, conference calling, and so on. Signaling information is transmitted in one of two forms: either via tone dialing (paired dual-tone multi-frequency tones to signify digits dialed) or dial pulse (sequences of make and break of DC voltage, to signify digits dialed).

Integrated services digital network (ISDN) is a means of simultaneously delivering voice and data over copper and has been for all intents and purposes superseded by xDSL.

Digital subscriber line (xDSL) is a family of technologies that provides digital data transmission over the copper wire pair of a local telephone network. DSL uses high-frequency (>25 KHz) signals, whereas regular voice telephony services use low-frequency (0–3.4 KHz) signals. The technology

requires a filter and specialized modem in the consumer premises and a digital subscriber line access multiplexer (DSLAM) at the telephone exchange to separate voice from data. Simultaneous voice and data is possible. Typically, DL speed of consumer DSL services ranges from 512 kbps to 24 Mbps, depending on DSL technology, line conditions, and service level implemented. Recent advances in technology suggest that xDSL will be able to provide up to 100 Mbps in the near future. Services are configured as asymmetric or symmetric. Symmetric services are typically less common and more expensive to operate and tend to be associated with business services, including delivery of VoIP. Contention ratios are typically 50:1 for consumer services, whereas business services may be provided at a 1:1 contention ratio. The data rate degrades with distance from the exchange, a distance of no more than several kilometers is optimal, but many factors can impact the capability. Thus the ability to support high bandwidth and low latency services, such as real-time video (or indeed VoIP), can be quite unpredictable.

	Real-time data transactions	Nonreal time data synchronization	Interface to head office IT systems	Customers' access to helpdesk	
				Data	Voice (real time)
xDSL	viable	viable	viable	viable	viable for VoIP
DSL technologies will meet the requirement where there is available copper wire. This is a significant issue in rural areas, so DSL may in fact be viable only for branch-type applications in larger centers (particularly for Interface to HO IT Systems). In this instance it would also be competing primarily with microwave technology.					

Coaxial cable networks are also used to deploy television and POTS services. These have been partly supplanted by **hybrid fiber coaxial** (**HFC**) networks, which use a mixture of fiber optic and coaxial cable to provide the capacity required to service large numbers of cable television customers.

An **optic fiber** is a length of glass through which wavelengths of light are transmitted to convey digital signals. These signals provide a high-capacity alternative to copper or microwave. Optic fiber is relatively cheap, but can be expensive to deploy, because it needs to be placed underground or underwater, and depending on distance, repeaters and amplifiers need to be installed (and subsequently maintained). Once in place, it provides a high-capacity high-availability system. The most common cause of failure is generally a result of the ground being dug up. Fiber optic is primarily used to connect network elements and interconnect networks (wired and wireless, national and international) and application systems (i.e., video servers, PBXs, etc.). It is not used to connect much in the way of end-user systems, except where a business may require a high bandwidth wide area

network (WAN) connection. The advent of high-definition multimedia is leading to the deployment of fiber to the node (FTTN) and fiber to the home (FTTH) networks in some municipalities (replacing HFC networks), but the cost is significant (primarily a consequence of significant subterranean deployment). The use of optic fiber is thus not directly applicable to rural communities at this time.

Short-range wireless access technologies

Short-range wireless access technologies do not have wide-area range and are thus nomadic in nature. They typically provide a wire-free user environment or complement another access technology—enabling local mobility where the main access technology could not provide it or local access to a particular service or capability.

Wireless fidelity (WiFi) IEEE 802.11 is the WiFi Alliance branded name for the IEEE family of standards addressing local area wireless networking. It is a radio technology using 2.4 GHz or 5.8 GHz unlicensed spectrum and typically has a range of 100 m. The technology consists of a wireless access point—deployed in a manner similar to a radio base station, albeit on a much smaller and cheaper scale—and a wireless data card (typically a Personal Computer Memory Card International Association [PCMCIA] card or equivalent built-in functionality within a computer or laptop). Data rates vary according to the specific substandard (802.11a at 54 Mbps, 802.11b at 1 Mbps, 802.11n at >100Mbps) but because unlicensed spectrum is used, it very much depends on the local environment (walls, materials) and the impact of interference. It is thus typically used in consumer, home office/small office, and hot spot environments to extend wired broadband (e.g., via cable or xDSL) into a wireless environment.

The primary issues associated with WiFi networks today continue to be security, quality of service (partly because of interference and partly because there is no prioritization capability for different types of traffic), and power consumption of WiFi devices. To date WiFi has been used primarily to extend data services; however, the advent of dual mode mobile phones that support WiFi has led to its use for voice calls. There are also standalone WiFi devices, but these are relatively rare. Dual mode WiFi devices provide standard cellular access on one hand and cheaper IP voice calls on the other. The latter may leverage enterprise calling rates via VoIP technology. Mechanisms exists (IP multimedia subsystem [IMS] and unlicensed mobile access [UMA]) to provide automated handover between the two radio interfaces. These may in fact optimize the use of the various networks based on parameters such as signal strength and cost of the various available networks at any given point in time.

Bluetooth IEEE 802.15.1 is a short-range (no more than 100 m) standardized wireless communications protocol specified by the Bluetooth Special Interest Group. It enables broadband (up to 3 Mbps) communication among a wide range of consumer electronics devices, including computers and mobile phones. It uses ISM unlicensed spectrum band (as per WiFi) and does not require line of site. Version 1 was prone to interference—particularly from WiFi—but Version 2 is much improved, with higher data rate and is available in most new devices. Bluetooth can be used for both voice and data; a typical application for the former is when a mobile phone and a hands-free device are used for voice communication.

Radio frequency identification (RFID) ISO14443 is an identification method that relies on storing and remotely retrieving data using very small tags or transponders, which can be as small as 0.05 mm square. The range of communication between the tag and the corresponding reader is typically a few centimeters—or no more than a few meters. Most RFID tags contain at least two parts: an integrated circuit for storing and processing information and an antenna for receiving and transmitting the signal. Tags themselves can be passive (no battery), which use power induced by the electric magnetic field of the reading device, or active (battery). RFID is increasingly used for inventory-style applications, such as those currently using bar codes, but in the context of MFIs, are typically being used to securely move data on a smartcard to another device, such as a mobile phone.

Near-field communications (NFC) ISO14443/18092/21481 is often confused with RFID and, indeed, has many similarities. The basic principles as described above, and articulated in ISO14443, are the same. It is primarily an extension of ISO14443, which is the proximity card standard, merging the capability of a smartcard interface and a reader into the one device. However, NFC is specifically focused on the mobile phone and has a much shorter range (typically a few centimeters, and certainly no more than 20 cm) and a much faster setup time. It is being applied to Bluetooth to automate the establishment of "pairing" to make this a fast and seamless user experience. There are no security mechanisms available, so eavesdropping and spoofing are possible, unless the relevant application implements an end-to-end security mechanism.

Infrared is a short-range data communication technology used primarily among computer peripherals, consumer electronics, and devices, such as mobile phones. These devices typically follow standards set by the Infrared Data Association (IrDA). Remote controls and IrDA devices use infrared light-emitting diodes (LEDs) to emit infrared radiation that is focused into a narrow beam. The beam is modulated (i.e., switched on and off) to encode

the data. The receiver uses a silicon photodiode to convert the infrared radiation to an electric current. It responds only to the rapidly pulsing signal created by the transmitter, and it filters out slowly, changing infrared radiation from ambient light. Line of sight, or near line of sight, is necessary for this to work reliably. Infrared does not penetrate walls, and so it does not interfere with other devices in adjoining rooms—but as such, it has limited range and capability. Although still provided with many mobile devices, it is gradually being replaced with Bluetooth.

Ultra wide band (UWB) IEEE 802.15.3 is another technology within 802.15 (which covers personal area wireless networks). UWB provides a maximum data rate of 480 Mbps over very short distances—typically of several meters. It is likely to use spectrum in the GHz range; however, standardization is not yet complete. It may replace Bluetooth in the long term, particularly as a high bandwidth application in consumer environments wherein one may need to transfer multimedia around the home. At this time, it does not have a realistic use in MFI applications.

Summary Evaluation

Table 2 provides a summary of the types of application requirements and how the various access technologies compare. The parameters for the service attributes should be revisited with specific MFI application solutions in mind, so that the capabilities of the access technologies can be reevaluated for fit and commercial viability. The data provided should be used as a guide, and they should not be regarded as set in stone because these attributes can vary enormously among service providers, and specific MFI application solution designs may have significantly different requirements.

The table shows that, on a purely technically viable basis, there are several technologies that are capable of providing solutions for rural connectivity—the emphasis is clearly on using an access technology that could be used in all aspects of delivering the suite of MFI applications, for a given MFI, because this simplifies the client and server application development, and hence cost of the solution. However, in practice, issues with coverage or service provider implementations may prevent this.

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Table 2: Mapping of MFI application requirements and available access technologies against connectivity service attributes

	MFI applications				
	Real-time data transactions	Nonreal time data synchronization	Interface to head office IT systems	Customers' access to helpdesk	
				Data	Voice (real time)
Connectivity Service Attributes					
Bandwidth	<100 Kbps	<100 Kbps	<1 Mbps	<100 Kbps	variable
Capacity	<50 Kbytes per transaction	<1Mbytes per synchronization	<1 Gbytes per day	<100 Kbytes per user	variable
Coverage & mobility	Nomadic, on location	Nomadic, as required	Fixed	Nomadic	Nomadic
Latency	<500 ms	<10 s	<500 ms	<500 ms	<480 ms
Quality of service	50:1 contention ratio Availability>99.9%	50:1 contention ratio Availability>99.9%	50:1 contention ratio Availability>99.9%	50:1 contention ratio Availability>99.9%	GoS<1% Availability>99.9%
Satellite	viable, long call setup	viable, borderline	viable, but not recommended[4/]	viable, but not recommended[4/]	viable, but not with VoIP
Cellular/mobile access technologies					
GSM	14.4 Kbps circuit switched data not optimal[1/]	14.4 Kbps circuit switched data not optimal[1/]	not viable	14.4 Kbps circuit switched data not optimal[1/]	viable, optimized
HSCSD	viable, long call setup	viable	not viable	viable	not viable for VoIP
GPRS	viable, data rate ok	viable, borderline	not viable	viable	not viable for VoIP
EDGE	viable	viable	viable	viable	not viable for VoIP
WCDMA	viable	viable	viable	viable	viable for VoIP with HSDPA & HSUPA
CDMAOne	14.4 Kbps PSD nonoptimal/115Kbps ok	14.4 Kbps PSD nonoptimal/115Kbps ok	not viable	14.4 Kbps PSD nonoptimal/115Kbps ok	viable, optimized
CDMA2000 1xRTT	viable	viable	not viable	viable	not viable for VoIP
CDMA2000 EV-DO	viable	viable	viable	viable	viable for VoIP with Rev A
Wide area wireless / limited mobility technologies					
LMDS	not recommended with handheld[2/]	not recommended with handheld[2/]	viable	not recommended with handheld[2/]	not recommended
MMDS	not recommended with handheld[2/]	not recommended with handheld[2/]	viable	not recommended with handheld[2/]	not recommended
Microwave	not recommended	not recommended	viable	not recommended[3/]	not recommended
WiMAX	viable	viable	viable	viable	viable for VoIP
Wireline technologies					
POTS[8/]	viable, not optimum	viable, not optimum	not viable	not viable	viable, optimized
xDSL	viable	viable	viable	viable	viable for VoIP
Short-range wireless access technologies[7/]					
WiFi[5/]	viable	viable	not recommended[6/]	not recommended[6/]	Borderline viable for VoIP
Bluetooth	viable	viable	viable	viable	viable
RFID	viable	viable	not relevant	not relevant	not relevant
NFC	viable	viable	not relevant	not relevant	not relevant
InfraRed	not recommended	not recommended	not recommended	not viable	not viable

NOTES:
"Viable"indicates that this option is technically viable; any comment otherwise indicates some criteria that makes this less than ideal.
[1/] Transactions can use SMS or USSD as a bearer; this, however, can be problematic without adequate service provider performance targets.
[2/] These technologies are better suited to being used with desktop type devices rather than handheld devices.
[3/] Microwave would provide significant bandwidth but may not be cost beneficial without additional business uses for this bandwidth, e.g., WiFi and localized use for remaining categories.
[4/] Cost would almost certainly be prohibitive.
[5/] WiFi is only viable with credible backhaul, such as Wireline or WiMax. In this sense it could be classified as "for localized use only."
[6/] WiFi does not have the performance or reliability in the short term to adequately support.
[7/] Short-range technologies are for localized use only—in other words, these maybe part of the solution but assume at least one other access technology is in use.
[8/] POTS assumes dial-up for data access. ISDN is not considered because it is superseded by xDSL.