

Terrestrial Wireless Connectivity

Technical Review - East Africa

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Executive Summary

This technical study reviews terrestrial wireless technologies, their status of implementation and outlines future trends in East Africa. Ten wireless technologies has been clustered in four main groups: Wireless LAN/MAN, CDMA2000, Proprietary CDMA and GSM.

The first group of technologies studies IEEE 802.11 (WiFi) and IEEE 802.16 (WiMAX) including mesh networks. The second group includes CDMA2000, the main 3G standard based on CDMA and two subprotocols 1X and EV-DO. The third group of solutions covers three proprietary systems and their future evolution: Navini, IPWireless and iBurst. Finally, we discuss the status of GPRS and EDGE, two mobile data services of GSM networks.

Recommendations and future work related to each of the technologies is included in each of the sections. A summary of conclusions and recommendations follows:

1. **IEEE 802.11-based solutions** using OFDM, including standard WiFi certified products are the **most suitable option** for rural community wireless networks with low investment capacity. The technology has a low starting cost in comparison with any other alternative.
2. **IEEE 802.16-based solutions** (WiMAX) are a promising technology in environments where Internet bandwidth comes at a very low price (urban). In a rural setup WiMAX will require high investments in the core infrastructure. As of today, WiMAX pricing model is not suitable for a community wireless network in a rural environment with low investing capacity. **Base stations price and energy requirements are prohibitive.**
3. **Mesh networks** in a rural environment **should be explored only when the network topology can fully benefit from them.** Many of the networks studied can be implemented using a simple and basic star topology where only one node (the central hub) needs to be constantly connected to power.
4. The study shows a **high penetration of CDMA2000 in the rural areas.** It is recommended that a **deeper study be undertaken of possible technical alternatives using CDMA2000** for upstream connectivity. The study should cover: integration of VoIP, guaranteed bandwidth and CDMA2000-based gateways.
5. Systems based on **proprietary solutions** as: Navini (SCDMA), IPWireless (UMTS-TDD), iBurst (HC-SDMA) **should be discarded** for community wireless development as they imply one single vendor locking. The transition of these companies and related technologies (smart antennas) into WiMAX is worth a follow up.
6. **GPRS and EDGE based solutions** can be an alternative **worth considering** for the Internet upstream connectivity. **Partnerships for rural connectivity with global operators** in the region as Safaricom (Telkom Kenya, Vodafone), MTN and Celtel (MTC) should be explored.

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1 Wireless LAN/MAN

1.1 *WiFi*

1.1.1 Introduction

The history of popular WiFi started as long as twenty years ago. Back in 1985 the U.S. Federal Communications Commission (FCC) decided to make several bands of the wireless spectrum available without a government license.

One of the radio bands was the "rubbish band of 2.4 Ghz", a part of the radio spectrum that was already allocated to other noisy equipment such as microwaves ovens. From 1985, one of those piece of the spectrum could be used not only for heating a glass of milk but also for Industrial, Medical and Scientific (ISM) purposes.

Although the spectrum was available, the technology that could operate in such a noisy band was not accessible to everyone. To improve communication efficiency in the "rubbish bands", the communication devices must "spread" the radio signal over a wide frequency range, a range several magnitudes higher than the minimum required. The communication devices used a military technique known as "spread spectrum". The history of spread spectrum dates back to 1940. The very first version of a spread spectrum method was invented by the actress Hedy Lamarr. The technology was patented as "Secret Communication System" and used to guide torpedoes. The technology was widely used for military communication systems after the patent expired in the 1950s.

It was not until 1990, when the Institute of Electrical and Electronics Engineer known as IEEE, formed a new working group, 802.11. One of the roles of the IEEE was to promote industry standards. Having the spectrum available (unlicensed ISM) and the military technology accessible (spread spectrum) was not enough to see personal wireless broadband taking off. A communication standard was needed.

Contrary to other standardization organizations as the European Telecommunications Standards Institute (ETSI)¹, the IEEE's standardization process is open to any individual irrespective of their industrial affiliation. The philosophy behind an IEEE Standard is somewhat similar to how Internet standards work: the mass adoption of a certain technology can be achieved only by representing a broad "consensus".

Although "IEEE 802.11 pre-standard devices" were manufactured, it was not until 1997 that IEEE approved the Standard IEEE 802.11 - Wireless Local Area Network (Wireless LAN). The first standard, IEEE 802.11, was soon followed by another IEEE standard called IEEE 802.11b in 1999 ("The B standard"). In order to guarantee interoperability between different implementations of the IEEE Standard 802.11, a new organization called Wireless Fidelity (WiFi, known as WFA today) was launched.

1 The ETSI is the organization behind GSM or TETRA, the cell phone and professional mobile radio system.

1.1.2 Indoor wireless communications

The IEEE Standard 802.11b was designed to operate in indoor environments and to deliver a maximum of 11 Mbps² using a spread spectrum technique called Direct Sequence Spread Spectrum (DSSS). Although it was initially conceived as a short range, low power wireless technology for indoor use, it did not take long until vendors created WLAN-based products in point-to-point (PtP) and point-to-multipoint (PtMP) outdoor solutions in metropolitan area networks (MAN) and rural areas.

Due to the mass adoption of the technology, the cost of a radio implementing IEEE 802.11 became insignificant in comparison with traditional telecommunication equipment. The possibility of using low cost radio to carry Internet data and voice encouraged vendors and users to find innovative approaches to overcome the IEEE 802.11b native problems in outdoor environments.

WiFi is no different to any other type of technical development: vendors prefer to implement a non-compliant solution that wait for standardization to take place. Taking advantage of the low cost of radio chips, non-compliant solutions were continuously developed and several players added proprietary extensions to the protocol to overcome the lack of performance in some particular scenarios (e.g. presence of hidden nodes, lack of Quality of Service, big overhead in Voice over IP (VoIP), etc.).

Although the work of IEEE continued and enhancements for Quality of Service are now standardized (Wireless Multimedia in IEEE 802.11e), proprietary solutions are still a trend in wireless outdoor solutions.

With the conclusion of the IEEE 802.11e standard in late 2005, WiFi will keep growing stronger since it enables deployment of wireless infrastructure at a very low cost.

1.1.3 WiFi and Community Wireless Networks

WiFi was never intended to be the best radio technology for long distance point-to-multipoint radio links but WiFi will always be remembered as the technology that did for to the radio world what the open architecture did for the personal computer.

Reasons for its worldwide success in data infrastructure can be found in the low cost of the radio equipment due to its mass production, the possibility of easy integration with personal computers and operative systems, the existence of a certified interoperability between vendors (WiFi) and the possibility of finding a very favourable regulatory framework in comparison with other radio technologies and related services.

WiFi based solutions are probably the best option for rural networks with low investment capacity. The technology has a low starting cost in comparison with operator oriented type of solutions such as WiMAX.

² The nominal speeds of wireless standards do count number of possible bits on the “air”.
Due to different overheads, the effective speed for a Internet communication is normally far from the nominal rate.

1.2 *WiMAX*

1.2.1 Introduction

During the latest years, WiMAX has been marketed as the future broadband wireless standard. Many Wireless Internet Service Providers (WISPs) and governments running solutions based on IEEE 802.11 are considering investing in WiMAX-based solutions but they are not sure what exactly WiMAX can offer them and especially at what price. Is WiMAX the latest “techno-hype” or does it open realistic new opportunities for broadband wireless connectivity?.

This introduction aims to serve as a reference of some of the technical differences between IEEE 802.11. The document assumes that the reader is already familiar with IEEE 802.11-based solutions and want to know what IEEE 802.16 can offer. It is important to mention that this document just provides an overall comparison and that in many cases, IEEE 802.11 based solutions (wireless access points and routers) include enhancements both in the physical and IP layer that are not even mentioned here.

IEEE 802.16³ has been designed specifically for point to multipoint outdoor environments which a single media access control (MAC) that can accommodate different physical layers (PHY) in the frequency range of 11-66 Ghz (and lately sub-11 Ghz). In simple terms, although the radio modulation technique changes depending on the frequency of operation, the packet format, medium sharing or the error control techniques are independent of the frequency of operation. Many of the “electronics” used in IEEE 802.16 are not dependent of the frequency of operation.

IEEE 802.16 is intended to satisfy wireless ISP and industry requirements in almost all possible scenarios and to become the facto broadband outdoor wireless standard. That said, it does not necessary mean that other technologies should be considered automatically obsolete. In many cases the discussion is about spectrum efficiency, regulatory aspects, access to technology or investment costs.

Discussions should focus on the appropriateness of one solution in the local context rather than on a purely technological comparison.

There is no simple, general answer to the question “WiFi or WiMAX?”.

3 IEEE approved the initial 802.16 standard for wireless MAN for the 11-66 GHz frequency range in December 2001. The 802.16a extension for sub-11 GHz was approved in January 2003. The 802.16-2004 standard was ratified by the IEEE in June 2004. The 802.16e standard is being reviewed by IEEE was to be approved in late 2005. Industry speculation suggests the standard will be officially named 802.16-2005. The purpose of 802.16e is to add data mobility to the current standard, which is designed mainly for fixed operation.

1.2.2 Technical differences

The WiMAX Forum, an organization formed in 2001 and dedicated to certifying the interoperability of broadband wireless access products, define WiMAX as the Worldwide Interoperability for Microwave Access. WiMAX and WiFi are not technologies, rather a certification of interoperability with the IEEE 802.16 and IEEE 802.11 family of standards. As in the case of WiFi, we use WiMAX to refer to the IEEE 802.16 family of standards for “simplicity”.

1.2.3 Range and Coverage

IEEE 802.11 is a wireless LAN (indoor) protocol that was designed to operate in small cells (up to 100 meters) and that in the design phase never was considered as a point-to-multipoint outdoor solution. IEEE 802.11 MAC suffers from the hidden-node problem and is known for bad performance in long distance links⁴ with many stations.

The access method in IEEE 802.11 (CSMA/CA) assumes that all nodes that are communicating with the access point can hear each other to avoid collisions. Collisions in IEEE 802.11 can be avoided if all nodes can effectively sense if the channel is occupied or not. Unfortunately, this requirement can not always be satisfied when implementing IEEE 802.11 based network in an outdoor environment. When more than ten <someone might say twenty> stations are associated to the same access point and the rate of collisions increases, the consequent backoffs and retransmissions introduce a significant waste of airtime resources.

In simple terms, IEEE 802.11 performs badly when many users are linked to an access point in an outdoor environment. In order to solve some of these problems, proprietary solutions based on the principle of “polling the clients” or bandwidth reservations in the IP layer have been implemented. By introducing “polling” in IEEE 802.11, the access point decides at which moment a station is granted to talk to the access point. The hidden node problem is nothing new and even before IEEE 802.11 was standardized there were already modifications to solve the problem (e.g. Karlnet TurboCell). Many other proprietary solutions became available but interoperability between vendors was not guaranteed.

The development of IEEE 802.11 has not stopped and today (November 2006) there are already products that implement the quality enhancement IEEE 802.11e. The WMM (WiFi Multimedia), part of the IEEE 11e standard, defines four categories derived from 802.1d. The WMM allows to give different priorities to specific types of traffic (voice, video, best effort and low priority data).

If we now consider similar aspects with WiMAX, we find that IEEE 802.16 was born to be a wireless metropolitan outdoor solution and was designed as an outdoor solution from the beginning. IEEE 802.16 is designed to operate in a typical cell size of 7 to 10 kms and can handle distances up to 50 Kms. The hidden node problem was solved

⁴ The effects of the distance needs to be consider in links operating over 3 Kms

from the very early design phase by including DAMA-TDMA for the uplink where the base station allocates slots to each station. IEEE 802.16 DAMA-TDMA uses the same principle that a satellite network where the stations (clients) can not hear each other.

To be able to operate better in non light-of-sight environments (NLOS), IEEE 802.16 included a more complex modulation based on 256-points of Fast Fourier Transform (FFT) of OFDM instead of the 64-points in IEEE 802.11a/g. By including 256 instead of 64, IEEE 802.16 has a better non-line of sight capability. IEEE 802.16 can tolerate 10 times more multi-path delay spread than 802.11.

IEEE 802.16 can make better use of the available channel resources in an outdoor environment since the base station schedules the subscribers using dynamic scheduling algorithms. The number of subscribers does not effect the number of collisions and retransmissions of packets.

As mentioned before IEEE 802.11 coverage is limited by the hidden node problem. IEEE 802.11 performs well in a indoor environment or in point-to-point solutions but is not optimal for an outdoor point-to-multipoint solution. The possibility in IEEE 802.16 of dedicating certain bandwidth to a subscriber, by means of TDMA, without worrying about hidden nodes allows the introduction of smart antennas. A smart antenna combines multiple antenna elements with a signal-processing capability and can optimize its beam pattern automatically. IEEE 802.16 will allow advance antenna techniques and hence better cell planing.

IEEE 802.16 has also included support for mesh networking. In mesh networking each subscriber access point is also part of the routing infrastructure. IEEE 802.16 makes a smarter “adaptive” modulation than IEEE 802.11 and enables optimization of each subscriber’s data rate by allowing the base station to set modulation schemes on a link-by-link basis. A subscriber station close to the base station can use high data rate modulation as 64QAM, while the weaker signal from a more remote subscriber might only permit the use of 16QAM or QPSK. The adaptive modulation included in the IEEE 802.16 MAC also allows to have different modulation method for downlink and uplink bursts.

1.2.4 Scalability and throughput

While IEEE 802.11 has a fixed channel bandwidth of 20 Mhz, IEEE 802.16 has the flexibility of allocating different bandwidth in each radio channel, from very narrow channels of 1.5 Mhz to a maximum of 20 Mhz. The possibility of setting different channel bandwidth enables frequency reuse and better cell planning. While the number of non-overlapping channels in IEEE 802.11b is 3 and 8 in IEEE 802.11a, the number of IEEE 802.16 channels is limited by total available spectrum.

When it comes to data rates, IEEE 802.11 can provide a peak data rate of 2.4 bps/Hz. In the 20Mhz channel, i.e IEEE 802.11 can provide a maximum of 54 Mbps. IEEE

802.16 allows a theoretical maximum of 70 Mbps in a 20 Mhz channel. The level of actual throughput will depends on Light-of-sight, distance, air quality, interference and other factors (real values of 50 Mbps are expected).

1.2.5 Quality of Service

IEEE 802.11 has included better quality of service in the new standard IEEE 802.11e. Unfortunately IEEE 802.11e will only support a limited prioritization on a single connection between the IEEE 802.11 access point and the station. On the other side, IEEE 802.16 has implemented QoS in a “per-flow” basis, where multiple connections between a subscriber station and a base station can have different QoS attributes.

QoS in IEEE 802.16 is achieved by means of “polling”. The basestation polls the subscribers stations for bandwidth requests and schedules the traffic according to their responses.

1.2.6 WiMAX and Community Wireless Networks

From a technical point of view, there is no doubt that WiMAX addresses most of the challenges that broadband outdoor wireless faces. When selecting the technology to use in a community wireless network, it is important to consider if the scenario requires those extra functionalities and whether it is worth the added price. WiFi or proprietary solutions build at the top of IEEE 802.11 technology offer far better value than WiMAX or similar solutions do today.

The explanation is simple. WiMAX is targeting the end consumer as such. It has the backing of the leading telecommunication vendors and expects to take over Metro Area Networks. The MAN market is mainly urban and generates large returns after backbone infrastructure investment. In rural areas, the investment costs of WiMAX are out of reach for any community network. Price of base stations ranges at about 10,000 USD for a single-sector and can go up to 30,000 USD for a multi-sector deployment. To the price of the equipment, energy backup, towers and security of the premises must be added. The current business models of metropolitan wireless solutions are not very different to those of cellular telephony. The cost of clients (350-500 USD) is “subsidized” by the costs of the central infrastructure. This model does not work in a rural environment where investments costs are very limited. WiFi provides a more linear model: High quality outdoor base stations are available for less than 1000 USD and indoor clients are available under the 100 USD price tag.

WiMAX is a promising technology for rural networks in environments where Internet bandwidth comes at a low price. Building a WiMAX network connected to a satellite network is definitely over-dimensioning. Most of the rural setups using a satellite connection are in the 64/128 Kbps to 512/1024 Kbps range.

When it comes to energy, WiMAX solutions are energy-hungry. A typical base station operating 6 sectors will need 1500 W. Clients move in the range of 15-30W. A base station requires a reliable source of energy (generator or a solar-powered backup system).

A good example of how WiMAX is currently being deployed and also of the amount of media confusion that is always generated is available in Kenya; Kenya Data Networks (KDN) signed several deals with Alvarion to roll out the technology in five cities: Kisumu, Eldoret, Diani, Ukunda and Malindi. Although a lot of media attention was given to the deal, it is worth noticing that most of the equipment that KDN runs is not WiMAX. Most of the data carriers in Africa are using some sort of pre-WiMAX solution. Pre-WiMAX solutions integrate some of the advantages of WiMAX into existing products, heavily based on 802.11 hardware.

Some of the most popular vendors of WiMAX equipment include: Alvarion, Airspan, Alcatel, Motorola, Redline and Navini Networks.

1.3 Mesh Networks

1.3.1 Introduction

Mesh networks differ from traditional networks in the way that connections are established. In a traditional network the connection path between wireless nodes is static while in mesh networks reconfiguration can take place when links are broken or blocked.

Mesh networks aim to provide extra reliability by being able to self-heal. That extra feature comes at the price of including a new protocol into the network capable of discovering and communicating the status of the alternative paths. Unfortunately, there is a single dominant technology in mesh networks and most of the commercial solutions are based on proprietary protocols. The major free implementations use AODV, OSLR, DSR or (A)-HSLR. There is general agreement that an effective mesh network requires that each of the wireless nodes have more than one radio and that a critical number of nodes have access to reliable power.

1.3.2 Mesh Networks and Community Wireless Networks

Mesh networks in a rural environment should be explored only when the network topology can fully benefit from them. Many of the networks studied can be implemented using a simple and basic star topology where only one node (the central hub) needs to be constantly connected to power.

If mesh networks using low cost WiFi devices are to be considered, adequate support for energy in the critical nodes of the infrastructure must be part of the planning and budgeting.

Commercial mesh networks are commonly deployed in urban environment using a single vendor solution. That has been the case of the mesh (or partial) network being implemented in Nairobi, Mombasa, Kisumu and Eldoret by Kenya Data Networks (KDN). The network, known as “Butterfly”, uses Strix Systems Access/One Network Outdoor Wireless Systems (OWS) and Indoor Wireless Systems (IWS).

Strix system uses a multi-radio, multi-channel, multi-RF solution based on a proprietary technology. As with many other vendors, Strix also promises a simple upgrade to WiMAX.

Other proprietary solutions are available from Tropos, Motorola, Cisco, SkyPilot and Firetide. There are numerous free and open implementations that do or can integrate mesh technology: LEAF, ME2000, GNAP, Amsel, Pebble, CUWiNware, Metrix, Pebble, WRAPCOP, Voyage, AstLinux, Locustworld, Meshnode, etc.

2 CDMA2000

2.1 CDMA2000 1x

CDMA2000 is a family of standards that includes CDMA2000 1X and CDMA2000 1xEV-DO technologies. CDMA2000 is backwards compatible with cdmaOne (IS-95), the first CDMA system from Qualcomm.

CDMA2000 is a competitor of the other major 3G standard UMTS. It operates in a large range of frequencies (400, 800, 900, 1700, 1800, 1900, and 2100 Mhz) and African GSM operators are deploying a parallel infrastructure in the 450 MHz and 800 MHz frequency bands as it is significantly less expensive than deploying other wireless technologies in the higher frequency bands.

The typical CDMA2000 cell size is 29.4 Kms in 800 Mhz, and it is the technology of choice for most liberalized African Local Loop Operators for the provision of fixed-line services. The most common CDMA2000 networks (1X) has built-in data capacity of 153kbps, and can be upgraded to higher speeds using EV-DO.

2.2 CDMA2000 EV-DO

EV-DO is the high-speed data component/layer of CDMA2000 networks. Currently, networks are upgrading to new version of EV-DO (revision A) which increases the uplink bandwidth of a cellular sector to 1.8Mbps and downlink to 3Mbps.

2.3 CDMA2000 and Community Wireless Networks

MTN (800 Mhz) and UTL (450 Mhz) in Uganda and Zanzibar Telecom in Tanzania are operating CDMA2000 networks. CDMA2000 telephones are available under 100 USD capable of providing voice and data services. Internet access is available for a flat rate of 60 USD/month. Although a theoretical limit of 153 Kbps is possible, tests conducted in Uganda gave an average throughput in the rage of 60-100 Kbps.

In Rwanda, Terracom is rolling a CDMA2000 in 800 Mhz and in Kenya E.M. Communications (1900 Mhz), Flashcom (1900 Mhz) and Telkom Kenya (450 Mhz) have CDMA2000 licenses.

Due to the high penetration of CDMA2000 in the rural areas, a further study is justified on solutions built upon CDMA2000 infrastructure. The study should consider aspects as: integration of VoIP with CDMA2000, guaranteed bandwidth and dedicated CDMA2000 based gateways.

The main vendor of CDMA2000 in the region is Huawei.

3 Proprietary CDMA/SDMA

3.1 *Navini*

3.1.1 Introduction

TD-SCDMA (Time Division-Synchronous Code Division Multiple Access) is a third generation mobile (3G) standard developed by the Chinese Academy of Telecommunications Technology, Datang and Siemens AG. The standard is an alternative to CDMA patented by Qualcomm.

Navini is a wireless broadband company funded by one of the authors of the first initial draft of TD-SCDMA. Navini Networks uses a protocol derived from TD-SCDMA to achieve NLOS coverage. Their flagship is “Ripwave”. Ripwave runs in 2.4 GHz ISM and 2.6 GHz MMDS spectrums.

Navini’s base station uses smart antennas. Smart antennas can electronically steer the beam and mitigate the impact of unwanted signals. The base station is software upgradeable to IEEE 802.16e while supporting smart beamforming functionality.

3.1.2 Navini and Community Wireless Networks

A company known as Benson Online <http://www.bol.co.tz> is using the TDD-MC-SCDMA (Time Division Duplex, Multi Carrier, Synchronous Code Division Multiple Access) technology from Navini in Dar es Salaam and Arusha.

The RipWave, battery-powered modems, work almost anywhere in Dar es Salaam and Arusha, using about 3-5 Base Stations in each region. The cost of the RipWave modem ranges from 350 to 500 USD.

Navini is also being rolled out in Ghana by <http://www.internetghana.com>

One of the main drawbacks of Navini's proprietary technology is that is a single vendor solution. In the future it is worth studying the transition of Navini smart antenna into WiMAX.

3.2 IPWireless

3.2.1 Introduction

IPWireless is another proprietary solution based based on the implementation of the international 3GPP Universal Mobile Telecommunication System (UMTS) standard. Their solution uses TD-CDMA in air interface and Time Division Diplexing (TDD) to separate the uplink from the downlink. UMTS-TDD is not directly compatible with UMTS as they use different air interface technologies and frequencies of operation. IPWireless technology operates in a non line-of-sight environment Cell radius can be as large as 29km.

3.2.2 IPWireless and Community Wireless Networks

UMTS-TDD technology has been deployed in the six biggest cities of South Africa (2500-2686 Mhz) by Sentech <http://www.sentech.co.za> and in Dar-es-salaam, Tanzania (1900-1910 Mhz) <http://www.cats-net.com>).

Although IPWireless is a member of the “UMTS TDD Alliance”, interoperability and roaming between different UMTS TDD implementations is not guaranteed. A follow up on interoperable alternatives based on UMTS TDD should be included in a further study.

3.3 iBurst

3.3.1 Introduction

iBurst is a proprietary system developed by ArrayComm that now is being integrated in the IEEE 802.20 and ISO TC204 WG16 working groups. iBurst uses High Capacity Spatial Division Multiple Access (HC-SDMA) to optimize the use of bandwidth with the help of smart antennas.

In January 2006, the IEEE 802.20 Mobile Broadband Wireless Access Working Group adopted a technology proposal that includes the use of the HC-SDMA standard for the 625kHz Multi-Carrier Time Division Duplex (TDD) mode of the future IEEE 802.20 standard. By the end of 2006, the iBurst system is expected to be authorized as an official specification at IEEE802.20.

iBurst system uses fully adaptive smart antennas based on IntelliCell technology from ArrayComm. Each base station uses a small array of traditional antennas coupled with a processor that is able to selectively amplifies the desire signals. Opposite to conventional base stations the energy is not transmitted in all directions but beamed to the intended user.

3.3.2 iBurst and Community Wireless Networks

iBurst has been implemented in South Africa by Wireless Business Solutions and distributed by Tradepage. It is also available in Ghana <http://www.iburstghana.com> and in Kenya and Tanzania <http://africaonline.com>

Africa Online will commence iBurst wireless broadband services in Nairobi, Kenya's capital, with plans to expand service into Mombassa, Nakuru, Kisumu, and Nanyuki.

As Navini (SCDMA) and IPWireless (UMTS-TDD), iBurst (HC-SDMA) is a non-interoperable technology and implies vendor technology locking.

4 GPRS and EDGE

4.1 Introduction

GPRS and EDGE are two mobile data services that can be deployed in GSM networks

Packet-switched data under GPRS is achieved by allocating unused cell bandwidth to transmit data. Although a theoretical limit for packet switch data is 171.2 Kbps, realistic values range between 30 and 80 Kbps. As GPRS uses unallocated channels, the more occupied is the radio cell, the less capacity is available for data services. As operators normally make more money out of voice calls, data connections do normally have less priority.

A change to the radio part of GPRS resulted in Enhanced GPRS or EDGE (Enhanced Data rates for GSM). EDGE can achieve better data rates than GPRS (theoretically 3 times more). The main problems with the technology in rural environments is that the connection speed drops logarithmically with distance from the base station.

GSM operators in the identified countries are currently rolling out GPRS services nationwide, and EDGE in major urban areas.

As it is easier and cheaper for wireless carriers to migrate to EDGE than installing new equipment (UMTS or CDMA2000), it is expected that EDGE will coexist with its competing technology CDMA2000.

4.2 GPRS/EDGE and Community Wireless Networks

Safaricom in Kenya (GPRS, EDGE), MTN in Uganda, Celtel (Uganda, Tanzania and Kenya), MTN Rwanda (GPRS).

The pricing model is very different from country to country. In Tanzania the price is 0.8 USD/MB, in Rwanda there is a flat rate of 30 USD/month. In Kenya, Safaricom prices at 0.15 USD/MB.

GPRS and EDGE based solutions can be an alternative worth considering when a flat rate (Rwanda) is available. A further study should explore partnerships for rural connectivity with global operators in the region as Safaricom (Telkom Kenya, Vodafone), MTN and Celtel (MTC).