

Closing the Digital Divide: Towards wireless technology architecture for rural connectivity

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Abstract

Of late, demand for connectivity and broadband has considerably increased. However, developments in network technologies have always been trailing behind the actual demand and there is always an existing gap between what the users need and what technology is capable to offer. In many developed countries, wireless communication systems have been in use for voice communications for many years. However, the emergence of broadband technologies, such as xDSL and Cable Modem, saw the displacement at one moment, of the welcome the wireless technologies had enjoyed. Wireless technologies have however emerged as the solution to connectivity in developing nations especially in rural regions. In this paper we analyse different wireless technology alternatives that might be used for connectivity in rural regions to provide data and voice communication services. We also present proposed wireless connectivity architecture: the SRTR.

Key words: Digital Divide, Wireless Technology, Rural, WiMAX, WiFi, VSAT, Backhaul.

1. Introduction

Information has long been underlined as the backbone of development. What is of great concern is the access to it. This access to information has an array of attributes that include technology, which is the focus of our discussion. In general, the access capacity and the exchange of information can contribute to the development process of any nation, improving the following aspects:

Efficiency or the cost-production relation, *Effectiveness* or the quality of services and products (e.g. better attention in health through telemedicine), *Reach* or the capacity to have contact with new consumers or clients (e.g. artisans who reach the world market through the Internet, educationists who reach students at work or at home) and *Equity* or the fair distribution of development benefits in every society (e.g. remote rural

areas, the minority and handicapped populations). The whole range of those aspects depends squarely on the successful development of infrastructures such as transport, energy and telecommunications.

The transport infrastructure [14] was the epicenter of economic development in the 20th century and envisaged as a vehicle for improving the quality of life [14] of people world wide. The 21st century has seen focus shifting to telecommunications infrastructure to enhance a wide range of social, political and economic factors aimed at championing the development of countries alike. Unfortunately for most of the rural areas, especially of developing countries, little effort to provide these vital infrastructures has resulted in marginalization, and to what a number of researchers refers to as ‘Digital Divide’ [14]. Telecommunication incumbents have for economic tradeoffs between investments and returns, always deployed their networks in urban areas. The basis of their decision is the high population density in urban centers, which translates to high economic returns. Even in urban areas of some developing nations, rollout of communications has been at a snail pace.

Fiber-optics provides a wide range of properties of a network. These include reliability, almost unlimited connection, high bandwidth and less signal degradation. Such properties achieve customer satisfaction which comes out of its Quality of Service (QoS)¹. Detailed discussions on QoS can be found in [13, 12, and 1]. Despite good properties, high deployment costs of fiber-optic networks [7] heavily discourages possible investors in rural areas of developing countries, thereby rendering such networks uneconomic.

While most developed regions are relishing tremendous success in wireless technology especially in

¹ QoS is a desirable property for networks. It is the network’s capability to deal with network traffic challenges like congestion, latency, bandwidth and jitter.

areas previously unconnected, the emergence of this technology has had little impact, as most of these wireless networks are being deployed side by side with wired networks in urban areas. Wireless technologies hold the promise to unlock connectivity bottlenecks experienced in developing nations [14, 10, and 9]. This has been confirmed by successful deployment of broadband access in the populated cities of the developing countries.

A notable positive trend in most developing countries has been the massive roll out of cellular [14] network infrastructures even in their rural areas. In our view, this technology has been the fastest ever since to diffuse rapidly in rural areas of developing countries. Although cellular networks may in future provide all time critical applications including teleconferencing which is sensitive to latency, they are presently not a solution to a wide range of services that can benefit rural areas and improve quality of life.

Companies that have the potential to deploy networks are however skeptical about venturing into rural areas of those countries. This uncertainty perhaps is because deploying a network can be a very complicated issue economically. The question is should we wait for a demand that breaks tradeoff costs even? Or should we deploy, provide services and anticipate demand to follow? Such a problem space is described in [7] as a ‘chicken-or-egg’ problem. Admittedly, the driving force in the search for the solution in this problem space should be the unavoidable need for connectivity. In this work we discuss wireless technologies with the focus to their deployment in under developed areas. Such technologies are looked at from the access network point and the backhaul network point. We also put forward envisaged network architecture suitable for rural areas of developing countries. The rest of this paper is organized as follows: we discuss the background of rural areas of developing nations in section 2. To have a wider view of the available wireless technologies we make an overview in section 3. There are a number of related articles and research papers which motivated our research. These are discussed in section 4. The proposed architecture called the SRTR is outline in section 5. Section 6 contains our conclusions.

2. Background of rural areas of developing regions

The deployment of communications infrastructure depends squarely on the availability of electricity. Such a dependency potentially place a big fraction of disadvantaged regions into near oblivion vis-à-vis technological rollout. Most rural areas in developing nations are still to benefit from electrification programs. Regrettably, this has only seen an insignificant number of people enjoying services such as television, radio

and telephony. Nevertheless, communication infrastructure can still be deployed in those regions with renewable energy like solar, substituting electricity. Complementing solar energy’s reliability especially in Africa one of the least developed continents, are long hours of sunshine. For those areas that have electricity, deploying communications infrastructure especially wired, can still be an arduous task.

Most rural areas are located on mountainous terrain and along valleys. This makes deploying infrastructure very difficult. Beside terrain, most of the inhabitants are poverty stricken and are ‘naturally’ not worried much about technology. Poverty is accepted as the act of God and prevalent hunger spells reign in totality on the planning of one’s activities. Levels of literacy are very low and income is by all standards meager.

One of the underlying causes of lack of communications infrastructure in least developed countries is partly related to low population density and low income [15]. As the “Cost of infrastructure is generally proportional to the area covered... [14]”, low population density negatively impacts on infrastructure investment returns. Emphatically many new telecommunication applications such as e-commerce, e-education voice over IP and telemedicine are becoming globally imperative and developing regions including their rural areas are no exception. Deliberate policies are needed to “decree the deployment of infrastructure as each national goal even though it might not make economic sense [14]”. It must not be overlooked that there are some countries that have seen deployments of low cost wireless networks like South Africa.

3. Overview wireless technologies

Wireless technologies need to be looked into from two perspectives: that of access network and the backhaul network [15]. Even the access networks are principally categorized into two groups. There is cellular network group and the popularly known 802.11x family [2]. Cellular networks have enjoyed successful diffusion right across developing nations with their rural areas included. Detailed discussion on this group of wireless access networks can be found in [2]. The 802.11x family has seen the proliferation of different standards since its inception. Such diversity has been necessitated by a number of properties desired from them. Desired properties include range, bandwidth, costs of deployment and time taken to complete deployment. Range determines the maximum area that can have full coverage. As more and more network applications emerge, bandwidth becomes critical to network efficiency. Different network standards have been developed to provide needed bandwidth. Bandwidth of a network is responsible for a number of QoS attributes that the network exhibits.

Deploying a network is associated with a lot of costs. These costs determine the viability of a project and efforts are directed to balance the investment tradeoffs. Cost of deploying infrastructure is proportional to the time taken to complete deployment. For that reason, different IEEE 802.11x standards have been developed. These are discussed below.

3.1 Bluetooth

Bluetooth is a short range technology that can connect devices like laptops, cell phones and computers within a radius of 10 meters. It is used primarily in personal area networks (PANs). PANs are ad hoc and can be used anywhere within the reach of signals, they don't require any infrastructure. The blue tooth technology operates on 2.4 GHz frequency spectrum and does not need a licence. More information on blue tooth can be found in [5].

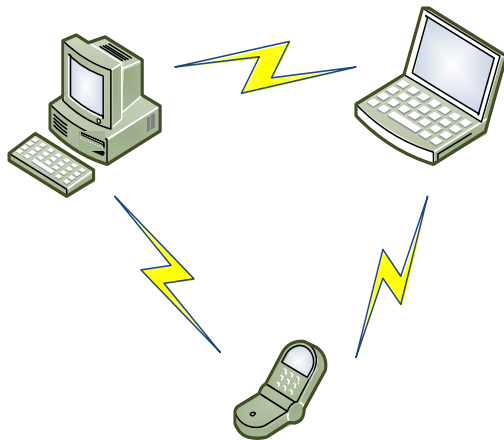


Figure 1: Bluetooth Piconet
Adapted from (Sibanda K, Muyingi H and Mpofu N, 2007)²

3.2 WiFi

WiFi has become a very useful technology across the corporate world and university campuses. Its inception was for convenience of employees in their corporate to stay connected in all buildings within their premises. It was later developed to extend connectivity to surrounding areas that can stretch for about a kilometer. There are three different standards of WiFi, the 802.11a, the 802.11b these two use spectrum frequency of between 2.4 and 2.4835 GHz, and the 802.11g which operates with frequency of 5.725 to 5.85 GHz. One advantage of WiFi is that since it operates at

²Figure 1 was adapted from: Emerging Wireless Technologies a Panacea for Closing the Digital Divide in Developing Countries, a paper to be published soon in the SACLA Proceedings 2007.

2.4 GHz, this spectrum is license free in most countries. A lot of end user devices are now WiFi enabled and are available at low prices from vendors because of standardization and interoperability between different vendors.

3.3 WiMAX

WiMAX is the 802.16 IEEE standard technology that has the potential to replace all forms of telecommunications. While WiFi is good for campus buildings, WiMAX can provide connection to areas spanning more than 25km from the base station on line of site. Its ability to offer broadband connection makes it suitable for a wide range of applications. The deployment of WiMAX can be to provide backhaul for another technology e.g. WiFi, and can also be used as a last mile e.g. used as cellular towers. The 802.16 has a lot of applications which makes it a promising technology. The following are applications listed and captured from the Wikipedia [6]:

- Connecting Wi-Fi hotspots with each other and to other parts of the Internet.
- Providing a wireless alternative to cable and DSL³ for last mile (last km) broadband access.
- Providing high-speed data and telecommunications services.
- Providing a diverse source of Internet connectivity as part of a business continuity plan. That is, if a business has a fixed and a wireless Internet connection, especially from unrelated providers, they are unlikely to be affected by the same service outage.
- Providing nomadic connectivity.

Security is more improved and throughput of a maximum of 72Mbps can be reached. There is quality of service guarantee, but signal strength decreases proportional to the increase in distance from the base station (figure 2 shows WiMAX base station).

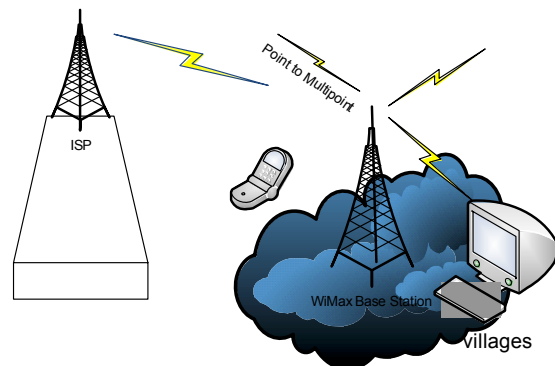


Figure 2: WiMAX base station

³ Digital Subscriber Loop is a technology used to transmit digital data over wired telephone lines

Table 1 shows some of the WiMAX's interface characteristics at Physical Level and Media Access Level. There is both flexibility and cost effectiveness, rasgos that makes the technology suitable for remote areas. On flexibility, WiMAX can be deployed in any terrain across all geographical areas. Because deployment can be done in a short time, costs are circumvented by reducing costs associated with installing cables and labour costs.

Table 1: IEEE 802.16 wireless interface

Physical Level	Media Access Level
Frequencies of between 2 and 6 GHz	Adopted modulation
Reduced channel of between 5 and 10 MHz	Adopted Codification
Transmission control potential	Point to multipoint serves
Adaptive modulation	Quality of Service
Antenna diversity	Dynamic packet size
Wide band of more than 10Mbps	Dynamic multiplexing
	Encryption and Decryption

Adapted from (Sibanda K, Muyingi H and Mpofu N, 2007)

3.4 Very Small Aperture Terminal (VSAT)

Although VSAT [3] does not fall under the 802.11x family, it is a wireless technology worth discussing especially when designing rural network architecture. This technology uses a very small satellite transmitting and receiving station that transfers internet applications via satellite. Its advantage in remote areas is that it can provide backhaul connection to access networks where other technologies are not viable. Its bandwidth capability ensures that it can provide service for all Internet applications.

4. Related Work

There are unprecedented researches going on and that have been done within the wireless network architecture's sphere of influence. One such research is the telemedicine architecture described in [8]. This work proposes WAN architecture to link rural clinics and hospitals in Ethiopia. VSAT technology is used as backhaul providing uplink and WiFi is deployed in clinics to provide access. The authors go on to suggest that to cut down expenses on VSAT mechanical backhaul could be used. Specially equipped buses follow certain routes where there will be kiosk with devices equipped with WiFi technology and start

uploading data and also downloading it simultaneously. This works well with applications that are delay tolerant like e mail. There are also several articles that are helpful for wireless architecture, like Falsafi, Pahlavan and Yang [4] on their article about Wireless Local Area Network system. Their discussion dwells much on data communication. They carry out a survey and compare several wireless systems. Deployment costs play an important role when designing communications architecture. There are several articles in this regard, but one such article that became a motivating factor was the Akshaya case study in India [11]. The study shows that using WiFi as Backhaul and CDMA450 for access and shared PCs for end user equipment delivers a model with a low cost.

5. Proposed architecture

In designing our Semi-Rural To Rural (SRTR) network architecture, we take cognizance that communication infrastructure vary from country to country and from region to region within the same country. The SRTR (figure 3) is from two angles: connecting rural areas that are not very far from the urban or business centre (semi-rural) where there is fiber connection and rural areas (remote rural) that are very remote. The total costs of deploying a network are greatly influenced by the section of the technology to be used as backhaul. VSAT technology has been proposed by various researchers as the only solution to connect rural areas. We however note that VSAT can at times be very expensive to deploy, depending on the remoteness of the area. The SRTR divides a rural area into semi-rural and remote rural. Terrestrial Fiber is used as backhaul technology linking up with the already existing Fiber network in the near by town or business centre. This is done on the background that VSAT's monthly payments will be uneconomic where an alternative can be used. Because of the proliferation of numerous wireless technologies, prices for cables have drastically fallen. WiMAX is used as access technology in areas that are not very far from terrestrial fiber. Using WiFi instead of WiMAX would appear good but we prefer the latter because of its high bandwidth standard and the ability to transmit for a considerable distance (close to 15 km) without line of site. The backhaul provides point to point connection while access will provide point to multipoint connection. However, if the areas are too far from terrestrial fiber, trying to lay cables will result to an enormous cost and VSAT is a better option. The SRTR uses VSAT for uplink and downlink connection (backhaul). This connects to WiMAX as point to point connection. WiMAX serves as a base station and provides connection to another WiMAX (point to point

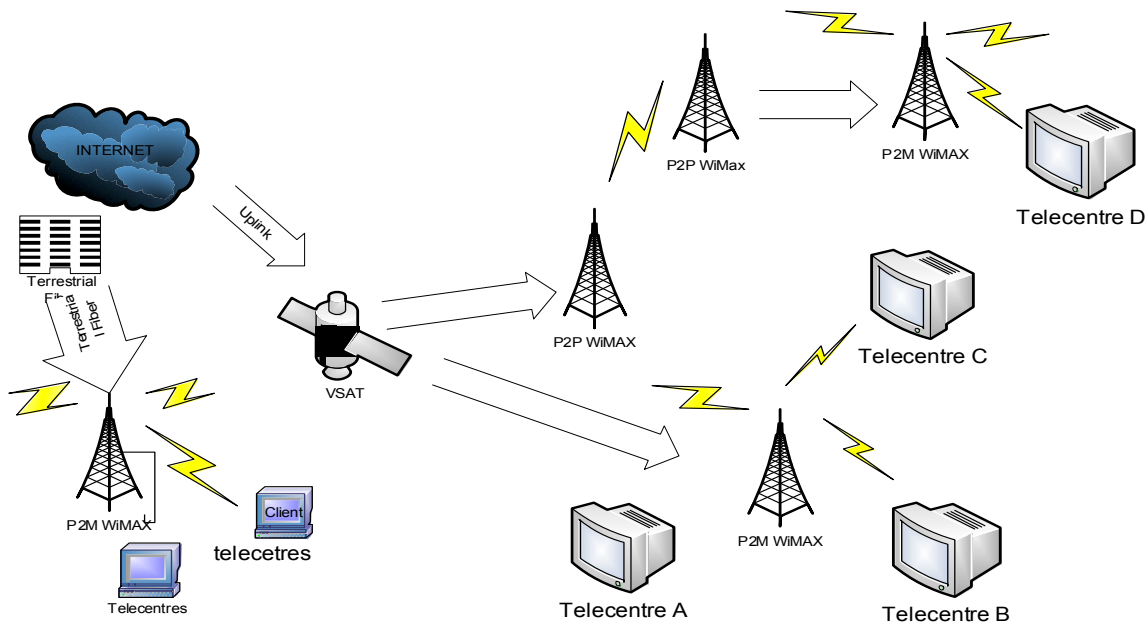


Figure 3: The SRTR architecture

(P2P)) and also serves as access to surrounding areas. The further P2P WiMAX will connect to a point to multipoint (P2M) WiMAX that will serve telecentres in villages. Telecentres are equipped with end user equipment and villagers can access their services at some fee charged.

6. Conclusions

The IEEE 802.11x wireless family emerged from experiments and has since resulted to viable connectivity solutions for both urban and rural settings. We believe that since technology evolves, their proliferation will soon lead to even better new technologies suitable for rural network deployment. VSAT provides big bandwidth and this is proportional to the costs. For villages to benefit from VSAT, they have to join up with others whose telecentres benefit from VSAT and buy their bandwidth in larger volumes. This will ensure cost effectiveness. The SRTR architecture can be used to deploy networks in any rural environment although individual countries can modify it to suit the technologies available and the prevailing prices. Wireless networks irrespective of which technology is being used, will soon become a universal communication infrastructure because of fast deployment and less labour intensive.

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