Networking Technologies in Developing Regions; Emergency Networks and Dependable Infrastructures

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***Abstract*—Rural areas especially those of the developing countries provide challenging environment to implement communication infrastructure for data and Internet based services. The main challenges are the high cost of network implementation and lack of customer base, as rural areas are characterized by low income, highly scattered and low population density. Four main technology needs are connectivity, low-cost devices, appropriate user interfaces (UI) and power. Although wireless has broad use in urban areas, most rural areas are without coverage. The low population density in rural areas (even in the US) limits the ability to deploy base stations profitably.The wireless networking technologies such as WiFi, CDMA450 and 802.16(WiMAX) provides the most economic and attractive options. This paper analyze these networking technologies for rural with dependable infrastructures.**

***Index Terms*—wireless technology, access network, WiFi, CDMA450, IEEE 802.16(WiMAX)**

I. Introduction

The lack of network connectivity in many regions around the world is as much an economic problem as a technological one. This is strikingly true for rural regions in developing countries with low income levels and low population densities. A connectivity network can be categorized as a backhaul or an access network. The access networks provide the so called "last mile" connectivity that connects end users to the backhaul network which finally connect to the internet. The existing access network technologies constitute of enhanced copper wires based on Digital Subscriber Line (xDSL), coaxial cable, fixed and mobile wireless, satellite based wireless and fiber optic technologies.

It is worth to note that wired technologies have distance limitations. Therefore the data rates provided depends on the distance covered. The data rate decreases as soon as the distance covered exceed the specified range. Characteristics of rural areas of the developing countries provide a challenging environment in terms of network costs and time of deployment to implement wired technologies such as xDSL, coaxial cables and optical Fibers. Long-distance wireless technologies, especially those based on standards can enable networking in rural regions. Wireless access technologies that are candidates for broadband rural access networks include: Wireless Fidelity (WiFi), Worldwide Interoperability for Microwave Access (WiMAX), cellular mobile wireless networks and satellite based technologies such as Very Small Aperture Terminal (VSAT). The attractive features of these networks include the low-deployment cost, ease of deployment and the ability to cater to a wide-range of geographic terrain. On the ٩p side, these wireless networks have capacity constraints that limit the maximum available bandwidth and also suffer from reliability problems.

The rest of this paper is organized as follows: First the existing impact of technology in rural setting is discussed. Later the networking technologies are analyzed. Finally conclude the paper by suggesting the suitable technology for rural regions.

II. Existing Impact of Technology in Rural Setting

Although environmental and cultural concerns require consideration, the long-term impact of technology depends on its economic sustainability. Projects can be sustainable either because they serve a public good and have ongoing support, for example, through taxation-or because they are at least self-sustaining financially. All projects cover the major areas such as health, education, disaster management, e-government, and economic efficiency. [1]

A. Healthcare

Adequate healthcare is one of the greatest needs in developing regions, which remain home to the vast majority of preventable diseases, including 96 percent of malaria, 95 percent of HIV/AIDS, and 90 percent of

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tuberculosis [2]. Child mortality rates are also high: 10 percent of children under age five die compared with one in 143 in high-income nations [3]. Although it may be difficult to have an impact on certain health issues like malnutrition, it can directly impact some areas including disease control, telemedicine, improving doctors' efficiency, offering low-cost diagnostics, improving data collection, and providing patient management tools. Telemedicine is using telecommunications for the remote diagnosis and treatment of patients which requires designing low-cost, low-power, long-range, and high-bandwidth wireless technology. Although several projects show promising results [4], there are problems due to frequent power outages and poor telecommunications. This is a strong motivator for work in developing low-cost intermittent networking devices.

B. Education

In recent years, several attempts have been made to integrate rural and low-income urban schooling. By combining technology with sound educational principles and teaching practices, many of these initiatives have demonstrated increased learning. There exists several research opportunities in this area. Digital story authoring tools is found to be highly motivating to create multimedia digital stories that impress fellow students. Creating these stories fosters active learning because the authors must explain academic concepts while they are developing their writing and communication skills. However, current authoring tools such as Microsoft PowerPoint and simpler tools like KidPix are not necessarily culturally appropriate.

C. Disaster Management

The Indian Ocean tsunami disaster in December 2004 was a tragic reminder of the urgent need for better disaster warning and relief systems. The MS Swaminathan Research Foundation runs a communications network in rural areas of Pondicherry in southern India through a web of "information villages" networked through wireless connections. The MSSRF network normally is used to provide communications, weather forecasts, wave and fish location patterns, and other similar services to coastal and inland villages. Rural wireless coverage becomes particularly important after a disaster. Although cellular coverage would be ideal, even intermittent networking using a range of technologies, including "sneaker net" and satellite communications, would be helpful.

D. E-government

E-governance encompasses three broad application areas: public information, digitization of records, and transactions involving the state. However, many areas—including sub-Saharan nations and parts of Asia—lack both online services and basic computerization of processes within the government. The Akshaya project is a large rural wireless network developed as a joint project between Tulip IT and the Government of Kerala, India, to provide connectivity to the Malappuram district.

The aim of this project is to provide connectivity to a group of people rather than individual users. 630 Akshaya centers (one for every 2000 families) are located throughout the district. The estimated costs for deployment are roughly a dollar per covered population. Each Akshaya center (AC) is setup and maintained by local entrepreneurs who receive a subsidized loan from the Government. These sites also provide computer training to one member of each household. Each entrepreneur pays Tulip a flat fee of $20 per month for network connectivity.

The Akshaya network consists of wireless backhaul links based on patented VINE (Versatile Intelligent Network Environment) technology from Wi-LAN, Canada. [5] This Technology has been incorporated in the VIP radios from Wi-LAN. Each VIP radio can serve as a base station (using sectored antennas) or as a repeater (using directional antennas). A single radio connects to the uplink node in the backhaul network. A second radio communicates with all the downlink nodes. These two nodes are bridged using a Wireless Ethernet Bridge.

The e-pay services are among the most successful in the state by using this service, and several entrepreneurs have raised their credit limits to handle the high demand.

III. Networking Infrastructure

Rural areas and smaller cities encounter limited telecommunications infrastructure, especially those which are geographically remote and isolated (Karthik et al., 2000). In addition to the common channels of communication such as face-to-face and written communication, rural people and visitors moving in and out of a rural area is another important source of information.

With the provision of Internet access via satellite links in rural areas, there are two alternatives of networking in rural areas, namely wired networking and wireless networking. However, wireless networking provides various advantages in rural conditions. First, in rural areas with scattered populations, using wireless networks can save the high cabling cost of the wired alternative. Secondly, wireless networks can ease installation in situations that are difficult-to-wire. Moreover, wireless networks also offer the benefit of increased reliability, where a frequently occurring problem faced by wired networks is the system downtime due to cable faults. Another primary advantage of wireless networks is that wireless networks support portability, which in turn allows greater flexibility when relocating, and mobility. This paper will provide various wireless technology standards.

A. WiFi

WiFi technology, also known as IEEE 802.11 was specifically designed for wireless local area network standard [6]. The WiFi technology offer theoretical peak data rate of 54/11/54/600 Mbps for IEEE 802.11a/b/g/n standards respectively.WiFi networks use unlicensed spectrum, which raises the possibility of interference

from other devices. Its coverage is limited in most cases to only 30 - 100 meters. With these standards WiFi can be deployed.

B. CDMA 450

CDMA450 represents a family of CDMA2000 technologies that operate across the 410-470 MHz band. CDMA450 systems support all CDMA2000 standards developed by 3GPP2 and published by the TIA as TIA-EIA-IS-CDMA2000 (CDMA-MC) including: CDMA2000 1X, 1xEV-DO Release 0, Revision A, and future enhancements to these technologies. These technologies are capable of delivering voice, Internet access, multicasting and broadband data services in both rural and urban settings using fixed, limited mobility and full mobility networks.

A significant advantage of CDMA450 is that it can provide advanced telecommunication services over wide areas economically due to enhanced propagation characteristics enabled by the low frequency band. By combining the expanded range of the 450 MHz frequency band with the benefits of CDMA2000's spectral efficiency, voice capacity, broadband data speeds, lower latency and quality of services (QoS) features, CDMA450 presents a powerful value proposition for operators and customers alike.

There is a broad range of commercially available CDMA450 devices that includes fixed wireless phones, desktop modems, machine-to-machine modules, ultra low-cost handsets and USB thumb-drive modems. There is significant momentum behind the deployment of 450 across Africa, Asia, Europe and Latin America. It is becoming the technology of choice for providing universal access to services that will help increase social and economic prosperity.

The advantages of CDMA450 derive from the capabilities of CDMA2000 technologies that allow the provision of a broad range of voice and broadband services, and the expanded coverage afforded by a low frequency band [7].

- Performance: Based on CDMA2000 standards, CDMA450 provides a robust and economical platform on which to deliver a large selection of enterprise and consumer applications, as well as public services such as education, telemedicine and public safety. CDMA2000 1X is the most spectrally efficient technology to support high-quality telephony services, enabling up to 55 simultaneous voice calls in a single sector within a 1.25 MHz channel. EV-DO is a broadband technology that is capable of achieving multi-megabit per second data throughputs and low latencies to enable high-speed broadband Internet access, multicasting and delay-sensitive applications, such as voice over IP (VoIP), push-to-talk (PTT), push-to-media (PTM), video conferencing and "see what I see" (SWIS).
- Economics: The propagation characteristics of the 450 MHz band allow the provisioning of wireless services over large areas with a minimal number of base stations, creating substantial capital and operating expenditure savings.. A base station coverage area in 450 MHz is three times larger than in the 900 MHz band and 12 times larger than in the 1.8 GHz and 2.1 GHz bands, with an excellent signal-to-noise ratio. The propagation characteristics of CDMA450 also make it ideal for in-building penetration, where up to 70 percent of wireless broadband connections are made. It also enables less power consumption and higher average user data throughputs due to fewer handoffs.

C. WiMAX

WiMAX, also known as IEEE 802.16, is a wireless communications standard that is intended for wireless Metropolitan Area Networks (MAN). WiMAX provides broadband wireless access of approximately up to 48km for fixed stations, and 5 - 15 km for mobile stations. The IEEE 802.16 standard has undergone different amendments for improvements which at the end results into the earlier amendments, the IEEE 802.16a/b/c standards to be withdrawn. The current available standards are 802.16d, 802.16e, 802.16m [8]. Their respective brief description and data rates are shown in Table I.

TABLE I. IEEE 802.16 STANDARD DESCRIPTION[9]

Standard	Description	Data Rates
802.16d(802.16-2004)	This amendment is also known as 802.16-2004 because it was released in 2004. The standard only support fixed operation.	70 Mbps
802.16e(802.16-2005)	This standard, also known as 802.16-2005 in view of its release date, designed for nomadic and mobile use	15 Mbps
802.16m	This is an amendment to the air interface; it can support both fixed and mobile users	100 Mbps for mobile applications and 1 Gbps for fixed applications.

There are three topologies for WiMAX network: fixed point-to-point (P2P), fixed point-to-multipoint (P2MP) and mobile WiMAX. The WiMAX network consists of two key components: a base station and a subscriber device. The WiMAX base station is mounted on a tower or tall building to broadcast the wireless signal. The subscriber can receives the signals on a WiMAX-enabled notebook or mobile Internet device (MID).

A point-to-point (P2P) topology consists of a dedicated longrange, high-capacity wireless link between two sites. The central site hosts the base station (BS), and the remote site hosts the subscriber station (SS), as shown in Fig. 1. The BS controls communications and security parameters in establishing the link with the SS. The P2P topology is used for high-bandwidth wireless

backhaul services at a maximum operating range of approximately 48 km using line of sight (LOS) or non-line of sight (NLOS) signal propagation [10].

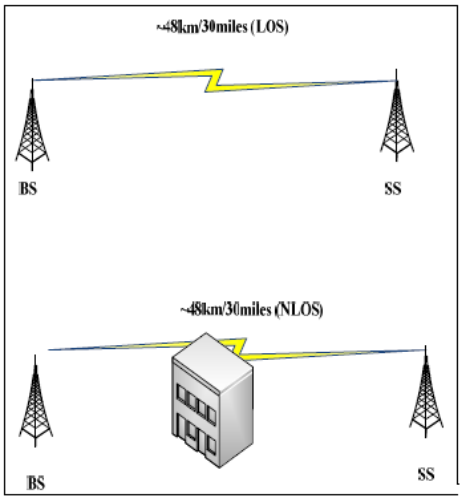

Figure. 1. WiMAX point to point (P2P) topology

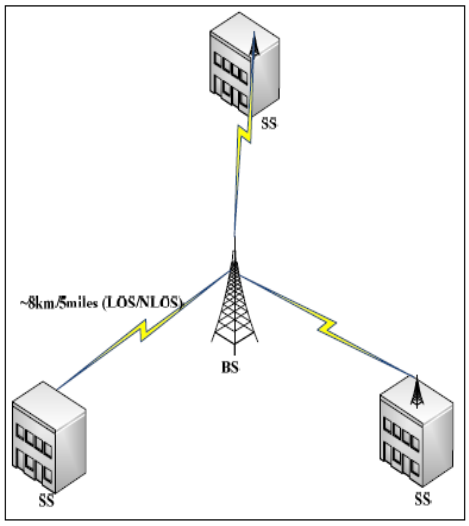

Figure. 2. WiMAX point to multipoint (P2MP)

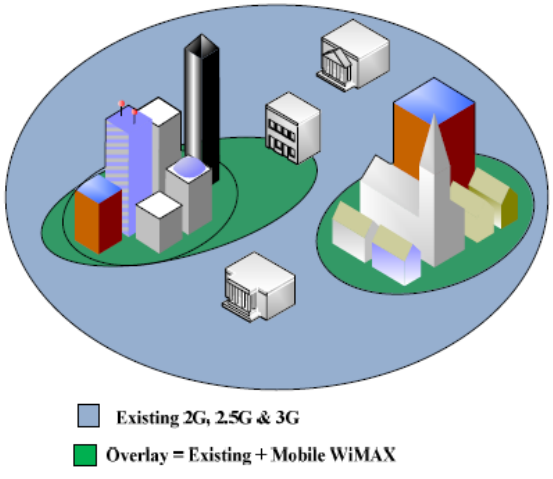

Figure. 3. WiMAX as a data overlay network to the existing cellular networks [12].

D. Topology

P2MP networks can operate using LOS or NLOS signal propagation. Each P2MP BS has a typical operating range of 8 km [11]. Fig. 2 illustrates the P2MP topology.

The mobile WiMAX in an overlay network operate in the Orthogonal Frequency Division Multiplexing (OFDM) & Multiple-Input and Multiple-Output (MIMO) antenna capabilities. This is an overlay network topology made up by coexistence of cellular mobile networks with mobile WiMAX network as shown in Fig. 3.

IV. Conclusion

The analysis carried out in this paper suggest that, the more attractive options for rural connectivity, are the emerging overlay network of cellular and mobile WiMAX.For the *Akshaya*case study, it shows that a wireless network using WiFi for the backhaul, CDMA450 for the access network, and shared PCs for end user devices has the lowest deployment cost. Once the expected spectrum licensing cost for CDMA450 is included, a network with lease exempt spectrum using WiFi for the backhaul and WiMax for access is the most economically attractive option. However, even with the WiFi/WiMax scenario, regulatory costs comprise nearly half the total cost structure of the network demonstrating the significant impact of regulatory policies on network economics.

Deployment of these emerging technologies is technically feasible as it was already demonstrated in some countries. However, it will be useful to analyze the economic standpoint and how the emerging technology will compete with the existing WiMAX and 3G for the market share. The analysis will help to forecast the future wireless technological dominance and hence identify which will be the feasible and sustainable wireless technology capable of connecting rural areas. Based on the survey conducted by this paper, the WiFi/Mobile WiMAX technology is suggested as the best technology for rural areas of the developing countries.

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