

Alternate Technologies for Telecommunications and Internet Access in Remote Locations

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ABSTRACT: Information and Communication Technologies are emerging as the most effective means of communication. Endowed with information, knowledge, education and business opportunities, provision of telecommunications and Internet access to people in remote locations can dramatically contribute to changes in the community socio-economic development. This paper investigates four alternate telecommunications technologies that potentially provide ICT infrastructure, as well as enable telecom and Internet connectivity in remote locations. These technologies include the traditional wireline access technology, the wireless local loop based technology, the recently introduced non line-of-sight wireless broadband technology, as well as VSAT satellite-based technology, as ways to span the last-mile connectivity to the remote users from the Internet backbone. This paper presents an overview of each system and shows how each technology could be integrated and deployed in remote locations. Also discussed are the present roles several technologies could play in the provision of access to telecommunications and Internet in the remote environment.

Keywords: Information and Communication Technologies (ICT), POTS, corDECT WLL, NLOS, VSAT, remote applications.

I. INTRODUCTION

Notably, the advent of Information and Communication Technologies (ICT) has a dramatic impact on achieving social and economic development goals in developing countries. The evidence has indicated that ICT has potential to empower the quality of lives for people living in poverty, simply by providing the community with communications services, business opportunities and power to access all kinds of information, knowledge, and distance education.

In many developing countries, ICT plays a key role in social development. For instance, in Gambia, ICT is being used in the community to facilitate remote consultation, diagnosis and treatment [1] – nurses in remote villages use digital cameras to download images of symptoms onto a PC and transfer them to nearby towns for examination by doctors. In Africa [2], ICT is also being used as a tool to achieve better learning outcomes and enable access to materials and resources from international, national and local sources in remote communities. Moreover, e-mail services have been made available by the use of a computer with Internet connection. As a result, communities become less bound by physical location or its remoteness and can extend its boundaries into the virtual community. In the economic

aspect, on the other hand, the digital revolution offers unprecedented opportunities for economic growth and facilitates global connectivity [3]. There are number of ways ICT can enhance rural productivity. These result in new ways of creating and delivering products and services on a global scale. In Chile, for instance, ICT enables access to market information via communications networks. This helps farmers make astute decisions about what crops to plant and where to sell their produce and buy inputs. Additionally, in Chincheros, a small rural village in Peru, ICT not only gives its farmers access to new markets, but also removes the wholesale intermediaries for their village produce. As a result, the village traditional crafts and farm products are now sold overseas daily [4].

Although the benefits of ICT have long been realized and several attempts have been initiated to integrate ICT into developing economy, Least Developed Countries (LDCs) are being left behind in their number of telephone and Internet subscribers. For example, Africa with 12.8% of the world's population has less than 2% of its telephones, and even fewer personal computers and Internet users [5]. According to a recent article in "The Economist", the percentage of the world's Internet users in LDCs constitutes less than half a percent [6]. Thus, in order to take advantage of the current technologies and accelerate the socio-economic development in the global economy, it is imperative for remote areas of developing countries to increase the number of their ICT users by improving their telecom and Internet infrastructure.

This paper investigates four alternate telecommunications technologies that have potential to provide ICT infrastructure in remote locations – plain old telephone service (POTS), wireless local loop based on DECT standard (corDECT WLL), non line-of-sight wireless broadband technology (NLOS), as well as VSAT (very small aperture terminal) satellite-based technology. Next section presents several options that can provide ICT infrastructure focusing on these four technologies. Then, in section III, the paper describes the most popular wireline access technology: POTS as a means to span last-mile connectivity from end-users to the backbone network. In section IV, another last-mile access technology, corDECT WLL, that offers better deployment scenarios in remote locations is discussed. Then, an emerging non line-of-sight wireless technology concept is presented in section V as an alternate to line-of-sight wireless technology. Next, the paper gives an insight into VSAT system, as well as its

deployment concepts for rural applications. The present status of POTS, corDECT WLL, NLOS wireless technology and VSAT in remote locations is then discussed. Finally, major conclusions of the paper are presented in section VII.

Terminal), LMDS (Local Multipoint Distribution Service), and MMDS (Multichannel Multipoint Distribution Service). With the improvement in wireless technology, next generation wireless link allows carriers to deliver broadband service to indoor subscriber premises (NLOS system).

Table 1: Performance of ICT Telecommunications Infrastructure

Technology	Speed	Physical Medium	Applications
Backbone network			
T-1	1.544 Mbps	Twisted-pair/ Coaxial cable/ Optical fiber	Large company to ISP, ISP to backbone
E-1	2.048 Mbps	Twisted-pair/ Coaxial cable/ Optical fiber	32-channel European equivalent of T-1
T-3	44.736 Mbps	Twisted-pair/ Coaxial cable/ Optical fiber	ISP to Internet backbone
OC-1	51.84 Mbps	Optical fiber	ISP to Internet backbone
OC-3 to OC-256	155.5 Mbps - 10 Gbps	Optical fiber	Internet backbone
Last-mile wireline			
POTS	Up to 56 Kbps	Twisted-pair	Home and small business
ISDN	64 - 128 Kbps	Twisted-pair	Faster home and small business access
DSL	512 - 8 Mbps	Twisted-pair	Home, small business, and enterprise
CATV	512 Kbps - 52 Mbps	Coaxial cable	Home and business
Last-mile wireless			
CorDECT WLL	35 - 70 Kbps	Wireless link (require LOS condition)	Home and small business
VSAT	64 Kbps - 2Mbps	Wireless link (require LOS condition)	Faster home and small enterprise access
MMDS	2 - 3 Mbps	Wireless link (require LOS condition)	Faster home, office and business
LMDS	100 Mbps	Wireless link (require LOS condition)	Faster home, office and business

II. ICT TELECOMMUNICATIONS INFRASTRUCTURE

Telecommunications and Internet network can be split into three major sections. These are the backbone network, the user premises and the access in-between [7]. The backbone network is an element of the network infrastructure that provides high-speed, high-capacity connections among the network’s physical points of presence [8]. The user premises are for instance households and residential or business units which require connection to backbone network. Lastly, the access part is accountable for interfacing between the backbone network and the user premises.

The provision of ICT telecommunications infrastructure – both the backbone network and the last-mile access – is a prerequisite for enabling a country to have telecom and Internet connectivity. Table 1 illustrates various carrier technologies for backbone networks and various types of last-mile access technologies including their speed of transmission. Typically, the backbone network, which is provided by national telecom entity, consists of high-capacity optical fibers, which provide high bandwidth. It generally spans from one major metropolitan area to another. Local ISPs then connect to this backbone through routers, which carry data through the backbone to its destination. Subsequently, last-mile access technologies are deployed to connect end users to the local Internet service providers (ISPs). The last-mile access medium can be either wireline links, i.e. twisted-pair, coaxial cable, or wireless links. Most popular wireline access methods include POTS (Plain Old Telephone Service), ISDN (Integrated Services Digital Network), DSL (Digital Subscriber Line), and CATV (Cable Modems) [9]. The other family of access technologies is wireless access. This wireless access may be provided to the home in some of the following means: corDECT WLL (Wireless in Local Loop based on Digital European Cordless Telephone standard), VSAT (Very Small Aperture

From this point onward, emphasized will be on POTS, corDECT WLL, NLOS wireless technology as an alternate to traditional wireless system, and the VSAT satellite-based technology, all of which potentially provide the sustainable telephone and Internet connections to virtually all households in remote locations.

III. POTS – WIRELINE ACCESS TECHNOLOGY

POTS is short for plain old telephone service. It refers to the standard telephone service that has long been used to provide basic telephony and Internet connection.

A. POTS Network Architecture

POTS connects end users to public switched telephone network (PSTN) through copper wires as shown in Figure 1.

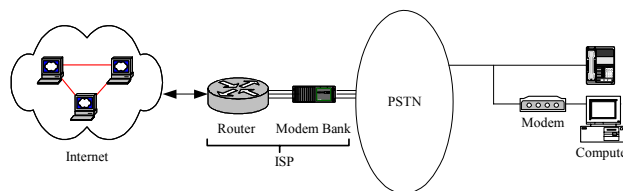


Figure 1: POTS and its Internet access

To connect to the Internet, a user at home or office uses a telephone line, with a moderately equipped PC or Macintosh and a modem, and dials an ISP. Then, the ISP connects the user to a router, which in turn is connected to other routers on the Internet. This enables a user to surf any information available on the Internet. Its popularity stems from the very simple connection and its low cost of entry approximately \$25/month in the developed countries like U.S. if wireline is available.

B. The Deployment Scenario of POTS in Remote Locations

In many far-flung areas in developing countries, the backbone network or optical fiber links that provide ICT connections with PSTN are generally installed along railway lines to cut installation costs. Consequently, basic telecom network allows the ICT connections only in places at or near the railway stations by routing copper wire to the villages or homes. For instance, in Bangladesh, it is possible to provide telephone services to approximately 28% of area and 40% of population by utilizing the fiber available along the railway lines [10]. Since this technique is limited by the uneconomical return of burying tons of copper wire and the associated switching equipment, most of the developing countries lack POTS. The WLL access technology that can disentangle these concerns is discussed in the next section.

IV. CorDECT WLL – FIXED WIRELESS BASED TECHNOLOGY

Wireless local loop (WLL) services may be defined as fixed wireless services intended to provide access to the telephone network. WLL systems can be based on cellular or PCS technology, either analog (AMPS, TACS, ETACS, etc.) or digital (GSM, DECT, PDC, CDMA, etc.). This section is dedicated to the architecture and the deployments of WLL system based on the Digital European Cordless Telephone (DECT) standard or corDECT WLL.

A. CorDECT WLL Network Architecture

A simplified version of the corDECT WLL system is shown in Figure 2. In this figure, CorDECT WLL system is composed of the DECT Interface Unit (DIU), Remote Access Switch (RAS), Compact Base Station (CBS), and a subscriber unit at the receiving end. In contrast to POTS where individual copper lines must be routed and wired to each subscriber from the backbone network (and linked to the PSTN central office), WLL connects end users to the backbone network wirelessly through an access unit.

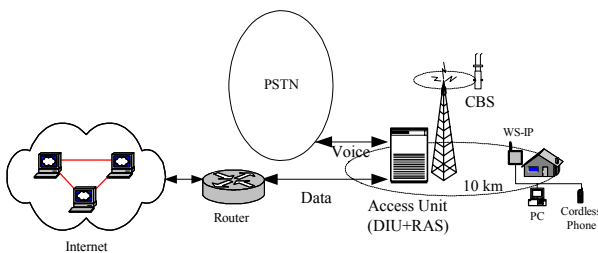


Figure 2: CorDECT Wireless Local Loop

In Figure 2, the subscriber terminal is a wallset with Internet port (WS-IP) as a standard interface (RJ-11) and a serial port interface (RS-232). It supports standard telephone, modem, and fax through the RJ-11 port, and provides a direct connection to a PC through the RS-232 port. The WS-IP provides high-speed Internet access at 35-70 kbps as well as normal telephone service for subscribers in the corDECT system. The WS-IP is connected to the CBS using a wireless

link. The CBS provides the radio interface between subscribers and an Access Unit (AU), which consists of a DIU and RAS. The DIU separates the voice traffic and directs it to the telecom network, as well as switches the Internet calls to a built-in RAS. The RAS then routes the traffic to the Internet network.

Since Internet traffic does not have to pass through the telecom network, corDECT WLL gets rid of the Internet tangle associated with POTS. Moreover, it offers a number of key advantages: faster deployment, sooner realization of revenues; lower construction costs; lower network maintenance, management and operating costs; and greater flexibility to meet uncertain levels of penetration and rates of growth [11].

B. The Deployment Scenarios in Remote areas

In corDECT system, a DIU can be collocated with the PSTN through the backbone network at any railway station by utilizing the optical fiber network along the railway lines mentioned in section II (B). Unlike the POTS system where copper wire is needed to connect remote subscribers to the backbone, corDECT WLL system offers wireless telecom and Internet connectivity to the backbone network. Thus, the coverage range of corDECT system could be extended from the railway stations up to distance 35 km or more without the need for copper wires. Note that line-of-sight is required in every hop in corDECT WLL system. Several deployment scenarios of corDECT system in remote areas are illustrated in Figures 2, 3 and 4.

1) The deployment scenario at the railway station

The corDECT system gives a good deployment opportunity for a small town located at the railway station. As shown in Figure 2, the DIU and CBS are located at the tower, which should be installed at the railway station, near the town center. The CBS wireless link distance could be as long as 10 km by using line-of-sight connection [12]. Thus, the demand could be concentrated at the tower or within a 10 km radius. In other words, this system enables more coverage area away from the railway station without using any copper wires. The subscriber density served could be as low as 3 subscribers per square kilometer (subscriber density = $1,000$ subscribers / 100π square kilometers). The subscriber density, however, can be increased by using more DIUs at the railway station.

2) The deployment scenario with relay base station

To serve more sparse rural areas, a relay base station (RBS) could be installed between the CBS and the WS-IP as shown in Figure 3. In this case, a two-hop DECT wireless link is used to provide telecom and Internet connection to the household [13].

One link is from the WS-IP to the RBS. The other link is from the RBS to the CBS. The RBS could extend the range of the corDECT system away from the CBS by 25 km or more with several RBSs. In turn, the RBS serves subscribers in a 10-km radius. This provides a subscriber density as low

as 0.5 subscriber/km² (subscriber density = 1,000 subscribers /625 π square kilometers).

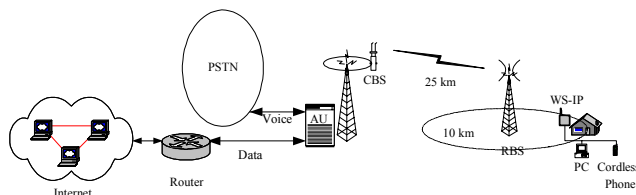


Figure 3: Deployment with RBS

3) The deployment scenario with base station distributor

The CorDECT WLL with a base station distributor (BSD) can be used for coverage distances beyond 35 km as shown in Figure 4. The BSD is a remote unit connected to the DIU using a standard E1 interface. The maximum distance between DIU and BSD depends upon the E1 link (radio, fiber, or copper). At the BSD site, a cluster of CBSs is mounted on a rooftop tower to serve an area of 10 km. The system is suitable for serving a load pocket in a remote mid-sized town or city.

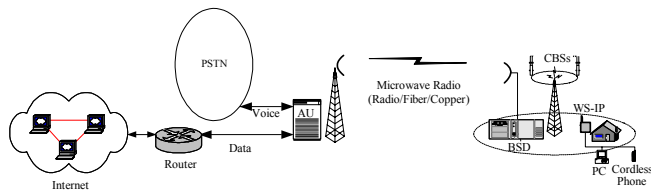


Figure 4: Deployment with BSD

C. Role of corDECT WLL Wireless Access Technology

As a result of becoming progressively less expensive than the wired alternatives and getting rid of Internet tangle, corDECT WLL technologies offer advantages of rapid and flexible deployment in remote areas. In India for example, the CorDECT technology has been installed in Kuppam, Andhra Pradesh, providing connections to about 65 villages. Moreover, the system is being installed by Basic Services Operators in Punjab and Rajasthan and by several ISPs. Outside of India, the system has been installed in Argentina, Brazil, Madagascar, Kenya, Nigeria, Angola, Tunisia, Yemen, Fiji and Iran.

V. NON-LINE-OF-SIGHT WIRELESS BROADBAND SYSTEM

A newcomer to the field, NLOS wireless broadband access technology provides another means of connecting the world's insatiable appetite for bandwidth to an efficient fiber-optic network backbone. Since acquisition costs are expensive in LOS systems (e.g., corDECT WLL), it is believed that NLOS, as an alternate technology, can create mass-deployable systems by bringing the customer premises equipment indoors, as well as reduce subscriber acquisition

costs by rendering truck rolls¹ obsolete. NLOS attacks the problem with smart antennas and, in some cases, a mesh architecture as explained below.

A. Smart Antenna System

Smart antenna system is the most important technology in point-to-multipoint NLOS systems. It combines multiple antenna elements with a signal-processing capacity to transmit and receive in an adaptive, spatially sensitive manner [14].

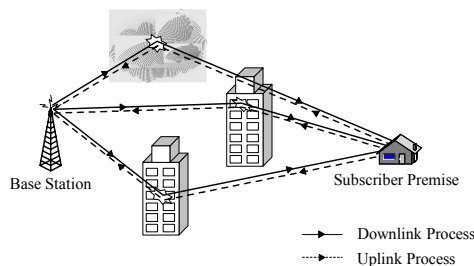


Figure 5: Smart Antenna Architecture

The concept of the smart antenna system can be classified as an uplink-downlink process. We assume that a smart antenna is only employed at the base station, and not at the subscriber unit. In the uplink process, illustrated by the dashed line in Figure 5, the indoor remote terminal transmits signals using omni-directional antennas to a base station. At the base station, the antennas at the base station monitor signals received from the subscriber unit to determine the characteristic of the environment. Due to the constantly changing environment, the base station must keep on monitoring, analyzing and updating the signals from subscriber transmissions. Then, in the downlink process, the antenna array transmits signals back along the same paths shown by the solid line in Figure 5, with complementary properties by negotiating the same terrain. The signals radiated by the array elements are intended to combine with each other at the location of the intended subscriber at the same time and in phase with one another. When the beams combine constructively, the result is a strong signal so that an indoor antenna can be used.

The first successful field demonstration of a NLOS fixed wireless broadband network was recently announced by Iospan Wireless Inc [15]. The system uses a smart antenna concept by employing Multiple Input, Multiple Output – Orthogonal Frequency Division Multiplexing MIMO-OFDM technology. The trials of this technology or “Air Burst” have been conducted in the San Francisco Bay area using the 2.5-2.686 GHz MMDS frequency band with customer-installable indoor equipment and on NLOS connection to base station. Statistics from the trials announced include peak individual downlink rates of over 13.6 Mbps, at distance up to 10 miles with a base station antenna of 100 feet [16].

¹ The process of having support people from utilities, industries visit the home to deploy services such as a residential gateway, digital modems, meter reading, etc. These truck rolls are usually very costly.

B. Mesh Architecture

Besides the smart antenna concept, another way to provide NLOS is the mesh approach. The mesh topology offers low overall system cost while providing both scalable capacity and coverage. It significantly reduces the cost to add a subscriber by requiring only a simple, user installable, low-cost radio at the customer premise.

According to Nokia's Wireless Routing Group [17], the mesh network is composed of the wireless routers, airheads and AirHood as shown in Figure 6. The wireless routers –the end-user equipment – accept the signals destined for their locations and other, which they boost and rebroadcast. Then, Nokia's system uses base stations called AirHeads, each of which serves area called an AirHood. The subscriber units and AirHeads are roof-mounted, but have no need for careful antenna siting and aiming.

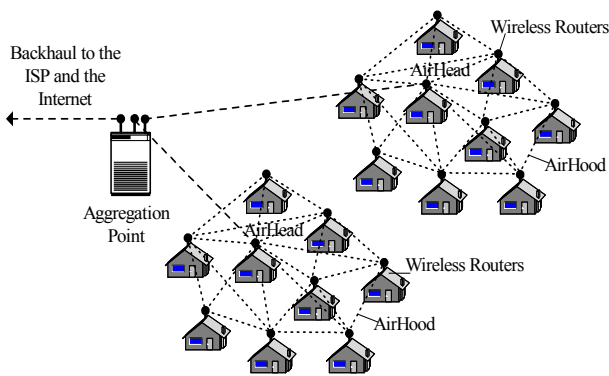


Figure 6: Mesh Architecture

The key idea behind this approach is to break the long transmitting distances into a series of shorter hops with the signal boosted every time at the subscriber premises as it is relayed from one node to another. The customer equipment acts as a means of connecting that user to the network and as a node through which communications traffic from other customers in the vicinity is boosted and rebroadcast. The subscriber units are parts of the infrastructure and as a result, this is a low-cost network to deploy. Moreover, the Mesh architecture offers a reduction in interference and high frequency reuse since a signal is regenerated at every hop with the range covered by one hop significantly smaller than the total coverage distance.

Right now Nokia is focusing its system in North America in the industrial, scientific and medical (ISM) public band as well as in Europe and Asia.

C. Role of NLOS Technology

NLOS wireless broadband technology is likely to play a dominant role in solving the digital divide in rural areas in the long term. This next generation wireless technology has several advantages over the traditional LOS wireless technology. It enables operators of cellular and WLL networks to realize significant improvements in wireless

system performance, and increases in signal quality, capacity and coverage. Moreover, with the system capable of NLOS operation it potentially creates mass-deployable systems by bringing the subscriber equipment indoors. This will get rid of the high acquisition costs (\$1200-\$1600 per subscriber) [18] for the visit to customer premises required in the LOS system. Although subscriber equipment (i.e. the antenna system in smart antenna architecture and wireless router in mesh architecture) is presently very expensive to deploy, its price is expected to come down as a result of several research and development activities underway.

VI. VSAT – SATELLITE BASED TECHNOLOGY

VSAT technology is a telecommunication system based on wireless satellite technology. The term VSAT, which stands for very small aperture terminal, refers to a small fixed antenna dish 2.4-m or smaller in diameter [19]. The VSAT unit is configured to support a variety of protocols, including the TCP/IP and PPP for Ethernet connection, as well as X.25, SDLC, Telnet, BSC, and dozens of additional legacy protocols. Thus, it can be used in satellite communications of data, voice and video signals, as well as Internet/Intranet connections.

A. VSAT System Architecture

There are three components in a VSAT network as shown in Figure 7. The first is called the Master Earth Station (MES) or a central hub, which is the network control center for the entire VSAT network. It is responsible for the configuration, monitoring and management of the VSAT network. The second component is the VSAT remote earth station. This is the hardware installed at the customer's premises, including the outdoor unit (ODU), the indoor unit (IDU) and the interfacility link (IFL).

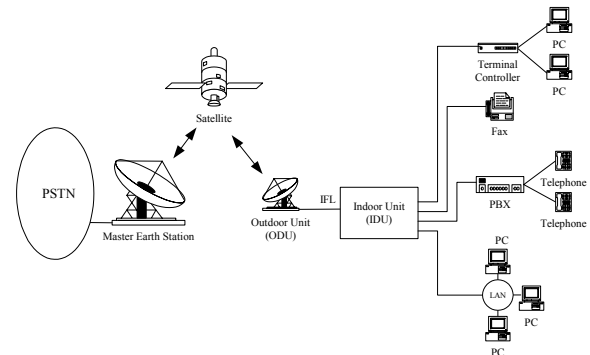


Figure 7: VSAT System Architecture

The ODU consists of an antenna and radio frequency transceiver. The IDU functions as a modem and also interfaces with the end user equipment like stand-alone PCs, LANs, FAX, telephones or PBXs. Lastly, the IFL consists of coaxial cables that connect the ODU to the IDU. The third component of a VSAT network is the satellite itself. The VSAT system uses a geostationary satellite, perched 36,000 km above the equator, through which all signals sent between the VSAT systems are beamed.

VII. CONCLUSIONS

Providing telecommunications and Internet services to the remote areas of the world, especially in underdeveloped and developing countries, has become a national priority. While at the national level, the backbone network is generally available to connect major provincial capitals and major cities, there is serious lack of service in the rural areas in most developing countries. In order to address this issue, this paper has investigated four access technologies – POTS, corDECT WLL, NLOS wireless broadband system and VSAT – that have potential to provide remote locations with telecom and Internet.

In many developing countries only a limited amount of POTs service is available in rural areas. However, the cost of copper wire would be astronomical in widely dispersed terrains. The paper suggests the corDECT WLL system as an alternative to POTS in expanding last-mile voice/data connectivity from PSTN to remote users. However, this option is subjected to line-of-sight conditions, requiring technician visits and high acquisition costs. Then, this paper presents NLOS wireless system as an alternative to the traditional LOS wireless system that promises to solve the digital divide in the long term. In addition, for areas that have poorly developed infrastructure, their unique needs can be served with VSAT rural communications systems at a slightly elevated cost.

The paper suggests WLL or VSAT be the ideal solutions for the initial demands for remote telephony and Internet services, and NLOS system as an alternate to WLL LOS system in the future. On the other hand, for more concentrated or populous remote areas the combination of VSAT and WLL is well suited to this application. They can be integrated as a means of providing rural areas with a cost-effective solution for emerging telephony and Internet requirements.

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IX. BIOGRAPHIES

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