A REVIEW OF UNIVERSAL ACCESS MODELS FOR A RURAL COMMUNITY

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**A RESEARCH PROJECT SUBMITTED TO THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF A BACHELOR OF ENGINEERING (B.ENG) DEGREE IN DEPARTMENT IN ELECTRICAL/COMPUTER ENGINEERING**

NOVEMBER, 2005.

DECLARATION

I Achikeh C. Victor hereby declare that this thesis is an original work of mine and to the best of my knowledge has not been presented in any form for the award of Degree certificate anywhere. It was carried out under the supervision of Dr. Y.A Adediran. In the department of electrical and computer Engineering.

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CERTIFICATION

This is to certify that this thesis "A REVIEW OF UNIVERSAL ACCESS MODELS FOR A RURAL COMMUNITY" is an original work of Achikeh C. Victor carried out under the supervision of Dr. Y.A. Adediran for the award of Bachelor of Engineering (B. Eng) Degree in Electrical and Computer Engineering of Federal University of Technology Minna, Niger state.

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DEDICATION

This work is dedicated to the Almighty God whose foremost love, guidance, mercies and protection has given me the opportunity to have come this far.

This work is also dedicated to my parents, Mr. V.C.O. ACHIKEH and Mrs. F.A. ACHIKEH, for their invaluable support, warmth, love and encouragement at all time, when the odds seemed insurmountable. To my brothers and sisters, and coupled with the unflinching support of other members of the family.

ACKNOWLEDGEMENTS

A work of this magnitude like any other human endeavors can not be successfully carried out single handedly. I bestore all credit and honor to Almighty God in making me accomplished this task.

I sincerely appreciate the assistance rendered by my supervisor Engr. Dr. Y.A Adediran, for out of his tight academic schedule, took time to monitor my project and corrected my write up. Many thanks to my head of Department Engr. Abdullahi, who has been like a father to us all in the department. In realization of this fact, I therefore register special thanks to all Electrical lecturers and other members of the Electrical Engineering Department.

I am indebted to my parents Mr. Mr. & Mrs. V.C.O Achikeh, for their love, support and understanding, during the cause of my study. I also appreciate the contribution of my beloved brothers and sister Maureen, Ifeoma, Ikenna, Chinedu, Olisaeloka, Ekene, Ogo, Onyeka, Adobi Tobi, Uju and Ebele, for there prayers and inspiration. Not left out is my beloved Jennifer Okokwu and Rose for her companionship, love and care...thanks, am proud of you.

I appreciate the assistance of my benefactor Rev. Fr. Umoru. I appreciate the criticism of my colleagues in my compound Unisa, John, Telvin, Funke, Habiba, Akin, Etitto and all the Peace villas.

Also Sir & Lady Dozie Okwuosah and family, Dr. Uche Achikeh, Dr & Mrs. Tony Okwuosah, are not left out for their financial assistance. Finally my immense goes to my project colleague Eke, Girrah, Jelele, Ameh, Alhassan, Uwada, Emmanuel, Akeem, for there immense knowledge and support.

ABSTRACT

The need for universal access in rural and remotes area has been a recurring subject of concern for most large developing countries. It is generally considered that rural telephone users do not generate the same level of telephone traffic and revenue as urban users; thus, lowering the need to invest in rural telecommunication.

Tele-based information community centers or just telecentres have been seen as the killer application to empower local companies in some developed and developing countries to meet the challenges of the information society. This project presents a number of models for introducing universal access of information to rural communities. The qualities of this models and an approach to achieve a network based on realistic operational cost in government incentives to various providers.

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CHAPTER ONE

INTRODUCTION

More than 2.5 billion people- over 40% of the planet population- live in rural and remote areas of developing countries; of the small fraction that has any access to telecommunications, radiobroadcasts and voice telephony, have traditionally been the services provided. Today, a wide variety of new telecommunication applications such as e-mail, e-commerce, tele-education, telehealth and telemedia services are important for rural and remote communities as voice connectivity alone (1).

Universal access generally refers to a situation where every person has a reasonable means of access to publicity available telephone. It may be provided through pay telephones, community telephone countries, teleboutiques, community Internet access terminals and similar means.

Each rural district or community requires a different mix of voice, text image, video and audio-communication to best meet its needs. The Valatta Action Plan (VAP), formulated at the second ITU world Telecommunication Development conference in march 1998, sought is promote Universal Access to basic telecommunication broadcasting and Internet as tools for development in rural and remote areas.

Focus Group 7 (body under ITU), has spent a year researching technological developments that have the potential to support telecommunication applications which are commercially viable or sustainable through other transparent financing mechanism in rural and remote areas of developing countries. Demands for Internet-based telecommunication applications in rural areas, particularly email, have resulted in new applications of old technologies, such as VHF radio systems and Meteor burst communications for non-rural-time services.

In addition, new combinations of existing technologies are extending the reach and flexibility of wireless access systems, as well as reducing total costs through the integration of shared systems and components. Many rural operations are now deploying very small aperture terminals (VSAT) and point-to-multipoint terrestrial radio systems integrated with wireless local loop systems based on standards such as Personal Handiphone System (PHS) and Digital Enhanced Cordless Telecommunications (DECT).

Access options on the horizon for rural areas include a number of technologies that are new to the market place or still under development in some countries. They include:

(i) CDMA 450 and GSM 400: Cellular base stations implemented in the 450MHz range. The use of the lower frequency bands will enable each base station to cover approximately double the areas achieved by existing digital cellular based station operating in the 800-900MHz frequency range.

(ii) IMT-2000 (Third generation System), designed to deliver a wide range of traffic types and volumes more efficient and inexpensive than the current generation of wired and cellular telephony network.

(iii) Wireless router network; integrated with IP telephony software, have the potential to provide significant cost savings and social benefits as multi-service application platforms for telecentres, government offices etc.

(iv) Gateway based on ITU-T Recommendation H.323 support real time, two-way communications between Local Area Network (LANs) and the PSTN. This option is to construct local and wide area networks to deliver telephony and other services in rural areas, without undermining existing investments in the PSTN [1]

1.1 OVERVIEW OF RURAL ACCESS PROBLEMS

Rural Communications has always been a recurring subject for most large and/or developing countries. It has been known for a long time that a country's economic development (as measured by it Gross National Product GNP) is strongly correlated to its telecommunication density (number of telephone lines per 100 people). This situation is more evident in countries with a vast area or with a large urban population, which requires a larger investment in its telecommunication equipment and which needs a shorter implementation time to generate revenue than the rural users.

Despite the vast potential, the impact of Information Communication Technology (ICT), which has been centered on few modern equipments, the need for basic literacy, computer skills and training in the use of ICT technology applications remains a significant challenge for rural areas in terms of development. The major problems of rural communication are classified into two distinctive parts: -

(i) Individual concerns:- This is characterized by the following;

- lack of skill
- lack of capital
- lack of information

(ii) Macro level concerns

- Scarcity or absence of public facilities such as reliable electric supply, water, access roads and regular transport.

- Scarcity of technical personnel
- Difficult topographical conditions e.g lakes, rivers, hills, mountains or deserts, which renders the construction of wireless telecommunication networks very costly.
- Severe climatic conditions that make critical demands on the equipment.
- Low population density
- Very high calling rate per telephone lines, reflecting the scarcity of telephone services and the fact that large number of people rely on a single telephone line.

These characteristics make it difficult to provide public telecommunication services of acceptable quality by traditional means at affordable price, in achieving commercial viability for the service provider.

1.2 AIM AND OBJECTIVE

Universal access is aimed at increasing the number of individual residence with telecommunication services and provides these services to all households within a country, including those in rural, remote and high cost locations. The focus of this project is aimed at supplying an appropriate means of providing rural areas with affordable means of communication and information using some models available i.e. CDMA 450, IMT2000, VSAT, wireless router, etc.

The access models depend on the country, its particular situation, the source for funding which include natural budget of government, UNESCO and NGO's in order to create structure/infrastructures like telecentre, telecottages etc.

The objective of the Universal Access is basically to provide policies and programs focused on social and economic development of rural and remote areas. The provision of telephone lines, Internet services, etc. is a means to accelerate and support social and economic developments in areas like agriculture, education, health etc.

The objective may also be tied directly to government goals and decentralization of government to regional and district areas in order to more effective social service delivery and more effective local decision making. The prime objective is to bridge the access gap to information in rural communities.

The overall objectives of establishing telecentres are:

- To create regional development and cohesion (cultural or economic).
- Infrastructure (1):- To provide access to IT and telecom facilities.
- To promote diffusion of usage and knowledge of IT.
- Training: - To train local people- particularly in ITR related qualification.
- Infrastructure (2): - To provide access to IT related business services.
- To create local employment.

1.3 PROJECT OVERVIEW

This project presents a set of methods for the technical and economic study of Universal Access Models. It discusses the rural telephony problems and reviews past and current technologies which have been used in attempt to provide telecommunication services to rural areas. Also to be discussed are economic indicators, performance requirements for universal access design and the best amongst all models for rural communities.

Chapter 1 presents universal access, the overview of the rural access problems along with its aim and objective.

Chapter 2 presents a comprehensive literature review on infrastructure for information access for rural areas.

Chapter 3 describes digital circuit and packet switched network with an emphasis on quality of service. Requirements for digital voice over satellite channels as well as satellite system and network performance and technology.

Chapter 4 describes a practical approach for Universal Access, the analysis and Economic issues in the design of rural telephony network.

Chapter 5 describes the various universal access funds and features available for rural community developments in ICT.

Chapter 6 shows a summary of this project, its main conclusion and recommendation.

CHAPTER TWO

OVERVIEW OF THE INFRASTRUCTURE FOR INFORMATION ACCESS FOR RURAL COMMUNITY

If all parts of the society are to enjoy the benefits of ICT services, it is necessary to provide universal access to everybody. Universal access is here defined as access to these services within a reasonable distance, and differs from the more ambitious goal universal service defined as connection of every household. One way to achieve this goal is to establish a network of community centers, where ICT facilities are made available to the public [3].

2.1 WHAT IS A TELECENTRE?

Telecentre may be defined as an independent individual agency or enterprise, part of a franchise, or perhaps a project of a national agency. All Telecentres aim to stimulate and respond to the demand for information and communication services. Each Telecentre is likely to have its own unique qualities that match the needs of the community. Telecentres aim at providing one or more of the following services:

- Access to telephones and faxes
- Access to E-mail
- Education in "Information Age' skills.
- Access to the Internet

MCTs (Multi-purpose Community Telecentres) are structures that can encourage and support communities to manage their own development through access to appropriate facilities, resources, training and services. Other names for

Multi-purpose Community Telecentres are: "Community Tele-Service Centers"; "Multi-purpose Community Information and Communication Centers"; and "Community Multimedia Centers".

Specialized services can be offered to healthcare workers, enabling them to use telediagnostics programs, order supplies, pass on public health information, and to obtain specialist advice for complex health problems. MCTs have a 'not-for-profit' legally viable to be successful.

2.1.1 DIFFERENT KINDS OF TELECENTRES

The size and scope of any Telecentre depends on what equipment it has. Generally, there are four sizes of Telecentre: Micro, Mini, Basic, and Multi-purpose Telecentres.

2.1.1.1 MICRO TELECENTRE

Micro Telecentres are usually housed at a shop or other business. They provide payphone(s) with a built-in web browser and possibly a smart card reader and a receipt printer. Many are used in South Africa and Australia, and are becoming increasingly common in public places world-wide.

2.1.1.2 MINI TELECENTRE

A Mini Telecentre will usually offer a single phone line (possibly GSM cellular) with a three-in-one scanner/printer/copier, a fax machine and a PC with a printer, Internet access and a call meter.

2.1.1.3 BASIC TELECENTRE

A basic Telecentre offer a number of phone lines, a call management system, fax machine, photocopier, several PCs with a printer, Internet access and perhaps a scanner.

2.1.1.4 FULL SERVICE TELECENTRE

A Full Service Telecentre will offer many phone lines, multi-media PCs with Internet access, a high-volume black and white and color printer, a scanner, a digital camera, a video camera, a TV, an overhead projector, a photocopier, a laminator, meeting rooms, and a telediagnostic and video conferencing room. The Telecentre starts out with basic services and adds to them as demand grows. The Telecentre must adapt to serve the needs of the local community [4].

2.1.2 EXAMPLES OF TELECENTRES IN AFRICA AND OTHER COUNTRIES

2.1.2.1 GHANAIAN TELECENTRE

Ghana has used a quite different model to establish a Telecentre which was due to the initiative of private entrepreneurs. So far, this type of center is mainly located in urban areas like Madina Nima Akatsi and Sogakael where there is a large population of customers without residential access to basic communication. [3]

Wireless local loop technology is now being used to establish Telecentre in these rural areas. Following the liberalization of the telecom sector, there are 3 providers of fixed services and 3 of mobile services out of these only two are active in the rural areas, namely incumbent operators (Ghana Telecom and Capital Telecom), which provide telephone services in rural areas in 1997 in southern part of Ghana. So far three hubs each with a capacity of 1000 lines are operational and seven hubs was planned to be operational in 2000 [4].

2.1.2.2 PUBLIC TELEPHONE SHOPS IN SENEGAL

In Senegal, the Public Telecom Operator (PTO) does not provide public phones, but there are over 8000 public telephone shops, called Telecentres. These are licensed by the Public Telecom Operator (Sonatel), and run by local entrepreneurs. Many have added fax and word processing services, and over seventy have added Internet access. No financing is provided, but to encourage their establishment, Sonatel gives a 40% discount on tariffs and provides advice for Telecentres wishing to add other services such as fax and Internet access.

2.1.2.3 A MULTI-PURPOSE COMMUNITY TELECENTRE IN UGANDA

The Nabweru Multipurpose Community Telecentre opened in May 1999. It is located approximately five kilometers from Kampala. This project is supported by government, industry, local NGO, the International Development Research Centre (IDRC) and international institutions – under the stewardship of the ITU. It aims to extend connectivity into rural and remote areas using Wireless IP and VSAT technology.

Uganda has developed a clear policy towards rural access and these new technologies can be seen in the context of a technological approach to universal access. The overall objective of the Nabweru Telecentre Project is to develop, test and promote community-based information and the applications of communication technology for the development of rural communities.

2.1.2.4 GASELEKA TELECENTRE, SOUTH AFRICA

The telecentre is situated in the north eastern part of South Africa about 40 Km from the Botswana border. The area is rural, arid and with 80 km from the nearest town. The telecentre at Gaseleka was established by the South African Universal Service Agency in 1998. There are; 6 phone lines - 4 used for telephones, 1 fax line and 1 for the Internet. Four Pentium PCs and four 386 PCs. All PCs are connected to a color printer via a peer-to-peer LAN. Other equipment includes; 1 telephone modem, 1 photocopier and 1 color scanner. In the future the telecentre aims to develop more information services. The community has expressed a desire to start a local community radio station as non of these facilities exist in the area [4].

2.1.2.5 ARAB STATES: Rural Network extension using Wireless IP, Yemen

In conjunction with the rural connectivity strategy of Yemen, this low cost wireless IP access network is connecting a dozen rural communities with an ICT infrastructure. The project is supported by local and national government and industry under the leadership of the ITU. The Yemen Project proposes to use a wireless router system based on the following network parameters: as show in fig 2.1 [3].

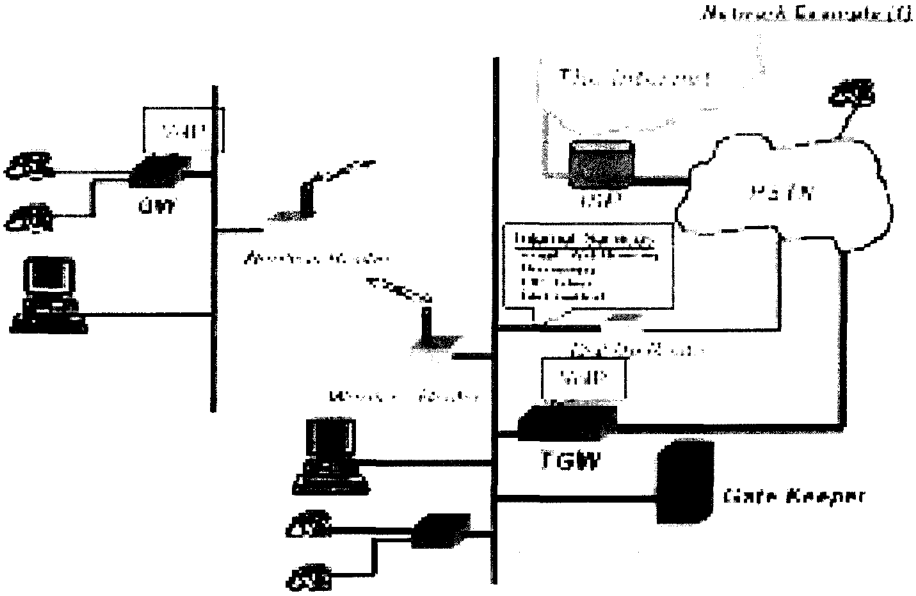


Fig 2.1 Yemen wireless IP access Network

2.1.2.6 EUROPE: Rural Telecentre Network in Septemvri Region, Bulgaria

Advanced telemedicine applications are running on a wireless IP infrastructure in ten remote communities in the outlaying area of Septemvri, Bulgaria. The project is supported by the local community and community medical centers, the Bulgarian Academy of Sciences, local and national governments and local industry. It provides a rural extension to the European Union-PHARE funded telecentre network.

2.1.2.7 LATIN AMERICA: Rural Access To Multimedia Library Project, Guaratiba,Brazil

The Instituto EMBRATEL 21, together with the ITU, is seeking additional global partners to deploy rural connectivity and extend its Multimedia Digital Library project and existing community access facilities using wireless IP/RLAN networks into the remote fishing community of Guaratiba.

2.1.2.8 OTHER TELECENTRES

In the UK which has a high concentration of tele-centers, most centers function as telework centers and provide facilities for teleworks. In France tele-working plays an important role in the creation of telecentres, the most successful centers act as IT Service Company with little or no emphasis on local development objectives.

A very different concept of telecentres has been used to promote rural development in Eastern Europe, most notably in Hungary, and later also in Estonia, where an active telecottage movement has been set up with support from Sweden . Australia telecentre activities contribute to development of rural community.

Also Indonesia has been successful in setting up telecentres (Warung telekomunikakasi or Wartels) have been established on franchise basis from 1988, and till 1994 there were 1500 centers generating about $9000 per line (ITU, 1998). Similar centers are planned in Thailand [3, 4].

2.2 WIRELESS REVOLUTION

Kofi Annan recently added his voice to a growing community of technologists, public policy officials and telecommunications practitioners who foresee a revolution in rural universal access. This revolution will be founded on a new suite of wireless technologies, matched by supportive public policies and business approaches, that can provide Internet access and voice service cheaply to rural and under-served communities [5]

2.2.1 THE NETWORK STANDARDS

One technology that is capturing the attention of industry and consumers is called "Wireless Fidelity" or "Wi-Fi". Wi-Fi describes a constellation of wireless technologies that comply with technical standards defined by the Institute of Electrical and Electronics Engineers (IEEE) under the nomenclature of 802.11b. Note that sometimes the term "Wi-Fi" also is used to refer to other technologies employing different but related standards, such as 802.11a.

Wi-Fi technologies are particularly well suited to providing WLAN connectivity that enables broadband Internet access like that illustrated between points C and D in Figure 2.2. Recent attention has particularly focused on the deployment of Wi-Fi "hotspots" (private WLAN available to the public)—often with a fee for use to enhanced universal access.

Wi-Fi and related terrestrial wireless technologies have actually been used to build network "infrastructure," such as the point-to-point and point-to-multipoint links discussed above. While 802.11b, in particular, was engineered specifically for use in a WLAN context, it has provided WMAN and backhaul service in some deployments. The standards include as follows:

802.11a – A specific wireless technical specification for use in the 5 GHz bands, termed the Unlicensed National Information Infrastructure (U-NII) bands in the United States.

802.11b – A specific wireless technical specification for use in the 2.4 GHz Industrial, Scientific and Medical (ISM) bands. 802.11b is currently the most popular specification and is popularly known as Wi-Fi.

802.16 – An emerging set of standards for fixed wireless broadband access.

Access Point – A WLAN transmitter/receiver that generally acts as a bridge between a wireless network and a wireline network. It can also, however, act as a wireless bridge between multiple wireless networks.

Hotspot – A WLAN available to the public in a location, such as an airport, coffee shop or neighbourhood.

Point-to-point -- A point-to-point radio has two highly directional antennas on either end of the radio link. It provides a symmetric connection between the two antennas.

Point-to-multipoint -- A point-to-multipoint radio has a broad coverage antenna at the hub side of the link and a highly directional antenna at the subscriber side of the link. Multiple subscribers can make use of the same hub.

WLAN - Wireless Local Area Network, a radio networking technology used generally to connect PCs (or other appliances) to a local network.

WMAN - For Wireless Metropolitan Area Network, a radio network that is larger than a WLAN, either in terms of geographic coverage or subscriber capacity; WMAN access might be offered across a community or city.

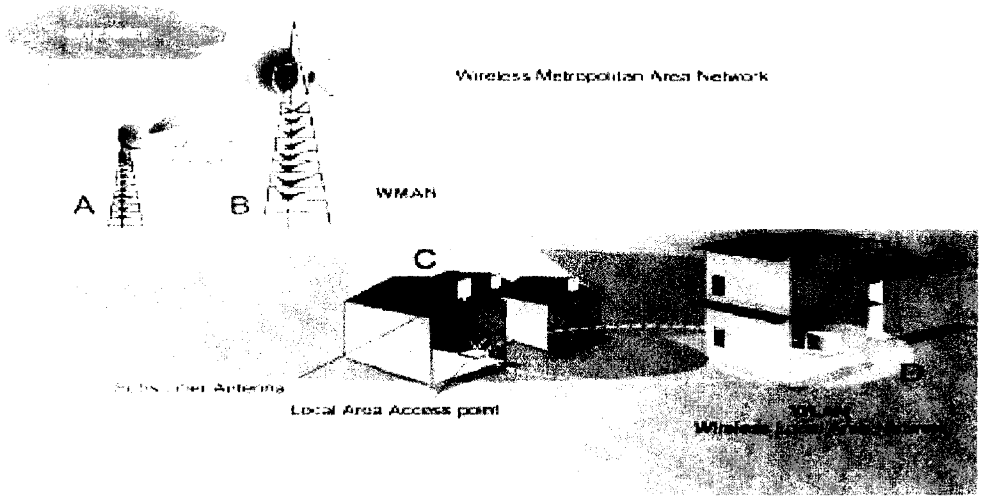


Figure 2.2: Connectivity in Wireless Networks

The link from radio tower A to tower B is a point-to-point connection, because it supports just a single radio and antenna on either side of the link. Tower B serves as a single point on a link, but it emits a broad sweep of radiation that covers an entire area around it, including all of the buildings marked C.

Finally, the picture envisions a radio connection between the subscriber equipment mounted on the side of the building (point C) and the individual personal computer inside the building (point D). Here, an access point emits radiation throughout the interiors of the building, allowing all personal computers outfitted with a simple wireless network interface card to connect to the access point--and ultimately, back up the chain to the Internet [6].

2.2.2 HOW WIRELESS NETWORKS ARE GROUPED

There are three important element of new terrestrial radio equipment that are central to its role in providing profitable universal access.

1. The decreasing cost.

1. The increasing capability of the technology.
2. The utilization of license-exempt radio bands.

Coverage distance continues to increase and the price continues to drop with Wi-Fi and related technologies. WLAN indoor access point can currently provide blanket coverage over a 100-meter radius for less than USD75.

Table 2.1 provides a comparison of the relevant features of selected wireless network standards and vendor equipment that can be used for universal access development. It is worth to note that these figures offer only rough estimates because field performance often varies from test or lab performance.

Table 2.1 Comparison of the Relevant Wireless Network Standards and Vendor Equipment

	IEEE STANDARDS		VENDORS			
	802.11	802.16	CANOPY	CorDECT	CFO-SS	Post Inc. Wireless Router
Pt-to-pt max distance	20km	50km	55km	-	20km	16km
Pt-to-multipoint max distance	1km	13km	15km	25km	10km	5km
Bandwidth	11Mbps shared large overhead	70Mbps shared large overhead	10Mbps shared large overhead	70kbps dedicated	10 or 18Mbps shared	11Mbps
Users unlicensed spectrum in many countries	Yes	Yes	Yes	Yes	Yes	Yes
Advantage	Popular inexpensive	Good range, good speed	Good range	Inexpensive proven in rural settings	Good range, high throughput with reducing data rates	Multipoint to multipoint IP routing
Disadvantage	Reduced data rates at long range inefficient spectrum use	Still emerging	Proprietary system, relatively expensive	Requires license	Proprietary system, relatively expensive	Insufficient spectrum use

2.3 GENERAL RURAL TELEPHONE NETWORKING BACKGROUND

Remote and rural communities in large or developing countries have historically been left with poor or non-existent communications due to a number of factors, although telephone service has often been considered important for regional growth. Wireline networks are often not an economic option due to high initial investment and low financial returns, especially in small communities and isolated locations. Most current rural telephone networks exist as an obligation from governmental requirements for telephone service providers to cover low density and small remote locations.

Wireless communication networks are gaining an increasing amount of attention for use in such applications due to more cost-effective performance. Although analog Multiple-Access Radio has been used before in rural applications, new wireless digital systems could help bring telephone communications to remote locations through the use of Wireless Local Loops (WLL) as mentioned by [7, 8, 9].

Since wireline service operators may not serve remote locations, high- and low- tier WLLs can provide a wireless "last-mile", but it still requires long distance access to the PSTN. This can be achieved with a satellite terminal, which has ubiquitous presence under the satellite's footprint. For that reason satellites are being considered as either a relay service (hybrid bent-pipe) or as part of an integrated cellular /satellite system, as reported by [10].

2.4 THE RURAL TELEPHONY PROBLEM: LOCAL AND LONG DISTANCE COMMUNICATIONS

Rural communities without telephone service have two different problems: they can neither call their neighbors (local calls) nor the outside world (long distance calls). Although many countries mandate their local telecommunications operators to provide long distance telephone service to certain size communities.

The local network's transmission media between the switch and the local user's premises is called the "last mile technology", and it may consist of cabled (wired) or radio (wireless) communication links.

Special attention is drawn to the remote (rural) and gateway (urban) earth station elements and overall satellite network technology that provides long distance telephone service using Very Small Aperture Terminal (VSAT) technology when following a cost-efficient design methodology [11].

2.5 TECHNOLOGY FOR RURAL APPLICATION

Access option on the horizon for rural areas includes a number of technologies that are new to the rural marketplace or still underdeveloped. In particular many rural operators are deploying Very Small Aperture Terminal (VSAT) and point-to-multipoint terrestrial radio systems integrated with wire-less local loop system based on standards such as Personal Handiphone System PHS and Digital Enhanced Cordless Telecommunications (DECT) [1]

2.5.1 VSAT TECHNOLOGY

VSAT Technology allows a user to provide services in a cost effective manner where terrestrial services are not easily attainable or reliable. VSAT technology is also a perfect disaster recovery or diverse routing solution. VSAT is the utilization of very small antennae which can provide multi-path connections anywhere in the world. With VSAT, dedicated data, voice, fax, Internet, or video conferencing can be provided with a guaranteed availability exceeding 99.95% with a BER better than 10 e-8 performances.

A typical VSAT system provides a point to point connection between locations providing either a single multiplexed carrier, a single application carrier, or multiple dedicated carriers between locations. Antenna size is restricted to being less than or equal to 3.8 m at Ku band and 7.8 m at C band. Typical applications for interactive VSAT networks are [11]:

- computer communications;
- reservation systems;
- database enquiries;
- billing systems;
- file transfers;
- electronic mail;
- video conferencing;
- point of sale transactions;
- credit checks and credit card verification;
- stock control and management.

The most common VSAT configuration is the TDM/TDMA star network. These have a high bit rate outbound carrier (TDM) from the hub to the remote earth stations, and one or more low or medium bit rate Time Division Multiple Access (TDMA) inbound carriers. With its star configuration network architecture, interactive VSAT technology is appropriate for any organization with centralized management and data processing.

The use of a single high performance hub allows the use of low cost remote VSAT terminals and optimizes use of satellite capacity. Even so, in most VSAT networks, the cost of the VSAT terminals usually far exceeds the cost of the hub (typically a VSAT terminal is 0.1 to 0.2% of the price of the hub). Figure 2.3 shows an interactive VSAT [12].

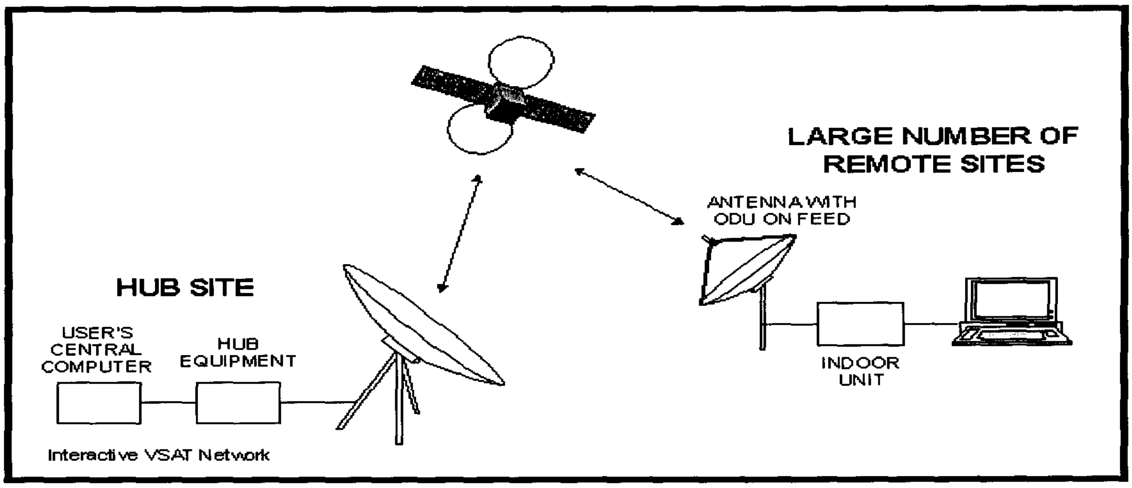


Fig 2.3 Interactive VSAT Network [12]

The principal characteristics of an interactive VSAT network are:

- Remote user sites have several low bit rate data terminal equipments (DTEs) operating at 1.2 to 9.6 kb/s. These are connected through the VSAT network to a centralized host processor. The DTEs are connected to the host through an X.25

Packet Assembler/Dissembler (PAD) or through a conventional or statistical multiplexer which concentrates the traffic.

- The amount of data transferred in each transaction is relatively small, typically between 300 and 10^5 bits. Interactive VSATs are not usually used for batch file transfer (10^7 to 10^{11} bits per transaction) unless the transmission plan is specifically designed to carry large files.
- Each VSAT terminal only operates with a low duty cycle, i.e. with only a relatively small number of transactions in the peak busy hour compared to the total available capacity.
- A large number of VSAT terminals (10 to 10000) share the same communications link using random access.
- Connections between remote VSAT terminals require a double hop through the hub and are rarely used.

VSAT terminals are controlled by microprocessors and can generally be reprogrammed remotely using downloaded software from the hub. Three different transmission schemes are used for interactive hubbed VSAT networks:

- TDM/TDMA
- Demand Assigned SCPC
- CDMA

It is also common for VSAT systems to support one-way TV transmission from the host to the remote stations. Two-way, 2 Mb/s transmissions can also be supported by some VSAT systems are show in Table 2.4. To make VSAT network more affordable, it is possible to share the hubs between several users thereby spearing the cost.

TABLE 2.4 Comparison of Interactive VSAT Network Characteristics

Supplier	Hardware	Type	Inbound Data Rate (kb/s)	Outbound Data Rate (kb/s)	Modulation
Gilat/Spacenet	Skystar Advantage	TDM/TDMA	9.6, 19.2, 38.4, 56, 64, 76.8, 128	64, 128, 256, 512, 1024, 2048	DPSK or MSK
Hughes	ISBN/PES	TDM/TDMA	64, 128, 256	128, 512	BPSK
Indra Espacio	Arcanet	CDMA			
NEC	Nextar V	TDM/TDMA	64, 128, 256	64, 128, 256, 512, 768, 1536, 2048	BPSK/QPSK
STM	X.Star	TDM/TDMA	96, 192, 384	64, 128, 256, 512, 1024, 1544	BPSK
TSAT	TSAT 2000	TDM/TDMA	0.3, 0.6, 1.2, 2.4, 4.8	0.3, 0.6, 1.2, 2.4, 4.8	4FSK, 2-4PSK
TSAT	TSAT 2100	TDM/TDMA	2.4 - 9.6, 14.4, 16.8	2.4 - 9.6, 14.4, 16.8	QPSK
ViaSat	Sky Relay	TDM/TDMA			

2.5.1.1 Shared Hub Networks

To make VSAT networks more affordable it is possible to share the hub between several users, thereby spreading the cost. In this case the hub is usually owned by a service provider who retains overall control of the network and manages the hub. Each user, however, is allocated his own time slots or carriers and can so operate his own private network using the shared hub facility without any loss of privacy.

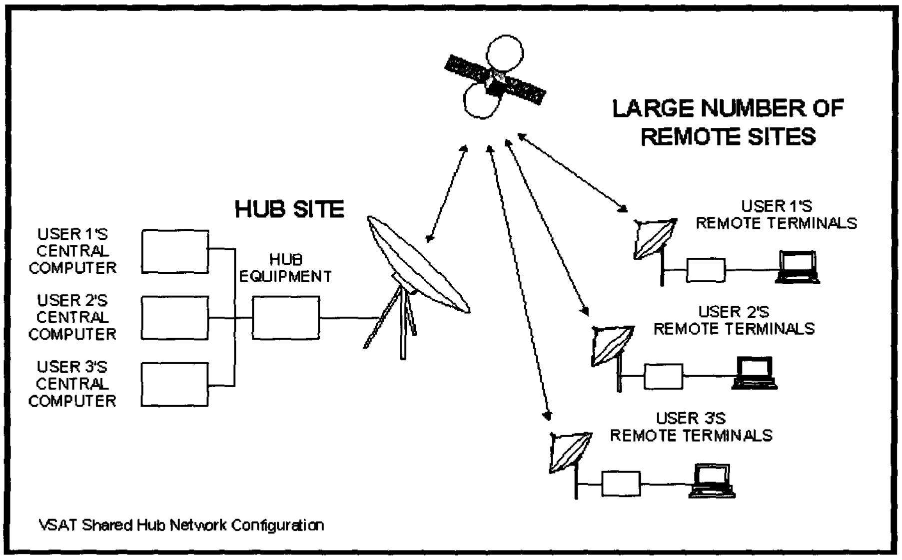


Fig 2.4 VSAT Shared Hub Network Configuration

2.5.1.2 Mini-Hub Networks

In this configuration, each user has his own "mini-hub" which is much smaller and simpler, and hence cheaper, than a conventional hub. The antenna diameter is typically only 2.4 m. Each user organization has complete control over his own communications. Overall management of the complete network is provided by the service supplier who has a "super hub" which provides network supervision and diagnostic support [12]

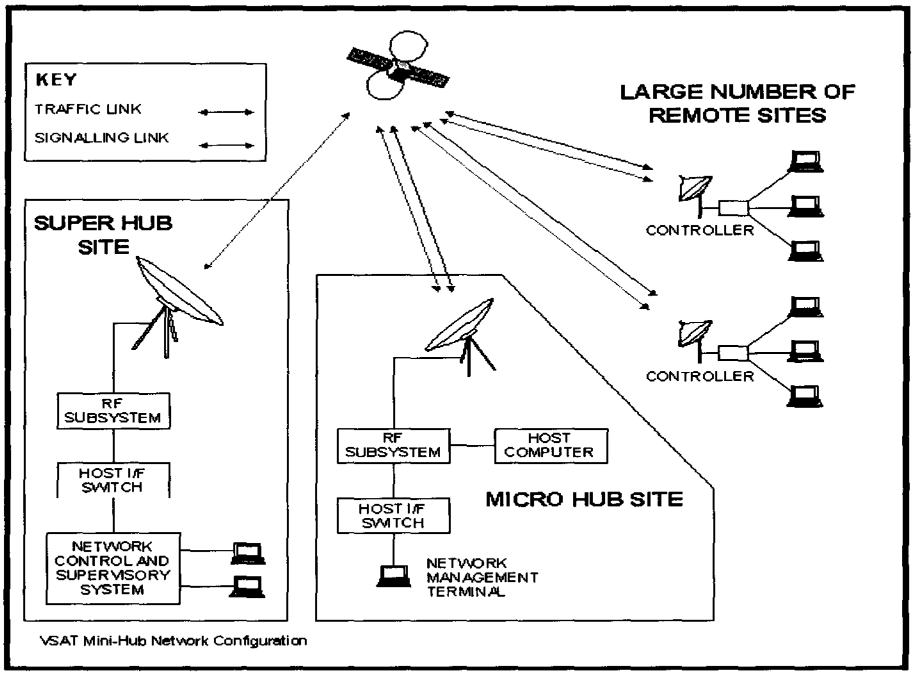


Fig 2.5 VSAT Mini-Hub Network Configuration

2.5.2 Wireless Local Loops (WLL) for Rural Local Communications

Currently, wireless technology offers different networking options for local loop telephone applications, not considering point-to-point or point-to-multipoint radiotelephones. Digital wireless telephone technology can be divided into two very well defined groups, based on its technology platforms, services and characteristics.

1) *Cordless telephone systems*, which are also defined as Low-Tier Wireless Local Loops (L-WLL).

2) *Cellular telephone systems*, which are also defined as High-Tier Wireless Local Loops (H-WLL).

Since both WLL groups work at UHF frequencies, rain is not a problem, and for rural, scattered, semi -fixed users, multipath is not as big a problem as it is in urban applications. In both cases, satellite access to the PSTN Central Office (CO) switch is needed for remote site applications. Either type of technology could provide adequate service in a remote Wireless Local Loop application if there is a satellite link to the PSTN.

The main difference between cordless (low-tier, L-WLL) and cellular (high-tier, H-WLL) systems is the coverage area, which in the first case is usually a few hundred meters for low mobility users, while in the second case the area may be a few kilometers for high mobility users. Each WLL technology also has specific characteristics regarding traffic capacity and performance depending upon the network size, and will be briefly described next.

2.5.2.1 High Tier (Cellular) WLL

A high tier WLL is basically a cellular radio mobile system which provides a wireless connection from the user's terminal (portable, mobile or semi -fixed) to the PSTN through a radio channel. Current cellular systems includes: Second Generation(2G), Third Generation (3G) systems,

The three most important 2G digital cellular standards are known as GSM, CDMA and TDMA. The first, Global System for Mobile or GSM/DCS1800, is a European standard and currently the most widely used digital cellular and PCS standard in the world.

The second, using Code Division Multiple Access CDMA/IS-95 is a U.S. standard introduced by the company Qualcomm, and the third, using Time Division Multiple Access or USDC/IS-136, is an evolution of the first generation AMPS system and also a U.S. standard. The main parameters of the 2G H-WLL systems mentioned above are presented in Table 2.1.

Table 2.1 High tier wireless local loop technologies

Cellular standard		*IS-54/136*	*GSM*	*IS-95*	*DCS 1800*
Multiple Access		TDMA/FDMA	TDMA/FDMA	CDMA/FDMA	TDMA/FDMA
Freq. Bands	Fwd	869-894 MHz	935-960 MHz	869-894 MHz	1805-1880 MHz
	Rev	824-849 MHz	890-915 MHz	824-849 MHz	1710-1785 MHz
Modulation		π/4 DQPSK	GMSK	BPSK/QPSK	GMSK
RF Channel		30 kHz	200 kHz	1250 kHz	200 kHz
Carriers per channel		3	8	Variable	8
Channel bit rate		48.6 kbps	270.833 kbps	1.2288 Mchip/s	270.833 kbps

2.5.2.2 Low Tier (Cordless) WLL

Low tier WLLs are currently the high-end evolution of indoor cordless telephones, which now feature digital services and allow more extensive coverage area than their predecessors. Frequency spectrum has been assigned to L-WLLs around 1900 MHz in most countries. In order to solve the last mile problem for the PSTN they are expected to cover only a neighborhood area, thus limiting fast-moving phones. L-WLLs could be used for large concentrations of users in small areas with low user mobility. Table 2.2 shows the basic parameters of each technology. Arguably the three most promising digital standards in the world are [11]:

- The Personal Access Communications System (PACS), designed to merge with the Integrated Services Digital Network (ISDN).
- Digital European Cordless Telephone (DECT),
- The Personal Handiphone System (PHS),

Table 2.2. Low tier wireless local loop technologies [11]

Cordless standard	*PACS*	*DECT / PWT*	*PHS*
Multiple Access	TDMA/FDMA	TDMA/FDMA	TDMA/FDMA
Frequency (MHz)	1850-1910 1930-1990	1880-1900	1895-1918
RF Channel (kHz)	1728	300	300
Number of carriers	16 pairs/10 MHz	10	77
Channels per carrier	8/pair	12	4
Channel rate (kbps)	32	32	32

2.5.3 CODE DIVISION MULITIPLE ACCESS (CDMA2000)

2.5.3.1 The Technology of Choice for WLL

There is strong and immediate need for readily available and state-of-the-art WLL systems in several developing regions because of the pressures on national governments to fulfill social, economic and political obligations related to tele-density objectives in rural and less developed areas.

Providing Internet access through wireline-based dial-up, cable and DSL service, especially in undeveloped or sparsely populated areas, is costly and time consuming. Incumbent and competitive local exchange carriers (LECs), as well as mobile service providers, can provide voice and data services to the subscriber using WLL systems at relatively lower costs and in a shorter period of time.

In emerging markets where PC penetration is low, the ability to support tele-centers or cyber-cafes can constitute an additional revenue source for the operator. This evolution of services from simple dial-up to higher speed (ISDN, cable and/or DSL) has raised the bar at which WLL services are expected to perform [13].

2.5.3.2 Competitive Advantages OF CDMA2000-Based WLL systems

- **Greater Spectral Efficiency:** CDMA2000 1X systems offer more than 35 voice channels per sector per 1.25 MHz carrier, making it the most spectrally efficient technology deployed today. Through the use of transmit and receive antenna diversity techniques, the voice capacity can be doubled. Enhanced capacity directly translates to increased spectral efficiency, fewer dropped calls and fewer blocked calls.
- **Superior Voice Clarity:** Based on mean opinion score (MOS) listening tests, CDMA systems offer the best voice clarity. The vocoders used in CDMA systems are rated better in voice quality tests than the vocoders used by other competing technologies.
- **Fewer Dropped Calls:** Soft and softer handoff techniques and multi-path rake receivers improve the signals received at the Mobile as well as at the Base Station; which significantly lowers the probability of dropped calls in CDMA systems.
- **Lower Transmission Power:** The inherent nature of CDMA spread spectrum technology and its dynamic power control capabilities allows CDMA mobile devices to transmit at lower RF power levels than the mobiles designed for other wireless technologies. This results in enhanced system capacity and longer battery talk time.
- **Higher Data Throughput Speeds:** With CDMA2000 1X systems, users can get peak data rates of 153 kbps with Release 0 and up to 307.2 kbps with Release A . Typical average user throughput is in the range of 60-100 kbps. With the introduction of presently available 1xEV-DO (Data Optimized) systems, users can receive higher down-link peak data rates of up to 2.4 Mbps with average

user throughput of 300-600 kbps and a sector data throughput of 800-1100 kbps per carrier.

- **Enhanced Global Roaming Capability:** With the availability of multi-mode, multi-band CDMA handsets, roaming between CDMA and GSM networks has become feasible. Qualcomm has already developed a multi-technology chipset that supports IS-95 A/B, CDMA2000 1X and GSM / GPRS all in a single baseband chipset.
- **Inherent Voice Security:** In CDMA systems, the use of an ESN-based long code mask (2^{41} length PN sequence) for voice scrambling provides greater over-the-air privacy and eliminates cloning, cross-talk and eavesdropping.

CDMA2000-based WLL systems are readily available in various frequency bands (450, 850, 1700 and 1900 MHz). The RF propagation loss is less at the lower frequencies and hence a CDMA2000 WLL base station operating at 450 or 850 MHz can serve a greater coverage area compared to a system operating at 1800/1900/2100 MHz.

Another lesser known coverage advantage of CDMA systems is that the signals are usable even across large distances. In traditional TDMA based systems, as the name denotes, time is used as the multiple access mechanism where traffic and control information is separated into time slots [13].

2.5.4 MICROWAVE LINK

A microwave link is a communications system that uses a beam of radio waves in the microwave frequency range to transmit information between two fixed locations on the earth as show in fig 2.6.

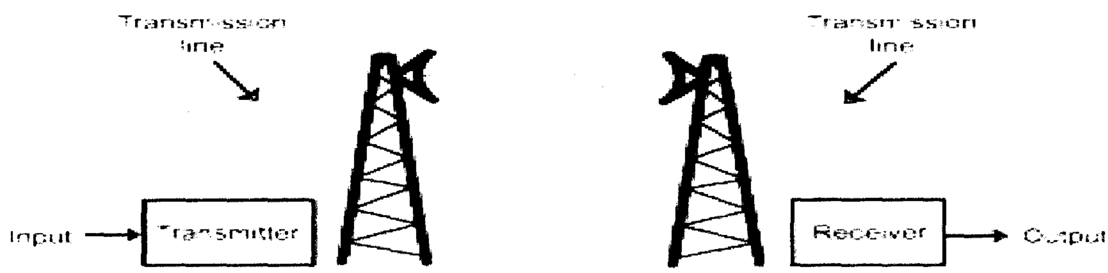


Fig 2.6 microwave link network

A simple one-way microwave link includes four major elements: a transmitter, a receiver, transmission lines, and antennas. These basic components exist in every radio communications system, including cellular telephones, two-way radios, wireless networks, and commercial broadcasting.

But the technology used in microwave links differs markedly from that used at the lower frequencies (longer wavelengths) in the radio spectrum. Techniques and components that work well at low frequencies are not useable at the higher frequencies (shorter wavelengths) used in microwave links. For example, ordinary wires and cables function poorly as conductors of microwave signals.

Figure 2.6 shows a typical microwave link, the transmitter has two fundamental jobs: generating microwave energy at the required frequency and power level, and modulating it with the input signal so that it conveys meaningful information.

The second integral part of a microwave link is a transmission line. This line carries the signal from the transmitter to the antenna and, at the receiving end of the link, from the antenna to the receiver. But at microwave frequencies, those media excessively weaken the signal and coaxial cables especially, hollow pipes called waveguides comes into play.

The third part of the microwave system is the antennas. On the transmitting end, the antenna emits the microwave signal from the transmission line into free space. At the receiver site, an antenna pointed toward the transmitting station collects the signal energy and feeds it into the transmission line for processing by the receiver. Antennas used in microwave links are highly directional, which means they tightly focus the transmitted energy, and receive energy mainly from one specific direction.

Between the link's antennas lies another vital element of the microwave link—the path taken by the signal through the earth's atmosphere. A clear path is critical to the microwave link's success. Natural obstacles also exist. Flat terrain can create undesirable reflections, precipitation can absorb or scatter some of the microwave energy.

At the end of the link is the final component, the receiver (demodulate), is used to separate the information from the microwave energy that carries it. The receiver must be capable of detecting very small amounts of microwave energy, because the signal loses much of its strength on its journey.

Microwave links are certain to be important building blocks of the world's communications infrastructure for years to come. [14]

2.5.4.1 EXPLANATION OF TERMS USED IN MIRCROWAVE LINK

1. Free Space Loss: Free space loss (FSL), measured in dB, specifies how much the signal has weakened over a given distance. Figure 2.7 shows the formula to calculate FSL and what the theoretical loss would be at sample distances. The type of antenna used has no effect on FSL, since at any appreciable distance all antennas look like a

point-source radiator. The difference in FSL between a 2.4 GHz link and a 5.8 GHz link is always about 8 dB, regardless of the distance. This is one of the reasons why 802.11a wireless local area network (WLAN) devices will have less than half the range of a 2.4 GHz WLAN device (e.g., 802.11b).

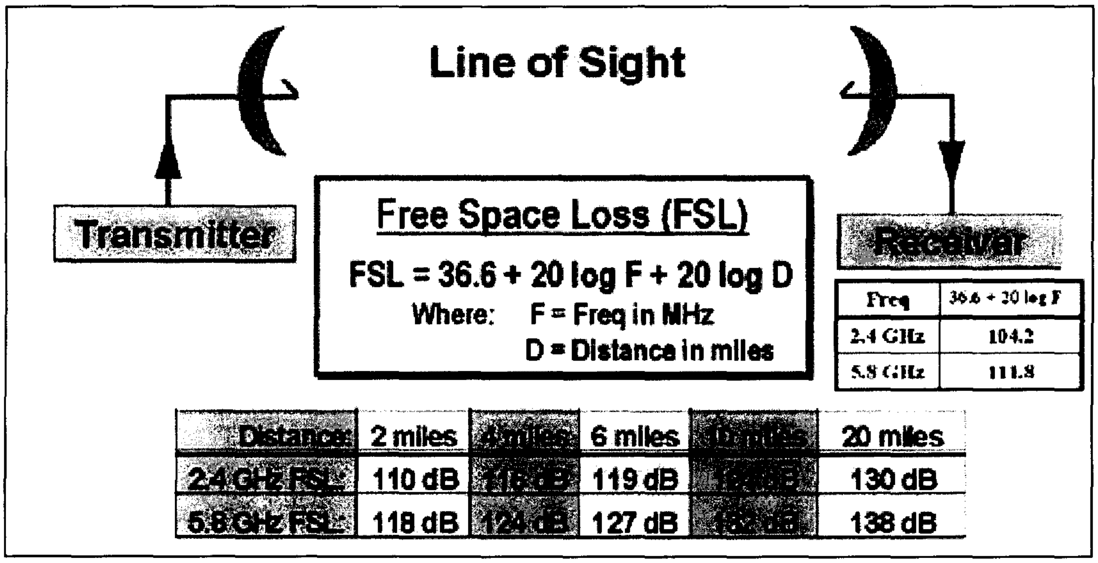


Fig 2.7: Formula to calculate Free Space Loss [14]

2. **Fresnel Zone:** Radio waves travel in a straight line, unless something refracts or reflects them. . If there is an obstacle in the Fresnel zone, part of the radio signal will be diffracted or bent away from the straight-line path. The practical effect is that on a point-to-point radio link, this refraction will reduce the amount of RF energy reaching the receive antenna. The thickness or radius of the Fresnel zone depends on the frequency of the signal. Figure 2.8 illustrates how the Fresnel zone is fattest in the middle.

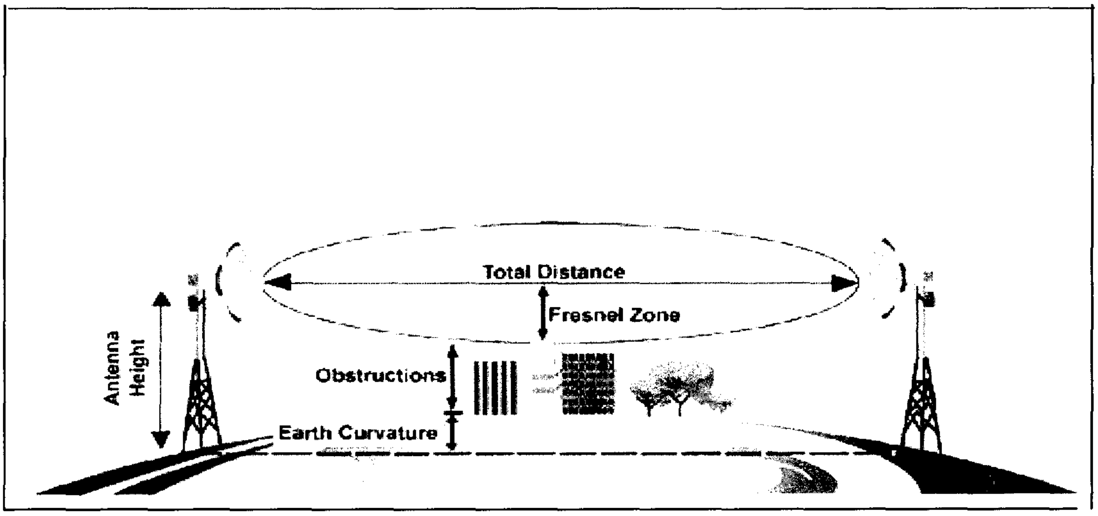


Fig 2.8 free zone [14]

3. Receive Signal Level: Receive signal level is the actual received signal level (usually measured in negative dBm) presented to the antenna port of a radio receiver from a remote transmitter.

4. Receiver Sensitivity: Receiver sensitivity is the weakest RF signal level (usually measured in negative dBm) that a radio needs receive in order to demodulate and decode a packet of data without errors.

5. Antenna Gain: Antenna gain is the ratio of how much an antenna boosts the RF signal over a specified low-gain radiator. Antennas achieve gain simply by focusing RF energy. If this gain is compared with an isotropic (no gain) radiator, it is measured in dBi. If the gain is measured against a standard dipole antenna, it is measured in dBd. Note that gain applies to both transmit and receive signals.

6. Transmit Power: The transmit power is the RF power coming out of the antenna port of a transmitter. It is measured in dBm, Watts or milliWatts and does not include the signal loss of the coax cable or the gain of the antenna.

7. Effective Isotropic Radiated Power: Effective isotropic radiated power (EIRP) is the actual RF power as measured in the main lobe (or focal point) of an antenna. It is

equal to the sum of the transmit power into the antenna (in dBm) added to the dBi gain of the antenna. Since it is a power level, the result is measured in dBm. Figure 2.9 shows how +24 dBm of power (250 mW) can be "boosted" to +48 dBm or 64 Watts of radiated power.

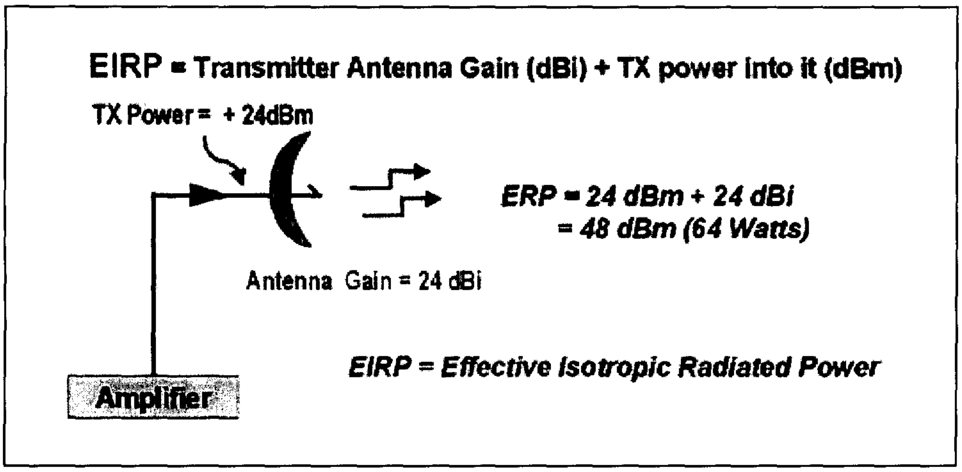


Fig 2.9 EIRP Calculation [14]

8. System Operating Margin: System operating margin (SOM) is the difference (measured in dB) between the nominal signal level received at one end of a radio link and the signal level required by that radio to assure that a packet of data is decoded without error (see Figure 2.10). In other words, SOM is the difference between the signal received and the radio's specified receiver's sensitivity. SOM is also referred to as link margin or fade margin.

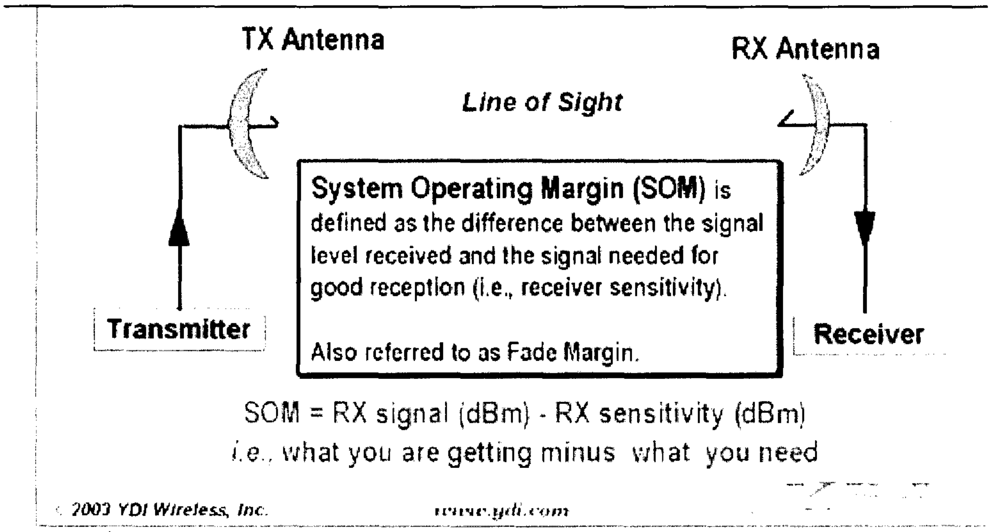


Fig 2.10 System Operation Margin [14]

9. Multipath Interference: When signals arrive at a remote antenna after being reflected off the ground or refracted back to earth from the sky (sometimes called ducting), they will subtract (or add) to the main signal and cause the received signal to be weaker (or stronger) throughout the day.

10. Signal-to-Noise Ratio: Signal-to-noise ratio (SNR) is the ratio (usually measured in dB) between the signal level received and the noise floor level for that particular signal. The SNR is really the only thing receiver demodulators really care about. Figure 5 illustrates that weaker signals are larger negative numbers. It also graphically shows how the SNR is computed.

2.6 Satellite Systems Used for Rural Telephony

Rural Telephony by satellite has been widely studied and described, but in fact much of that work never became a reality until recent times for several reasons. There were a few places where it had been implemented before, usually on small pilot networks as mentioned in [15] and [16].

Recent large applications are currently being deployed in South Africa (3,000 small terminals), Guatemala (600) and Australia (400) as reported in [17]. There have also been large network implementations in Chile (1,700) and Peru (190) as detailed in [18], but large VSAT manufacturing companies and telephone service providers are still looking for cost efficient designs, attractive for all involved (manufacturers, operators and service users). Typical uses of small or personal satellite terminals are

- Serve coverage areas without wire line or cellular service,
- Replace telephone networks in disaster situations, or
- Serve as an auxiliary buffer when the wired or wireless capacity has been reached.

Remote user can access the PSTN via satellite in one of two ways: through an indirect user link access to the satellite, or a direct link access. The indirect access to the satellite is made from a wired or Wireless Local Loop (WLL) user terminal through a VSAT terminal and a GEO satellite *(hybrid system,* Figure 2.11*)*. The direct access architecture allows the user to transmit from a mobile terminal directly to the satellite (integrated system, Figure 2.12). There are a number of assumptions for the earth station technologies that fall into the following parameters

- All earth stations are assumed to be under the satellite's main coverage area, with clear line of sight to the satellite and located at the –3dB edge of the satellite antenna's main beam.
- All Remote Earth Stations (RES, VSAT terminals) and Gateway Earth Station (GES, Hub) use high gain, directional, parabolic (center-fed, offset or Cassegrain) dish antennas.

- All earth stations include an Outdoor Electronic Unit (ODU) comprising an up/down frequency converter, a Low Noise Amplifier (LNA) or Block-converter (LNB), and a solid state or tube High Power Amplifier (HPA).
- A typical RES should not be larger than 1.8 meters in diameter and HPAs should not have more than 2 Watts of maximum RF output power.
- All earth stations use Indoor Electronic Units (IDU) comprising a generic satellite modem using BPSK, QPSK or any of its variants, and include multiple access control to the satellite.
- All RES include a user interface and terminal equipment (telephone, data port) for an individual user, provide a TDM interface and equipment for multiple users, or access to the PBX or WLL equipment, depending upon each case.
- All IDU equipment is sheltered from the open weather and provided with electric and electromagnetic shielding. All terminal equipment can be controlled and monitored by remote control supervisory operation, and electrical power supplies are assumed available.
- The gateway earth station (GES), or hub, provides direct access to the PSTN at all times through a number of physical connections (circuits or routers), according to the expected channel and traffic capacity analysis.

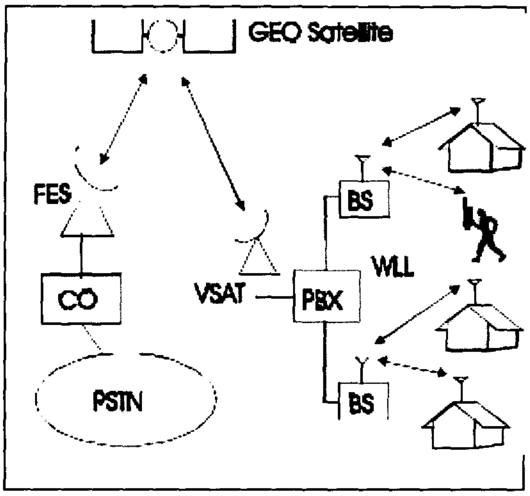


Fig 2.11: Hybrid satellite system

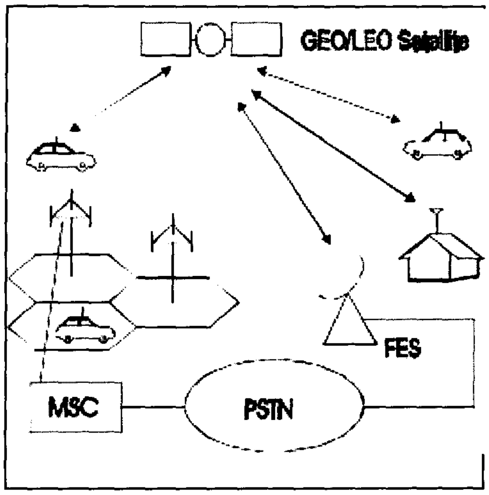


Fig 2.12: Integrated satellite system [11]

2.7 VSAT-Based Rural Satellite Systems

A Very Small Aperture System (VSAT) satellite network consists of a Master Earth Station (Gateway, Hub) which controls a number of smaller remote earth stations allowing digital transmission through a number of possible networking combinations, usually in a star or mesh topology.

The remote terminals are known as VSATs (Very Small Aperture Terminals) because they have small antennas. A VSAT terminal usually a 0.6 - 2.4 meter dish antenna and a transceiver radio (outdoor unit - ODU) and a set of baseband and IF subsystems (indoor units - IDU) and requires electrical power, which in some locations could mean solar panels and battery banks. In hybrid architectures the VSAT is connected to the WLL base station or radio port and to the local switching exchange.

Examples of rural telephony systems, some of them hybrid, are those offered by Gillam (Belgium), Gilat (Israel), and Titan, Scientific Atlanta, STM Wireless and Hughes Network Systems in the US [18]. These systems provide local wireless service plus a GEO satellite terminal for long distance access to the PSTN in a networked environment. The users only require a common wireless phone since the service provider or network operator provides the VSAT terminal.

The satellite frequency spectrum required for these systems might be that of any available C or Ku band transponder that services the coverage area, but the local WLL frequency spectrum, cell size and distribution and required radio power have to be defined and approved locally. [18].

2.8 Broadband Satellite Systems

Wireline terrestrial networks, Cellular and other current wireless systems do not have the capacity to provide wideband services either. A new technology, Local Multipoint Distribution Service (LMDS) will be able to provide this service in urban and some rural communities, but its reach is still limited. Satellite systems have entered the broadband communications arena through the use of different technologies, such as Direct Broadcast Satellites (Hughes's dual DirectTV and DirectPC).

VSAT technology is also being used for this application, mainly through similar systems offered by the same companies mentioned above (Gilat, HNS, STM Wireless, S-A) and others such as ViaSat, Datel, Norsat and Wi reless World Wide Web (W4). Most of these VSAT-based systems already offer a rural or remote high speed (64 kbps to 2 Mbps) satellite connection to the Internet through various hub gateways and operate on a star topology at Ku-band with antenna sizes between 0.8 and 2.4 m.

A number of companies are developing broadband mobile satellite systems at both LEO and GEO orbits in order to provide broadband multimedia capable digital services at a global level. These networks will be able to provide Broadband Integrated Services Digital Network (B-ISDN) channel capacity and high-speed IP and ATM packet switching services to every corner of the earth. The only part of the RF spectrum with available bandwidth for these applications is Ka band (30/20 GHz), so most broadband satellite systems are planning to use that frequency band. One such system, *Teledesic*, is based on an on-board ATM packet switching format through a constellation of 288 LEO satellites at Ka band and is expected to start operations by 2004 [19].

CHAPTER THREE

QUALITY OF SERVICE IN DIGITAL TELEPHONY OVER SATELLITE

3.1 Coding of Text, Voice, Image, and Video Signals

The information that has to be exchanged between two entities (persons or machines) in a communication system can be in one of the following formats:

- Text
- Voice
- Image
- Video

In an electrical communication system, the information is first converted into an electrical signal. For instance, a microphone is the transducer that converts the human voice into an analog signal. Similarly, the video camera converts the real-life scenery into an analog signal. In a digital communication system, the first step is to convert the analog signal into digital format using analog-to-digital conversion techniques [20].

3.1.1 TEXT MESSAGES

Text messages are generally represented in ASCII (American Standard Code for Information Interchange), in which a 7-bit code is used to represent each character. Another code form called EBCDIC (Extended Binary Coded Decimal Interchange Code) is also used. To transmit text messages, first the text is converted into one of these formats, and then the bit stream is converted into an electrical signal.

Using ASCII, the number of characters that can be represented is limited to 128 because only 7-bit code is used. ISCII is used to represent text of Indian languages. In extended ASCII, each character is represented by 8 bits.,in which a number of graphic characters and control characters can be represented.

Unicode has been developed to represent all the world languages. It uses 16 bits to represent each character and can be used to encode the characters of any recognized language in the world. Modern programming languages such as Java and markup languages such as XML support Unicode.

3.1.2 VOICE

To transmit voice from one place to another, the speech (acoustic signal) is first converted into an electrical signal using a transducer, the microphone. The important characteristics of the voice signal which is converted into an electrical signal using a transducer are given here:

- The voice signal occupies a bandwidth of 4 kHz. In telephone networks, the bandwidth is limited to only 3.4 kHz.
- Pitch is the fundamental frequency in the voice signal. A male voice, is in the range of 50–250 Hz,and that of a female is in the range of 200–400 Hz.
- Voice signal is considered a non-stationary signal. Therefore; the pitch value can be calculated using the voice signal of 20msec.

3.1.2.1 Waveform Coding

Waveform coding is done in such a way that the analog electrical signal can be reproduced at the receiving end with minimum distortion. The two important waveform coding techniques: pulse code modulation (PCM) and adaptive differential pulse code modulation (ADPCM).

3.1.2.1.1 Pulse Code Modulation

Pulse Code Modulation (PCM) is the first and the most widely used waveform coding technique. The ITU-T Recommendation G.711 specifies the algorithm for coding speech in PCM format. PCM coding technique is based on Nyquist's theorem, which states that if a signal is sampled uniformly at least at the rate of twice the highest frequency component, it can be reconstructed without any distortion.

The highest frequency component in voice signal is 4kHz, so we need to sample the waveform at 8000 samples per second—every 1/8000th of a second (125 microseconds). We have to find out the amplitude of the waveform for every 125 microseconds and transmit that value instead of transmitting the analog signal as it is. The sample values are still analog values, and we can "quantize" these values into a fixed number of levels.

As shown in figure 3.1, if the number of quantization levels is 256, we can represent each sample by 8 bits. So, 1 second of voice signal can be represented by 8000 × 8 bits, 64kbits. Hence, for transmitting voice using PCM, we require 64 kbps data rate. However, since we are approximating the sample values through quantization, there will be a distortion in the reconstructed signal; this distortion is known as "quantization noise".

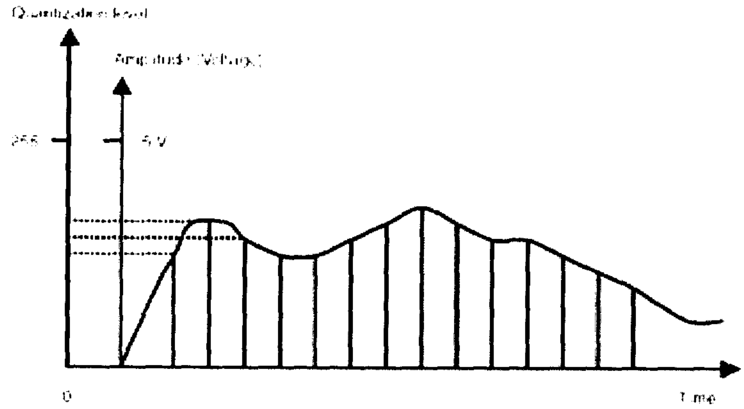


Figure 3.1: Pulse Code Modulation [20].

The speech quality produced by the PCM coding technique is called toll quality speech and is taken as the reference to compare the quality of other speech coding techniques.

For CD-quality audio, the sampling rate is 44.1kHz (one sample every 23 microseconds), and each sample is coded with 16 bits. For two-channel stereo audio stream, the bit rate required is 2 × 44.1 × 1000 × 16 = 1.41Mbps.

3.1.2.1.2 Adaptive Differential Pulse Code Modulation

One simple modification that can be mode to PCM is that we can code the difference between two successive samples rather than coding the samples directly. This technique is known as differential pulse code modulation (DPCM).

At the transmitting side, we predict the sample value and find the difference between the predicted value and the actual value and then send the difference value. This technique is known as adaptive differential pulse code modulation (ADPCM). Using ADPCM, voice signals can be coded at 32kbps without any degradation of quality as compared to PCM.

ITU-T Recommendation G.721 specifies the coding algorithm. In ADPCM, the value of speech sample is not transmitted, but the difference between the predicted value and the actual sample value is. Generally, the ADPCM coder takes the PCM coded speech data and converts it to ADPCM data.

The block diagram of an ADPCM encoder is shown in Figure 3.2(a). Each is predicted using a prediction algorithm, and then the predicted value of the linear sample is subtracted from the actual value to generate the difference signal. Adaptive quantization is performed on difference sample value to produce a 4-bit ADPCM sample value, which is transmitted.

At the receiving end, the decoder, shown in Figure 3.2(b), obtains the dequantized version of the digital signal. This value is added to the value generated by the adaptive predictor to produce the linear PCM coded speech, which is adjusted to reconstruct m-law-based PCM coded speech.

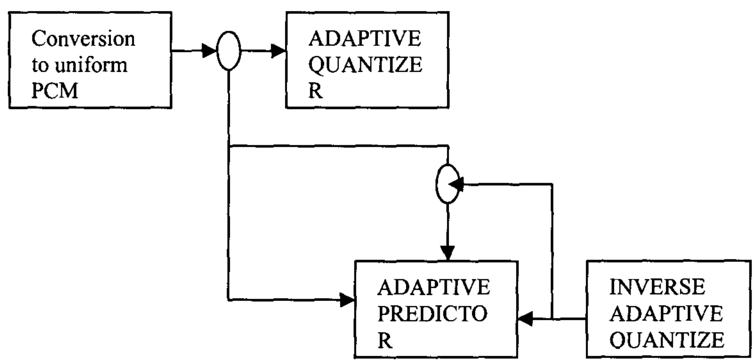


Figure 3.2: (a) ADPCM Encoder.

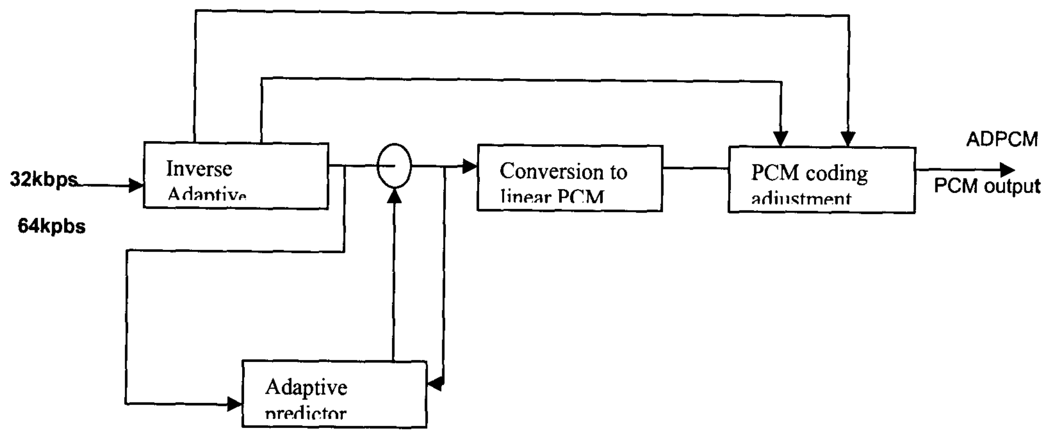


Figure 3.2: (b) ADPCM Decoder [20].

The PCM coding technique is used extensively in telephone networks. ADPCM is used in telephone networks as well as in many radio systems such as digital Enhanced Cordless Telecommunications (DECT).

3.1.2.2 Vocoding

A radically different method of coding speech signals was proposed by H. Dudley in 1939. He named his coder vocoder, a term derived from VOice CODER. In a vocoder, the electrical model for speech production seen in Figure 3.3 is used. This model is called the source–filter model because the speech production mechanism is considered as two distinct entities—a filter to model the vocal tract and an excitation source. The vocal tract filter is a time-varying filter—the filter coefficients vary with time. As the characteristics of the voice signal vary slowly with time, for time periods on the order of 20msec, the filter coefficients can be assumed to be constant.

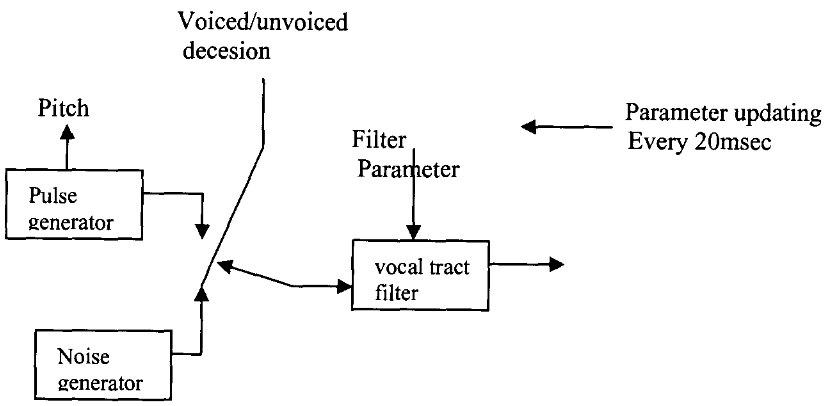


Figure 3.3: Electrical model of speech production [20].

In vocoding techniques, at the transmitter, the speech signal is divided into frames of 20msec in duration. Each frame contains 160 samples. Each frame is analyzed to check whether it is a voiced frame or unvoiced frame by using parameters such as energy, amplitude levels, etc.

These parameters—voiced/unvoiced classification, filter coefficients, and pitch for voiced frames—are transmitted to the receiver. At the receiving end, the speech signal is reconstructed using the electrical model of speech production. A number of techniques are used for calculating the filter coefficients. Linear prediction is the most widely used of these techniques.

3.1.3 IMAGE

To transmit an image, the image is divided into grids called pixels (or picture elements). The higher the number of grids, the higher the resolution. Grid sizes such as 768 × 1024 and 400 × 600 are generally used in computer graphics. For black-and-white pictures, each pixel is given a certain grayscale value. If there are 256 grayscale levels, each pixel is represented by 8 bits. So, to represent a picture with a grid size of 400 × 600 pixels with each pixel of 8 bits, 240kbytes of storage is required. To represent color, the levels of the three fundamental colors—red, blue, and green—are combined together. The shades of the colors will be higher if more levels of each color are used

For example, if an image is coded with a resolution of 352 × 240 pixels, and each pixel is represented by 24 bits, the size of the image is 352 × 240 × 24/8 = 247.5 kilobytes. To store the images as well as to send them through a communication medium, the image needs to be compressed. One of the most widely used image coding formats is JPEG format. Joint Photograph Experts Group (JPEG) proposed this standard for coding of images. The block diagram of JPEG image compression is shown in Figure 3.3.

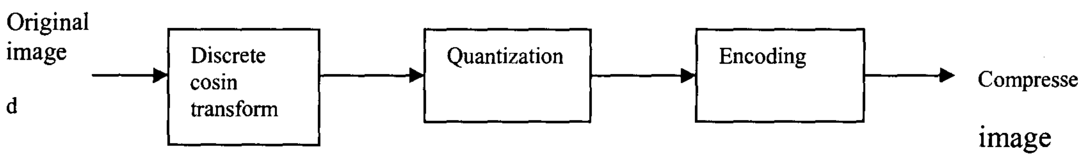


Figure 3.3: JPEG compression [20].

For compressing the image using the JPEG compression technique, the image is divided into blocks of 8 by 8 pixels and each block is processed using the following steps:

1. Apply discrete cosine transform (DCT), which takes the 8 × 8 matrix and produces an 8 × 8 matrix that contains the frequency coefficients.
2. Quantize the frequency coefficients obtained in Step 1. As a result, the quality of the image will slightly degrade.
3. Convert the quantization levels into bits. Since there will be little change in the consecutive frequency coefficients, the differences

in the frequency coefficients are encoded instead of directly encoding the coefficients.

Compression ratios of 30:1 can be achieved using JPEG compression. In other words, a 300kB image can be reduced to about 10kB.

3.1.4 VIDEO

A video signal occupies a bandwidth of 5MHz. Using the Nyquist sampling theorem, we need to sample the video signal at 10 samples/msec. If we use 8-bit PCM, video signal requires a bandwidth of 80Mbps. This is a very high data rate, and this coding technique is not suitable for digital transmission of video.

For video coding, the video is considered a series of frames. At least 16 frames per second are required to get the perception of moving video. Each frame is compressed using the image compression techniques and transmitted. Using this technique, video can be compressed to 64kbps, though the quality will not be very good.

MPEG-4: This standard is used extensively for coding, creation, and distribution of audio-visual content for many applications because it supports a wide range of data rates. The MPEG-4 standard addresses the following aspects:

- Representing audio-visual content, called media objects.
- Describing the composition of these objects to create compound media objects.
- Multiplexing and synchronizing the data.

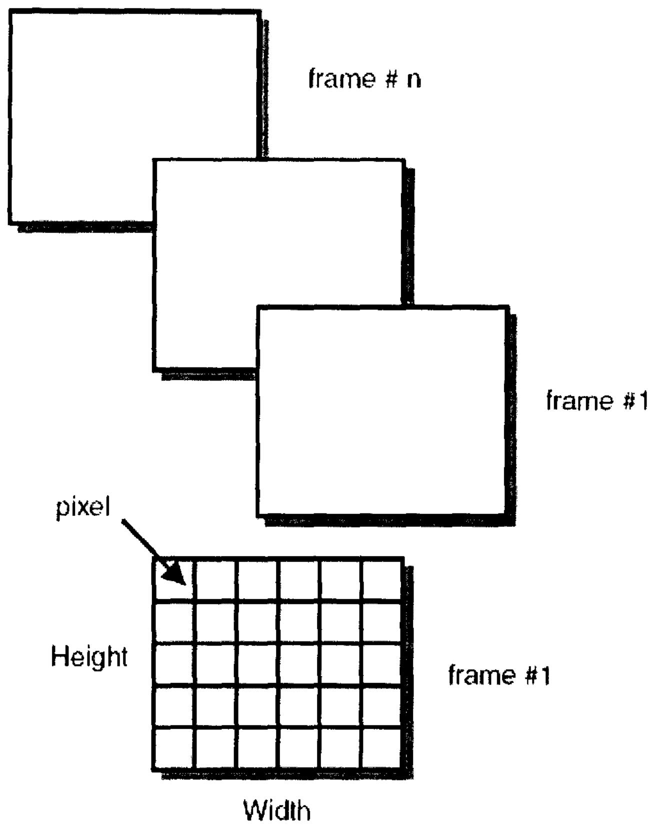


Figure 3.4: Video coding through frames and pixels [20].

The primitive objects can be still images, audio, text, graphics, video, or synthesized speech. Video coding between 5kbps and 10Mbps, speech coding from 1.2kbps to 24kbps, audio (music) coding at 128kbps, etc. are possible. MP3 (MPEG Layer–3) is the standard for distribution of music at 128kbps data rate, which is a part of the MPEG-4 standards.

For video conferencing, 384kbps and 2.048Mbps data rates are very commonly used to obtain better quality as compared to 64kbps. Video conferencing equipment that supports these data rates is commercially available.

MPEG-4 is used in mobile communication systems for supporting video conferencing while on the move. It also is used in video conferencing over the Internet.

In spite of the many developments in digital communication, video broadcasting continues to be analog in most countries. Many standards have been developed for digital video applications. When optical fiber is used extensively as the transmission medium, perhaps then digital video will gain popularity. The important European digital formats for video are given here:

Multimedia CIF format: Width in pixels 360; height in pixels 288; frames/ second 6.25 to 25; bit rate without compression 7.8 to 31 Mbps; with compression 1 to 3 Mbps.

Video conferencing (QCIF format): Width in pixels 180; height in pixels 144; frames per second 6.25 to 25; bit rate without compression 1.9 to 7.8 Mbps; with compression 0.064 to 1 Mbps.

Digital TV, ITU-R BT.601 format: Width 720; height 526; frames per second 25; bit rate without compression 166 Mbps; with compression 5 to 10 Mbps.

HDTV, ITU-R BT.109 format: Width 1920; height 1250; frames per second 25; bit rate without compression 960 Mbps; with compression 20 to 40 Mbps.

3.2 Performance Indicators for Quality of Service (QoS) in Digital Voice Transmission

Users do not need nor want to know about the specific technical parameters of a service, but they are certainly interested in obtaining a "quality service" for whatever application they are using since they are paying the service provider a usage fee.

Since there are many different applications demanded from communications networks, it is important to define the most important quality characteristics of a given application, although at times there may be more than one service or application running over a single network. A typical example of a large network running several applications is the telephone network (PSTN), which must run optimally for voice conversations but also for facsimile machines and low bit-rate data modems.

3.2.1 Circuit-Switched Digital Telephone Networks

With the development of the transistor and digital communications theory by the late 1940's, applications of digital telephony began to appear in the expansion of the telephone network during the 1960's with Pulse Code Modulation (PCM) transmission and switching systems. PCM was designed to serve speech telephony, and even today more than 80% of the traffic on the PSTN is voice telephony. That is the reason why all digital communication systems today are based around the 64 kbps PCM channel [21].

Telephone companies have been multiplexing long distance calls onto high-speed trunks since early telephone network years, since it is a proven economical advantage. When a large number of telephone calls are going in the same direction, it is possible to carry them as a whole instead of one-by-one, and multiplexing allows that. Since multiplexing equipment must be identical at each end, a number of digital multiplexing hierarchies has been developed around the world [22].

3.2.2 Integrated Services Digital Network

This technology allows customers a variety of services, including voice and non-voice, through a digital network that extends to the customer's premises on a limited set of standardized common interfaces. ISDN provides the user with a basic 64 kbps digital end -to-end connection. This is a big improvement over the analog subscriber lines that still exist in most telephone networks, which require the use of low bit rate modems (56 kbps) to use digital applications.

One advantage of ISDN is that it removes the need for telecommunications customers to have separate physical links to each service network by integrating them in a common 64 kbps channel. ISDN was designed to provide user interfaces to an existing digital network, working under ITU-T's Signaling System 7 (SS7). Under ISDN a single physical connection is provided to the customer's premises and a range of services are made available from it. The ISDN basic arrangement is designed to serve, among other services,

- Digital voice.
- 64 kbps data, both circuit- and packet-switched.
- Telex/teletext.
- Facsimile.
- Slow-scan video.

3.2.3 Satellite Circuit-Switched Network

Any satellite network can be designed for efficient operation and good commercial quality. However, the most critical problem encountered in the application of satellite telephone networks is interfacing to the terrestrial PSTN. Telephones are nearly the same all over the world but different standards apply in different countries, and when other OSI layers than the physical (satellite channel) are involved (data, network, transport and session), the information is coded and signaling features are included, the possibility for problem grows.

Therefore, interfacing to the PSTN is a potential bottleneck and design challenge, but as Figure 3.5 shows, the importance of satellite communications in thin route applications is also reflected in the many services offered.

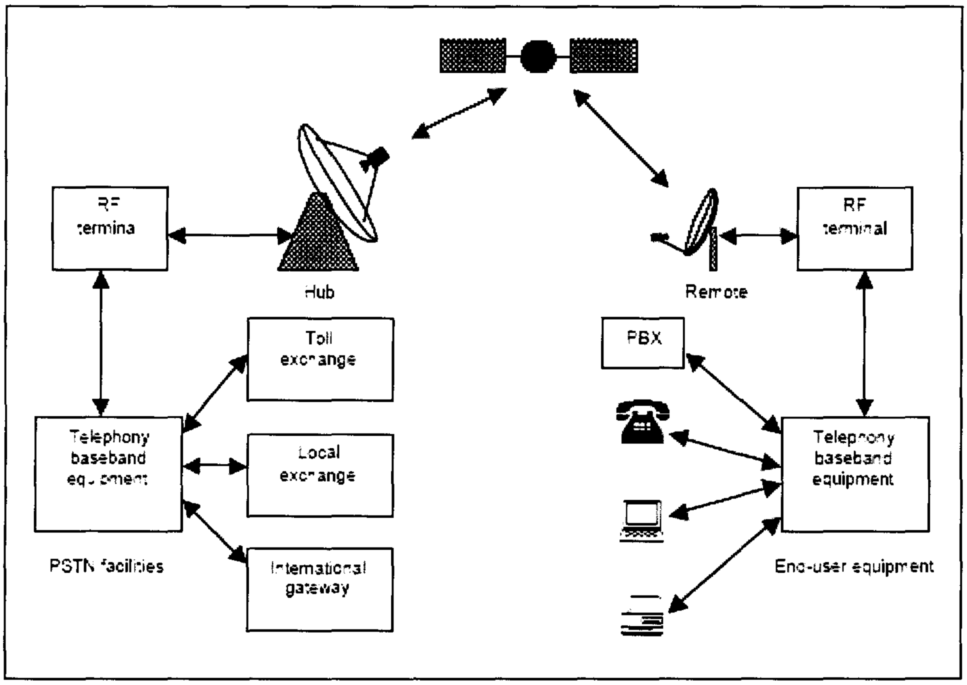


Figure 3.5: Different interfaces on telephone applications, from [22], p.327.

In many cases, such as in rural telephony, the satellite network provides the primary means of communication from a remote location and should be as flexible as the telephone network.

The satellite network telephone interface brings with it unique electrical, bandwidth and signaling characteristics that must be compatible with those at the PSTN gateway earth station. It is common to consider the gateway earth station similar to interconnecting a PBX to the PSTN, though the local exchange interface should be able to access international digital standards like E1, T1/DS1, SS7 and ISDN BRI interfaces, as shown in Table 3.1 [22].

Table 3.1 Digital standard interface [22].

Facility	Type of Access	Standard
Private: end-user	Telephone	Two-wire, touch-tone (DTMF)
	PC data	RS-232
	ISDN	Basic Rate (BRI)
	Modem/fax	Same as telephone
	PBX	4-wire E&M, alternatively T1 or E1
PSTN facilities	Local exchange	Two-wire touch-tone (DTMF); 4-wire E&M, T1 or E1
	Toll exchange	Four-wire E&M, T1 or E1
	International gateway	International connection, T1, E1 or SDH

3.2.4 Satellite Circuit-Switched Network Requirements

In Quality of Service, a low quality service will immediately be noticed. Satellite communications, especially over Geostationary orbit (GEO) satellites, generate a noticeable delay that is easily recognized, and that has long been known to degrade the quality of voice communications. However, this delay may be acceptable in some cases because it often is the only (or most economic) way to provide telephone service to remote places.

3.2.4.1 Propagation Delay

When transmitting over a GEO satellite channel there is always a propagation time delay, expressed by Equation 3.1, which is the time it takes for the signal to travel from the transmitting station to the satellite

$$t_p = d/c \qquad (3.1)$$

Where t_p *is* the propagation time, *d* is the distance to the satellite in meters and *c* is the speed of light ($c = 3*10^8$ m/s). In a typical case with a GEO satellite at an average distance of 38,500 km, it takes the signal about 0.128 s to reach the satellite and a similar amount of time to return to the receive earth station. This creates a 0.256 s propagation time delay on a one-way call from the transmit earth station to the receive earth station. This delay is important for two-way, real-time applications such as voice or videoconferencing, since it takes more than 0.5 seconds, not counting other minor sources of delay.

3.2.4.2 Echo

One of the most annoying effects on circuit-switched voice transmission over satellite is called "echo", which is caused either by an incorrectly adjusted element (the hybrid) at the remote telephone set, or by audio feeding itself from the handset speaker to the microphone at the remote end.

Another time -sensitive application is interactive data transaction, especially computer networks, which have a limited time period to acknowledge correct reception of data. Those applications that are time -sensitive must have a guaranteed access to the satellite at all times and show the lowest possible overall delay.

3.2.5 Packet-switched Digital Telephone Networks

Satellite voice transmission has been possible due to the use of advanced signal processing algorithms that allow low bit-rate voice compression, eliminating signal redundancy and optimizing bandwidth. Nevertheless, when voice is packetized its continuous bit stream is segmented into blocks of bits called cells, and with the addition of cell headers they become packets.

One problem with packetized voice is that if a packetized payload cell gets corrupted (bit error), little information is lost and the user will hardly notice it, but if a whole packet is lost (header error) or corrupted (burst error) then the QoS will be severely degraded. . Of the several technologies mentioned to replace the telephone network Voice Telephony over ATM (VTOA) and Voice over IP (VoIP) seem to be the most promising, and there are current efforts to provide both technologies over satellites, so a brief description of each will follow.

3.2.6 Improving QoS of Voice over IP Telephony

There are two main mechanisms being developed in order to improve the QoS of Voice over IP (VoIP), namely the Integrated Service Model (IntServ), and the Differentiated Services Framework (DiffServ) [23]. IntServ must manage resources (bandwidth and buffer) for each real time application. This requires a router to reserve resources using resource reservation protocol (RSVP) in order to provide specific QoS for packet streams, or flows.

The DiffServ architecture can offer each user a range of services differentiated on the basis of performance. Voice over IP would require specific IP hardware such as desktop IP phones and terminals, switches, routers and IP/PSTN gateways, as well as software such as the call manager. IP switches and routers connected to a PBX can carry voice traffic over data IP networks. Long distance calls can be routed through the WAN link and, best of all, the transport for IP telephony would be transparent to the users.

3.2.7 ITU Recommendation H.323: Voice over the Internet

The International Telecommunications Union (ITU-T) has been working for a number of years on recreation of a new standard for Voice Telephony over ATM (VoATM), which has been named Recommendation H.323. This recommendation defines procedures for multimedia communications services over packet based networks that do not provide guaranteed QoS. It includes H.323 endpoint elements such as terminals and gateways, where terminals are user devices that provide for real time, two-way multimedia communications with other H.323 endpoints.

Gateways provide for real time, two-way communications between H.323 terminals on packet networks and terminals on N-ISDN, B-ISDN or PSTN as shown in fig 3.6. Gatekeepers control access to the packet network at the endpoints and provide other services such as address translation between packet networks and the PSTN. Finally there are the Multipoint Control Units (MCU), which enable three or more terminals or gateways to participate in a conference.

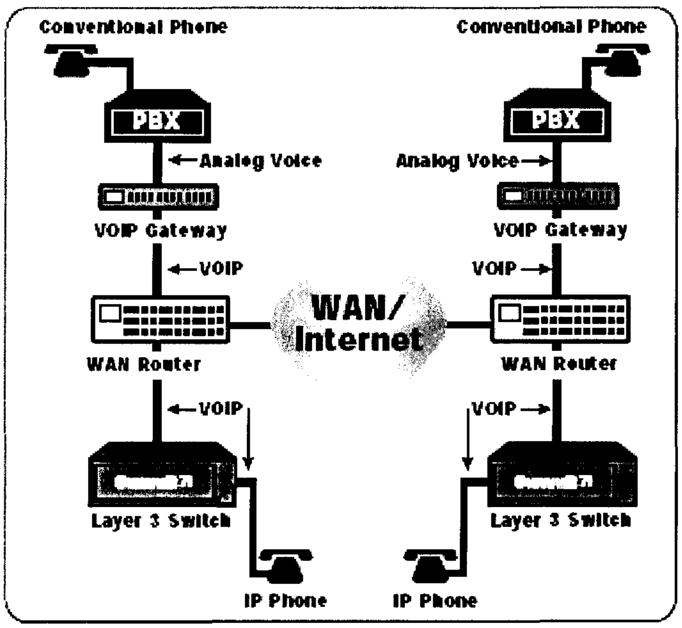


Fig 3.6 voice over IP on WAN

3.2.8 Voice Telephony over ATM (VTOA)

One of the functions offered on ATM by the equivalent to the OSI Transport Layer called the ATM Application Layer (AAL) is to segment a binary stream into same size cells, with the capacity to create different type services according to its application and time delay requirements. The ATM Application Layer 1 (AAL 1) provides for Continuous Bit Rate (CBR) service over a Circuit Emulation Service (CES) channel, requiring stringent traffic parameter values on its traffic contract.

Although voice can be supported by AAL 5, it is usually carried by AAL 1 for transport over a public ATM network. Until recently ATM only provided voice capabilities at 64 kbps (125μs/sample), so an AAL 1 voice cell would require 47 bytes (2.94 ms) of waiting time to assemble the packet and then send it. This is called processing delay and it also has an effect on buffering delay.

Much work has been published regarding voice over ATM, but only recently are standards emerging, mainly over an AAL 2 Class service platform [24,25,26].

CHAPTER FOUR

A PRACTICAL APPROACH AND ANALYSIS TO DESIGN FOR UNIVERSAL ACCESS

There are several existing approach for designing a more inclusive interface. However there are shortcomings of each of this approaches that prevent each of these from being used to provide the definite design approach that designers can use at all circumstances.

They can also be targeted at specific culture, for instance, universal design dominates US/Japanese approach to inclusive design, whereas Europe has general trends to develop other method such as the pyramid approach.

There is a need for a new approach that draws attention to the rural and remote areas of the communities of the world through government incentives and also the geological location of these rural areas

4.1 THE SEVEN LAYER DESIGN APPROACH

To meet the need for a new design approach for universal access, the seven(7) level approach has been based on known stages of interaction and usability heuristic. Developing the interface for universal access involves understanding the fundamental nature of the environment. These interaction components have to be combined with three stages of design.

- Define the problem
- Evaluate the solution

- Draw out the necessary models available to connect the area

Applying the seven (7) level design approach; address each of the system acceptability goals identified by Nielson [27]. The approach has been applied to a number of case studies including the design of a software interface for an interactive network.Figure 4.1 shows the seven design approach.

Level 1: Defines the need; that is the social motivation for designing the network. These can be identified through softer, sociological assessment method (Questionnaire and interview) are effective for identifying such users need.

Level 2: focuses on specifying the required utility of the network. Traditional engineering requirements captures techniques can be used as task analysis.

Levels 3: Focus on the stages of interaction. Usability and accessibility techniques can be applied directly to these levels, as can anthropometric and ergonomic data and standards. Prototypes of varying fidelity play a key role in these levels.

Level 4: Assesses the matching of the system contents and behavior to the user mental model. Once the output channels are defined, the content/utility can be added to the system and evaluated because the functionality for monitoring the system is in place.

Level 5: Focuses on the user input to the system. As with level 3, this involves assessing the nature and adjustability of the media, their appropriateness for the utility, and the physical layout. These can be supported by adopting user modeling techniques. Where user trials are impossible, suitably calibrated user models can be used to provide design data.

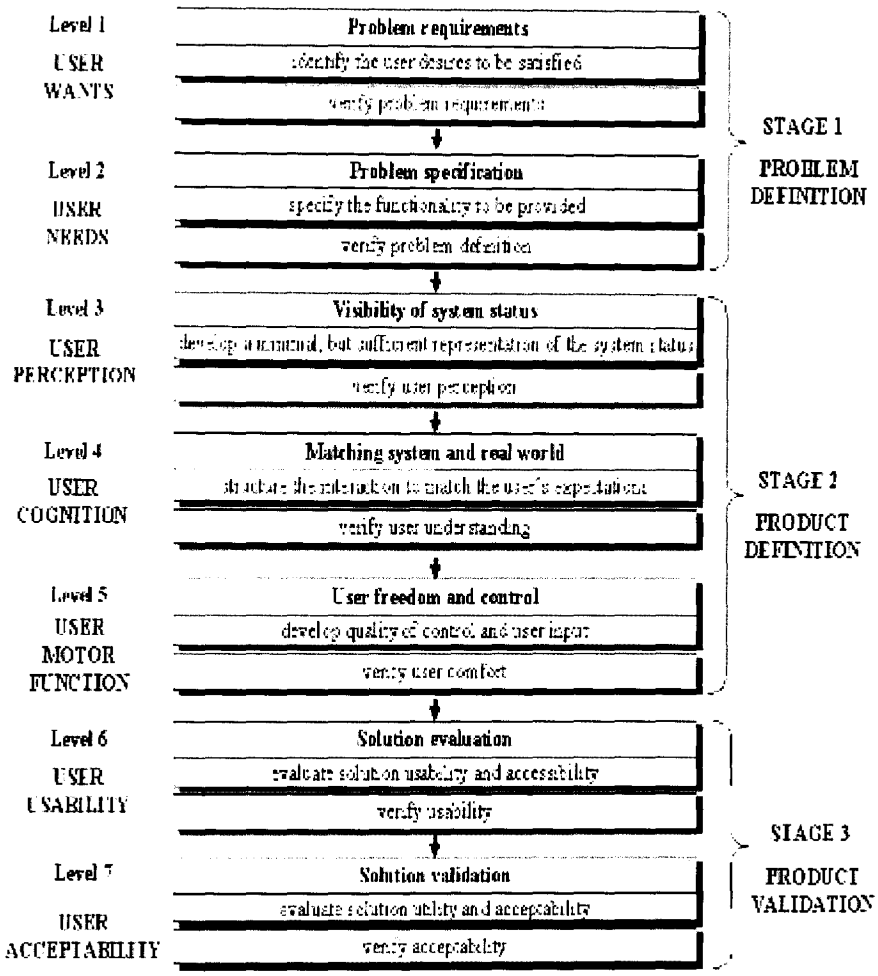


Figure 4.1: The 7-level design approach [27]

Level 6: Involves the evaluation of the complete system to ensure satisfactory utility, usability and accessibility. Formal user trials and usability/accessibility assessments are essential at this point, before the design can progress to the final level, 7.

Level 7: Assesses the resultant system against the user needs. This mirrors Nielsen's social acceptability requirement. Softer, more qualitative approaches are generally needed, such as surveys, interviews and questionnaires.

4.2 Parametric Analysis Results of the Economic Models

The user interface for the rural telephone network is assumed to allow a rural user to call a distant site by means of basic telephone and also to transmit data through the proposed satellite communications system if necessary. The interfacing public switched telephone network (PSTN) uses international communications standards and interfaces, for either basic circuit-switched telephone service as well as the VoIP and VTOA future systems.

The Remote Earth Station (RES), or VSAT terminal, has access to common user voice and data interfaces to the IDU equipment. The Gateway Earth Station (GES) is assumed to present a common interface to the PSTN or public IP or ATM networks, along with the proper ATM and Physical layer information. The voice quality must be equal to that expected from the PSTN, even if compressed and digitized. A connection fee to the PSTN is assumed at $0.04/min per voice channel [28].

4.2.1 DESIGN SPECIFICATIONS

Design specifications to consider before acquisition of the VSAT hardware resources and bandwidth requirement include:

- The type of application it will be put to use,
- The number of simultaneous end users,
- Transaction size per end user and
- The particular area or region with of operation respect to the choice of band-type whether C-band or KU-band.

An ideal rural community VSAT application will support both data and voice transmission. Therefore a VSAT of 2-4m diameter dish with indoor unit interface support for one to six telephone line channels and a local area network of about 5-to- 8 personal computers for Internet connectivity and broadband bidirectional data transfer services with a C-band frequency service will be considered ideal for parts of Western Africa. While 1.8m antenna diameter for Ku-band service can be considered for parts of Africa with relatively lesser rain experience than the south.

For every VSAT application in any given particular place, an estimation of link performance between the VSAT earth station and the satellite is performed in order to ascertain that the radio frequency equipment would cater to the requirement of the network topology and satellite modem in use. This estimation is called link budget. It estimates the VSAT and the satellite Equivalent Isotropically Radiated Power (EIRP).

Calculations of signal levels through the system (from transmitting VSAT) to ensure the quality of service should be done prior to the establishment of the satellite link. The link budget will highlight the various aspects of EIRP required at the transmitting VSAT, and the satellite EIRP which will be required for a desired specified gain of the receiving system. Also apart from the known losses due to cables and inter-connecting devices, it is customary to keep significant link margin for various extraneous noise which affect the performance.

The principle and parametric analysis of the parameters evaluated in a VSAT simulation is as shown in table 4.1 and 4.2

Table 4.1: Link Budget for 1.8m antenna (KU-BAND)

	Uplink parameter	Unit	Value	Downlink parameter	Unit	Value
1	Frequency, fu	GHz	14	Frequency Fd	GHz	12
2.	Antenna diameter	M	1.8	Antenna diameter	M	1.8
3.	Antenna efficiency		0.65	Antenna efficiency		0.65
4.	Antenna Gain	dBi	46.558	Antenna Gain	dBi	42.219
5.	Power at the feed	W	2	Receiver G/T	dB/k	24.427
6.	EIRP	dBw	49.568	System noise temper (antenna +LNA)	^oK	120
7.	Range (35778-19679)	Km	37923			
8.	Path loss	dB	206.951	Satellite EIRP	dBw	20.5
9.	Power feed at satellite	dBw/m^2	-113.010	Path loss	dB	205.6118
10.	Bandwidth	kHz	180	CN_D	Db	15.363
11.	Satellite uplink 6/T	dB/k	+2	C/interference (UNo1)D	Db	28.0
12.	C/Nu	dB	16.666	Satellite c/intermodulation	dB	21
13.	C/Interference $(U_{NOT})_u$	dB	28.0	Total link C/N	dB	12.093

Table 4.2: Link budget for 2.4m antenna (c-band)

	Uplink parameter	Unit	Value	Downlink parameter	Unit	Value
1	Frequency, fu	GHz	6	Frequency f_D	GHz	4
2.	Antenna diameter	M	2.4	Antenna diameter	M	2.4
3.	Antenna efficiency		0.65	Antenna efficiency		0.65
4.	Antenna Gain	dBi	41.697	Antenna Gain	dBi	38.175
5.	Power at the feed	W	12	Receiver G/T	dB/k	17.383
6.	EIRP	dBw	52.489	System noise temper (antenna +LNA)	^oK	120
7.	Range (35778-41679)	Km	37923			
8.	Path loss	dB	199.591	Satellite EIRP	dBw	20.5
9.	Power feed at satellite	dBw/m^2	-110.089	Path loss	dB	196.069
10.	Bandwidth	kHz	180	C/N_D	Db	17.861
11.	Satellite uplink 6/T	dB/k	+2	C/interference $(C/N_{int})_D$	Db	28
12.	C/Nu	dB	26.945	Satellite C/intermodulation (C/N_{imd})	dB	21.0
13.	C/Interference $(C/N_{in}t)u$	dB	28.0	Total link C/N	dB	15.302

4.2.2 RADIO FREQUENCY LINK ANALYSIS

The satellite channel of VSAT network conveys information by means of modulated radio frequency carrier which is relayed by the satellite transponder and then received by the destination earth station. The relayed uplink carrier is first amplified by the satellite transponder and frequency translated before being transmitted and received by the earth stations tuned to the downlink frequency. These uplink and downlink radio signals do not only attenuate but also get corrupted by noise with different origins along the signal path. Therefore, the retrieved baseband signals at the destination are contaminated by this noise.

However, between the physical layer level of the data transmission protocol of the signal source and the destination, the bit error rate is to be limited to an acceptable level to achieve error-free transmitted or retrieved data.

4.2.2.1 UPLINK ANALYSIS

The uplink is the radio frequency link from the earth station to the satellite. Basically the satellite receives the uplinked carriers conveying information from the transmitting earth stations within the field of view of its receiving antenna, amplifies those carriers, translated their frequency to a lower band in order to avoid possible output/input interference, and transmits the amplified carriers to the stations located within the field of view of its transmitting antenna.

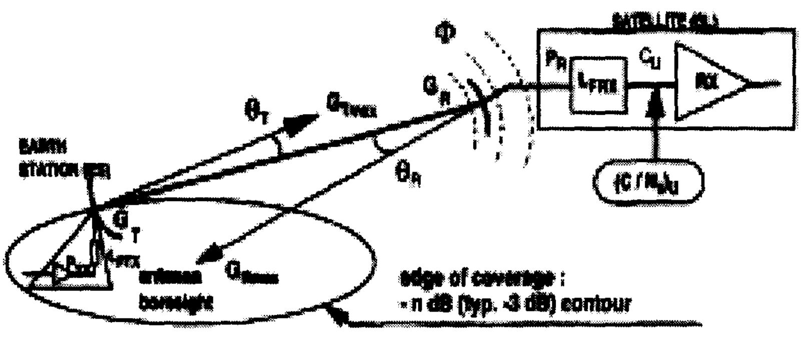


Figure 4.1Geometry of the uplink [9],pp172

where

P_{Tx} = transmitter output power; L_{FTx} = Feeder loss from transmitter to antenna

G_T = Earth station antenna transmit gain in direction of satellite;

θ_T = Earth station antenna depointing angle;

Rx = receiver

G_{Tmax} = Earth station antenna transmit gain at boresight

Ø = Power flux density at satellite antenna.

$Ø_R$ = Satellite antenna half beamwidth angle

G_R = Satellite antenna received gain at edge of coverage;

P_R = Received power at antenna output;

Cu = carrier power at receiver input

L_{FRx} = Feeder loss from satellite antenna to receiver input

Figure 4.1 illustrate the geometry of the uplink where the transmitting earth station is assumed to be located at the edge of the uplink coverage defined as the contour where the receiving satellite antenna has a constant gain defined relative to its maximum value at bore sight.

4.2.2.2 DOWNLINK ANALYSIS

To evaluate the worst case value of the downlink carrier power to noise spectral density ratio $(C/No)_D$, the receiving earth station is assumed to be located at the edge of the downlink coverage defined as the contour where the receiving antenna has a constant gain reduced by a factor of two compared to its maximum value at boreight, as demonstrated by the downlink link geometry of figure 4.2

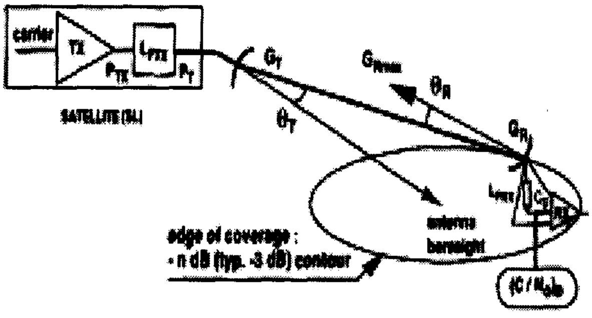


Figure 4.2 Geometry of the downlink [9],pp.187

where P_{Tx} = carrier power at satellite transmitter output

L_{FTx} = feeder loss from satellite transmitter to antenna

P_T= Carrier power fed to satellite antenna

G_T = Satellite antenna transmit-gain in direction of earth station

$\square_T$ = Satellite antenna half beamwidth with angle

G_{Rmax} = earth station antenna receiver gain at boresight

$\square_R$ = earth station antenna depointing angle

L_{FRx} = Feeder loss from earth station antenna to receiver input

C_D = carrier power at receiver input

R_x = Receiver

4.3 Fixed-single channel per carrier(SCPC) Model

The Fixed-SCPC economic model for a low traffic, a medium traffic (nominal) and a high traffic (optimistic) scenario, with changing projections in each case. The basic SCPC scenario is shown in Figure 4.2, along with its data tables and performance graphs. The network is composed of 100 nodes with a traffic intensity of 0.15 Erlang.

It is easily seen that the small number of nodes causes the VSAT unit price to be $7,500, a higher figure than that of larger networks, basically due to volume sales from more than 100 earth stations. The 3-Dimensional (3-D) plot shown in Figure 4.2 shows the Profits -vs.-Nodes-vs.-Traffic projections of the network for other values of traffic intensity and network size, obtained from the tale pivot value at the right bottom of the lifetime cost table [29].

4.3.1 Low Traffic Scenario

A low traffic, or pessimistic, scenario is the one that allows the economic projections to succeed with a very low traffic operation over a satellite network. The 3-D plot on Figure 4.2 shows how a low traffic scenario (0.025 Erlangs) will not only lose money in a small network ($8 million in losses for a 20-VSAT network) but also in a large size network ($271 million losses for a 500 VSAT-network).

The situation does not improve with a small increase in traffic, since up to 0.10 Erlangs (medium expected subscriber traffic) still generates losses at every network size.

4.3.2 Medium Traffic Scenario

The same 3-D plot in Figure 4.2 was projected from a medium, or nominal, traffic intensity of 0.15 Erlangs. This specific case was designed so the network's break-even point is met at 0.15 Erlangs of traffic over the system's lifetime for a 100-VSAT network. This means the medium expected, or nominal, traffic scenario is that with the most likely traffic intensity for the network.

In this case, the expected traffic will generate the initially planned network revenue, which is the initial amount presented to the financiers and investors as the targeted goal. Although it may look to be approaching the break - even point, it must be remembered that this point already includes a substantial amount of profit due to the larger interest rate used when quantifying the future value of money. Variations on network size will provide only a very small positive difference from the targeted value, so the scenario is still considered as nominal.

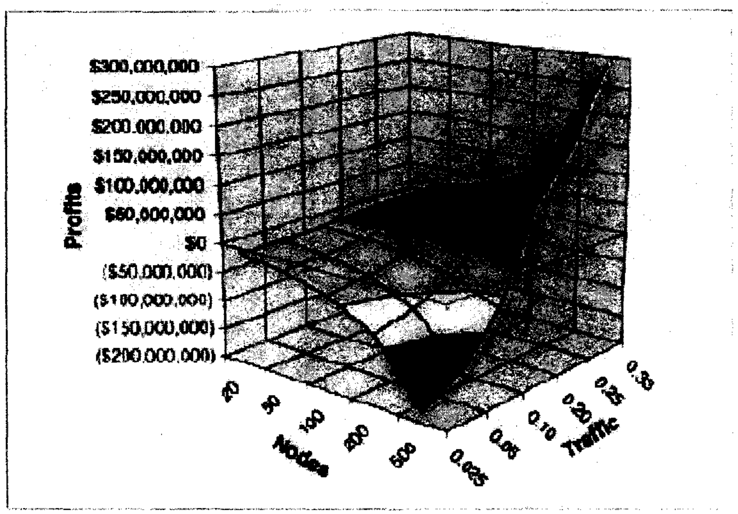
Fixed SCPC Economic Model

Interest Rate	18%	
Number nodes	100	
Expected Traffic	0.160	
Oper min/yr	46000	
Break-even cost	$0.3143	
	VSATs	Hub
Unit Price	($7,500)	($40,000)
Installation cost	($1,000)	($10,000)
Unit Lease	$0	$0
Maintenance	($360)	($100,000)
BW ($/carrier)	($5,500)	($550,000)
Fees / Licensing	($100)	($5,000)
PSTN access fee	($0)	$0
Capital costs	($860,000)	($55,000)

	Lifecycle economic analysis				
Year	VSAT Var cost	Hub Var cost	Total costs	Revenue/yr	Profits
1	($769,960)	($650,000)	$2,334,960	$1,445,310	($889,650)
2	($1,422,468)	($1,200,847)	$2,623,316	$2,670,149	($842,816)
3	($1,976,442)	($1,667,667)	$3,643,109	$3,708,149	($777,777)
4	($2,444,063)	($2,063,277)	$4,507,341	$4,587,809	($607,308)
5	($2,841,200)	($2,398,540)	$5,239,740	$5,333,284	($603,764)
6	($3,177,757)	($2,682,661)	$5,860,418	$5,965,043	($499,139)
7	($3,462,974)	($2,923,442)	$6,386,416	$6,500,431	($385,124)
8	($3,704,684)	($3,127,493)	$6,832,177	$6,954,150	($263,150)
9	($3,909,523)	($3,300,418)	$7,209,940	$7,338,858	($134,433)
10	($4,083,115)	($3,446,964)	$7,530,079	$7,664,512	$0

<-- Table pivot

Nodes	Projected traffic intensity (Erlangs)					
$0	0.025	0.05	0.10	0.20	0.25	0.33
20	($8,353,817)	($6,836,231)	($3,401,059)	$2,289,286	$5,304,456	$10,342,844
50	($18,360,440)	($14,556,475)	($6,968,544)	$8,207,317	$15,795,248	$28,391,212
100	($37,989,653)	($30,351,722)	($15,175,861)	$15,175,861	$30,351,722	$55,543,682
200	($80,215,625)	($65,039,763)	($34,688,041)	$26,015,404	$56,367,126	$106,750,985
500	($182,291,286)	($144,351,633)	($68,472,328)	$83,286,284	$159,165,560	$285,125,237



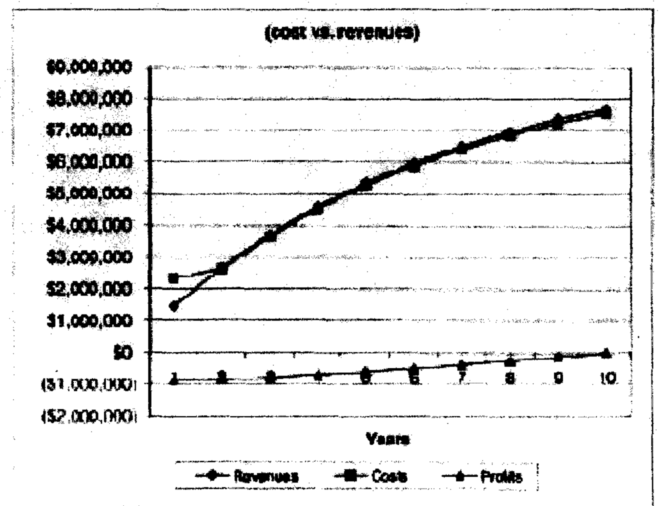


Fig 4.2: Low Medium and high Traffic Scenario [29]

4.3.3 High Traffic Scenario

From the same 3-D plot in Figure 4.2 is possible to see the projected earnings for a larger than-expected user traffic behavior, both in terms on network size as well as in terms of expected traffic intensity. The profits for a small network with a high traffic (around 0.25 Erlangs) are substantial ($9 million over the break-even point), even for a small (20 VSAT) network. A larger network provides a dramatically large profit ($271 million over the break-even point) for a 500 VSAT network.

Figure 4.3 shows the comparison of the profit earning curves for low, medium and high traffic analysis. The reason the low traffic curve generates higher profits is that the user cost per minute is much higher. This should not be taken as a way to predict gains, since an expensive system will probably have fewer customers than a more inexpensive system, covering with volume the lower revenue due to higher user cost. Figure 4.3 also shows the pie charts of the low traffic, medium traffic and high traffic scenarios for a Fixed-SCPC satellite network during the first year of operation, where the VSAT capital investment clearly dominates over the hub capita l cost.

The VSAT segment also generates more expenses in the variable costs, mainly due to the PSTN access fee for each user channel. It is also easy to see how by increasing the number of calls, or traffic, the variable costs of the VSAT segment particularly increase due to the satellite and connection fees for a larger number of terminals.

It is safe to conclude that, when using Fixed-SCPC satellite modeling analysis, network size defines the general cost of the network and that the network's operation is expensive. It also is safe to conclude that small Fixed-SCPC networks produce small profits or losses if traffic is low, but generate tremendous losses or profits in large networks. For that reason a careful traffic analysis must be made, considering different network sizes, since a poorly made traffic analysis (or business plan, for that matter) is a sure way to lose money in network planning and design.

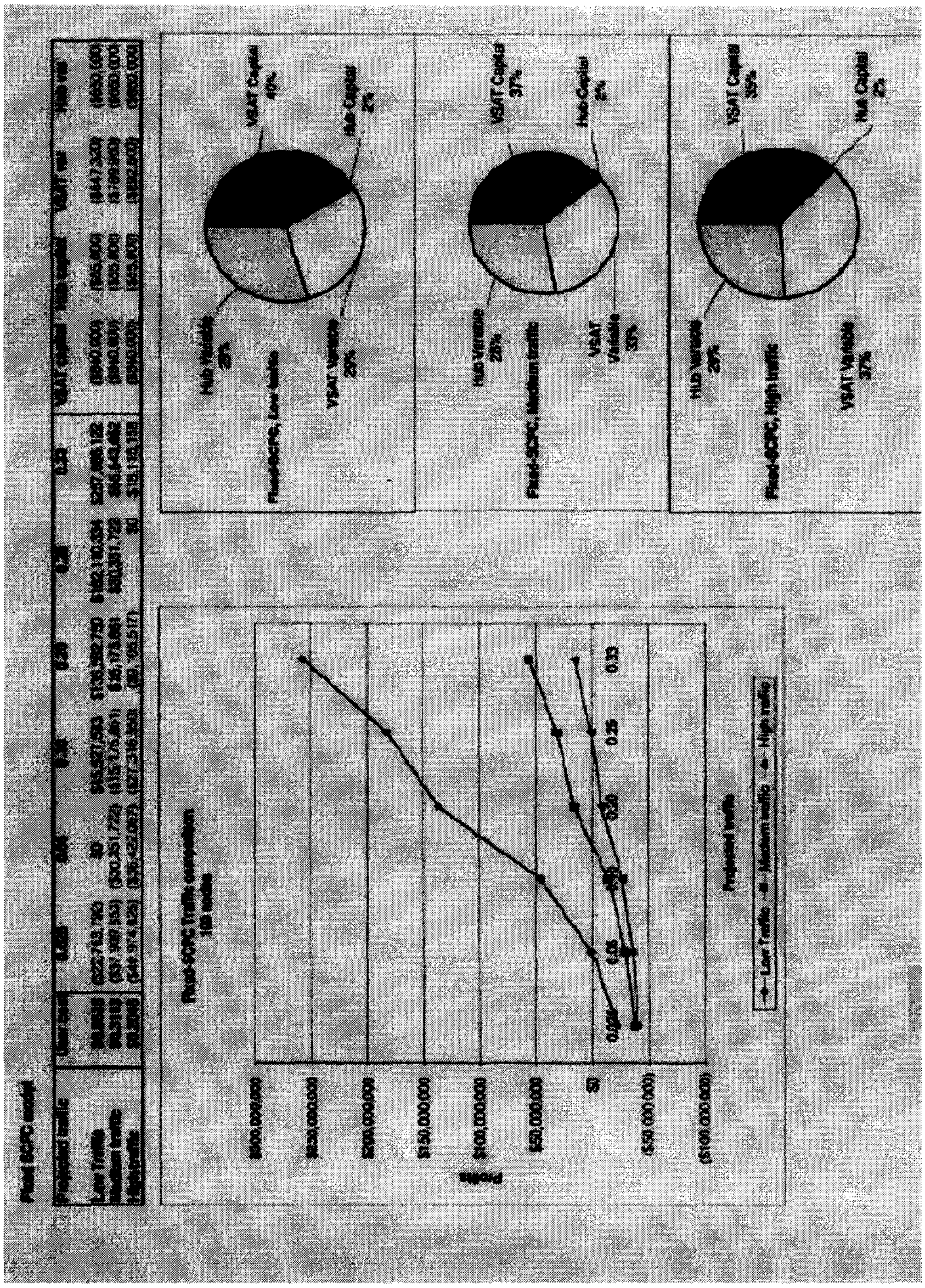


Fig 4.3 comparsion between low, medium and high traffic senerios for fixed SCPC [29]

4.4 Design of Rural Telecommunications Networks

The design of rural telecommunication networks, fall into three main areas: geopolitical, technical and economic. Geopolitical issues deal with the rural region's developmental level based on its social, political, educational and economic history.

Technical issues usually refer to available technology, regulatory and legal frameworks, rural communities' size and expected communications traffic, type of communication services and available technical workforce [11].

Economic issues deal with defining the initial investment required to deploy communications equipment in a remote region, its operational cost and the users' revenue generating capacity, so the service is self-supported financially and keeps subsidies to a minimum.

4.4.1 The Life Cycle Process

The design of any communications network must include the steps shown in Figure 4.1.

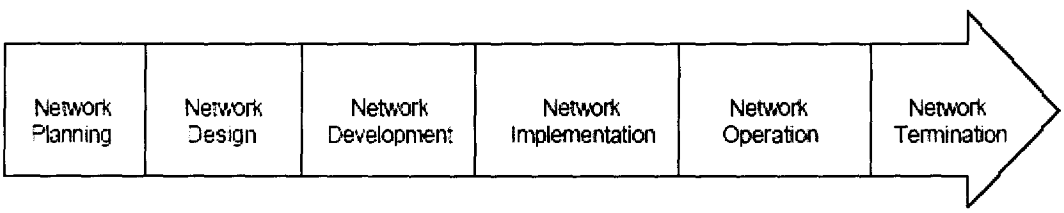


Fig 4.5: The systems engineering life cycle process.

1. Network Planning Stage: This refers to the basic identification of rural telephone needs, dimensioning of the networking problem and definition of possible solutions.

2. Network Design Stage: This refers to the search for real and feasible solutions once the basic needs have been identified. The input information must be

processed with whatever technical and economic constraints exist, and optimal solutions are delivered.

3. Network Development Stage: This refers to the necessary steps to develop the network elements as defined at the design stage. Includes the logistics to acquire, assemble and deliver systems and subsystems, personnel training and testing.

4. Network Implementation Stage: This refers to the construction of the network following the previously defined logistics plan by transporting the equipment to its final destination, assembly of systems and subsystems at each site, testing each terminal and local network, and training of local operators.

5. Network Operation Stage: This refers to the use of the communications network by rural users, as initially specified at the conceptual stage. It actually is the delivery of the end product to the consumer, in this case digital telephone service to rural users, and it should last throughout the expected equipment life cycle.

6. Network Termination Stage: This refers to the retirement of equipment after it has reached its operational lifetime. New regulations show increasing concern to dispose of old products in an environmentally friendly way.

4.5 CALCULATION ON SYSTEM OPERATING MARGINS FOR MICROWAVE TRANSMISSION

By doing an SOM calculation, you can test various system designs and scenarios to see how much fade margin (or "safety cushion") your link will theoretically have as shown in fig 4.4.

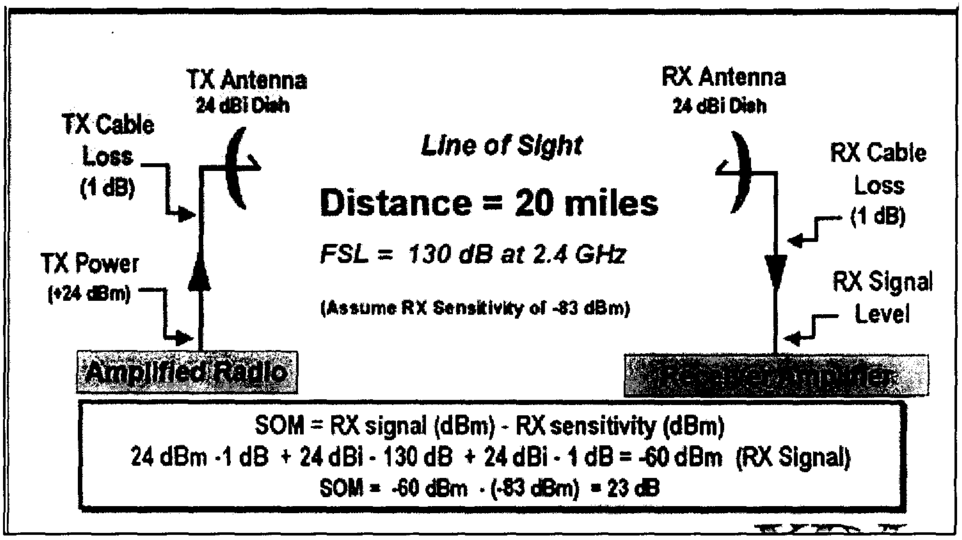


Figure 4.4 SOM calculation on a point-to-point link [14].

It presumes that the antennas are aimed at each other properly (i.e., they are in each others' main lobe). To calculate SOM in the example, start with the transmit power (+24 dBm), subtract the coax cable loss (1 dB) and add the transmit antenna gain (24 dBi). This gives you the effective isotropic radiated power:

EIRP = TX Power – Coax Cable Loss + TX Antenna Gain. (4.1)

Then subtract the FSL (130 dB), add the receiver antenna gain (24 dBi), subtract the coax cable loss (1 dB) and you get the signal reaching the receiver:

RX Signal = EIRP – FSL + RX Antenna Gain – Coax Cable Loss. (4.2)

Compute the difference between the received signal and the radio's receiver sensitivity to determine the SOM.

CHAPTER FIVE

UNIVERSAL ACCESS FUND

The terms "universal service" and "universal access" are closely related concepts and are sometimes used interchangeably, they hold different meanings. Universal service is aimed at increasing the number of individual residences with telecommunications services and providing telecommunications services to all households within a country, including those in rural, remote and high cost locations.

Universal service policies also focus on ensuring that the cost of telephone services remains affordable to individual users or to targeted groups of users (e.g. low-income families, people living in uneconomic areas). Universal service is a realistic policy objective in many industrialized countries.

Universal access is a more practical goal in most developing countries. Universal access policies work to increase *access* to telecommunications services on a shared basis, such as on a community or village-wide level. Universal access programs typically promote the installation of public payphones or public call offices in rural or remote villages or low-income urban areas with the aim of providing a basic and initial connection to the public telecommunications network. (e.g. telecentres). There are different approaches to financing universal service programs, some of which are [30]:

- **Conditional Licenses:** the telecommunication operator must provide service to rural and remote areas as a condition of the license. In South Africa, the national provider is obliged to roll out 1.7 million lines in disadvantaged areas during their 5 year exclusivity period.
- **Fee for Connection to the Backbone:** new competitors may be required to pay certain charges to interconnect with the dominant telecommunication

operator, with some or all of the charges being used to provide service to rural areas.

- **Incentives:** provision of incentives to encourage operators to provide telecommunications in less profitable areas. Some incentives may be:
  - tax concessions
  - removal of duty on telecommunication equipment targeted to rural and remote areas
  - lifting of foreign exchange restrictions
- **Micro-credit Programs:** Linking existing and successful micro-credit organizations with rural telecom operators to expand Public Calling Office (PCO) coverage in rural areas can relieve operators of many of the 'headaches' associated with rural telecom operation. Small loans to rural entrepreneurs, such as those established by GrameenPhone in Bangladesh, can effectively enable new ICT operators to establish PCOs which provide a variety of services including telephone, fax, email, the Internet, photocopying and word-processing services.

- **Rural Development Funds:** One approach to addressing the universal access challenge in underserved and high-cost areas has been the creation of special rural telecommunication funds, typically obtained from the telecom sector. Normally, these funds provide resources for one-time programs and have very defined coverage goals.
- **Build Operate and Transfer Arrangements:** Government sanctioned concessions to equipment vendors, integrators and/or operators who deploy infrastructure in rural areas and operate a system for a fixed period of time

before transferring the operation to an incumbent national operator, or other investors.

- **Cooperatives and Community-owned Systems:** Cooperative organizations active in rural areas (e.g. electrical cooperatives, agricultural cooperatives, etc.) are provided with incentives such as periods of exclusive operation to encourage provision of service in poor rural areas. For example, Bolivia passed a new telecommunications law in 1995 which affords cooperatives six years of exclusivity to operate in their markets provided certain conditions are met.

From a regulatory perspective, if subsidies are used to promote universal access, the amount of subsidies and their specific application should be measurable, identifiable and transparent to ensure that they are not regarded as anti-competitive.

5.1 FUND FEATURES

Universal access funds receive finance from various sources and provide targeted subsidies to encourage the provision of telecommunications services by private operators in otherwise uneconomic regions. These funds can be distinguished on the basis of three key features:

- ***Sources for funding***. Universal access funds can be distinguished by their sources for funding. Depending on the country and its particular situation, the sources for funding have included national budgets of governments, charges on interconnecting services, levies on subscribers (e.g. on access lines) and levies on operator revenues. Funding from international development agencies is also an option. Universal access funds today tend to collect their revenues from government sources or operator levies on a widely based range of telecommunications services (as opposed to only from specific "high margin services", like international long-distance). Broad based revenue collection mechanisms are favored because they have less of a price distorting effect on the marketplace.

• ***Fund management***. Universal access funds can differ in their management. While some funds (e.g. Colombia) are administered by government ministries, other funds are administered by the regulators (e.g. Peru, Chile) or special agencies (e.g. South Africa). The common perception is that funds administered by independent regulators and agencies are less likely to be influenced by government or political interest.

• ***Type of services***. Thirdly, universal access funds can also be distinguished by the types of services they support. Developing country funds in the past have placed greater emphasis on ensuring basic public access (i.e. voice-grade fixed access to the public telecommunications network). With the growing importance of the Internet to national economies, however, many of today's newer funds also support public access to value-added services, including Internet access. In Chile, the government has redefined its fund, which has been successful in extending basic telecommunications to rural and low-income areas, to support telecentre projects. The Fund is expected to soon launch a national telecentres program.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

Requirements for universal access can be key drivers for government and telecommunications providers to reach rural areas, but because rural markets are not as appealing as urban ones, providers tend to neglect them. Setting appropriate and attainable target service levels has proved difficult, and enforcing timetables has been equally so.

Deployment of wireless and VSAT technology has been a key facilitator for universal access in rural communities in some part of the world and implementing a basket of public policies for them, i.e Ghana, Chile, and Uganda etc. The critical element in these policies includes:

- Low entry barrier (for example, license emption or tax breaks).
- Permission to offer diverse value-added services with few or no regulation restrictions (for example a liberal allowance to use VoIP and other packet-switched services).
- Encouragement of micro and small business models (for example though subsidies, fair interconnection rules and /or zero-interest loans).

With the combination of effective regulatory policies and innovation, the use of wireless technologies may be able at this juncture, make dramatic gains in introducing connectivity to the rural population.

6.2 RECOMMENDATION

There is extensive evidence that with sufficient planning and analysis, the provision of rural telecommunication services can be profitable. Given the potential economies of scale achieved by a well-planned rural telecom installation, investments in rural and remote telecom service prior to the installation, for example the telecentre.

Unless telecom initiatives are established to satisfy the information and communication needs of the intended users, technologies will remain underutilized and thus will not survive. The following would therefore constitute a way out in terms of reaching the hard to reach:

- Improving rural incomes and in particular work on ensuring that the economic activities that people engage in have fair returns.
- Improve physical access through making communication services actually available by reducing the distance covered by the nearest facility.
- Diversify the languages used in the operation of these communication services to include regional languages.
- Make available the necessary basic knowledge and skill to operate the various communication gargets.
- Make deliberate effort to subsidize the rural parts of the country as a first step in looping them in.

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