Dissertation Title

ATM Performance in Rural Areas of South Africa

Submitted By

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DECLARATION

I, Sakhiseni Joel Mbatha, Student Number 9608761, hereby declare that the dissertation entitled **ATM Performance in Rural Areas of South Africa** is a result of my own investigation and research, and presents my own work unless specifically referenced in the text. This work has not been submitted in part or in full for any other degree or to any other University.

Acknowledgement

I would like to acknowledge and appreciate my supervisor Prof. TJ Afullo. Thanks for being so kind, patient and helpful towards the study of this thesis. My appreciation to the staff and technicians in my department for their assistance when I needed.

I would also like to recognize love, support and patience of my family while I was still studying. I wish to thank my colleagues and friends for the encouragement and the kind of friendship they have given to me. I am indebted to a number of individuals for their outstanding contribution to this project, especially Mr. Andriaan Steenberg, Palack Lutchman (Telkom) and Prof. Dawoud from Natal University.

I would also like to recognize my sponsors in particular Telkom, for the support and their availability when I needed them, Erricsson and THRIP for the support in the department.

Abstract

Rural areas in developing countries span vast areas with a variety of climatic zones, vegetation and terrain features, which are hostile to the installation and maintenance of telecommunication infrastructures. Provision of telecommunications services to these areas using traditional wired and existing wiring telephone system with centralized network architecture becomes prohibitively expensive and not viable in many cases, because there is no infrastructure and the area is sparsely populated. Applications of wireless systems seem to provide a cost-effective solution for such a scenario. However, deployment of ATM in rural areas as a backbone technology wide area network (WAN) has not been thoroughly investigated so far.

The dissertation investigates the feasibility of deployment of ATM backbone network (WAN) to be implemented in the rural. ATM is a digital transmission service for wide area networks providing speeds from 2 Megabits per second up to 155 Megabits per second. Businesses and institutions that transmit extremely high volumes of virtually error-free information at high speeds over wide area network with high quality and reliable connections currently use this service.

For the purpose of saving the utilization of more bandwidth, the network should support or have a high forward bit rate, i.e. it must convey high traffic from base station to the user (i.e. upstream) than from the user to the base station (down stream). This work also investigates the features from the rural areas that degrade the performance of the networks and have a negative impact in the deployment of the telecommunications networks services. Identification of these features will lead to the suggestion of the least cost-effective telecommunication service.

For the purpose of evaluating the performance and feasibility of the network, modeling of the ATM network is accomplished using Project Estimation (ProjEstim) Simulation Tool

as the comprehensive tool for simulating large communication networks with detailed protocol modeling and performance analysis.

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Glossary

AAL	:	ATM adaptation layer
ABC	:	Local access code for numbering
ABR	:	Available bit rate
ACD	:	Automatic Call Distributor
ADMOSS	:	Advanced Multifunctional Operator Services Africa
APL	:	Automatic Farm Lines
APS	:	Application software
ATM	:	Asynchronous Transfer Mode
ATMF	:	ATM Forum
B-ISDN	:	Broadband Integrated service digital Network
BRA	:	Basic Rate Access
CAC	:	Connection Admission Control
CBR	:	Constant bit rate
CLP	:	Cell Loss Priority
CSAS	:	Customer Premise Service Access Switch
CSN	:	Digital exchange concentrator (E10)
CSU/DSU	:	Channel Service Unit/Data Service Unit
CTO	:	Combined Local and ordinary transit
CTP	:	Combined Local and principal transit
DDI	:	Direct Dialing Inward
DDO	:	Direct Dialing Outward
DDR	:	Dial-on-demand routing
DEC	:	Digital Exchange Concentrator
DLU	:	Digital Line Unit (EWSD)
DPSU	:	Digital Primary Switching Unit
DSSU	:	Digital Secondary Switching Unit
e	:	Erlang
E10	:	Alcatel digital elec

EA	:	Exchange Area
EMS	:	Environmental Management System
Eqpt	:	Equipment
ESAS	:	Exchange Service Access Switch
ESNMP	:	Edge and Services Network Master Plan
ESP	:	Enhanced Services Platform
EU	:	Exchange Unit code
EWSD	:	Siemens digital electrical switching system
EX	:	Exchange code
FA	:	Full Availability
GiVoP	:	Gateway International Voice over Packet
GOS	:	Grade of service
GSM	:	Global System for Mobile Communications
GW	:	Gateway
ICASA	:	Independent Communication Authority of South
IN	:	Intelligent Network
INP	:	Integrated Network Planning
IP	:	Internet protocol
ISDN	:	Integrated Service Digital Network
ITE	:	International Trunk exchange
ITG	:	International Trunk Gateway
ITU-T	:	International Telecommunication
LAN	:	Local Area Network
LANE	:	Local area network
LTGA	:	Line Trunk Group A
MAN	:	Metropolitan Area Network
Mbit/s	:	Megabit per second
MP	:	Measuring point
MSC	:	Mobile Switching Centre
MSU	:	Metropolitan Switching Unit
ND	:	National Dialing

NIP	:	Network Infrastructure Provisioning
NPV	:	Network present value
NTSU	:	National Transit Switching Unit
OCB 283	:	version of E10 equipment
OFDC	:	Optical Fibre Distributed Concentrator
OHS Act	:	Occupational Health and Safety Act
OSI	:	Open system interconnection
PABX	:	Private Automatic Branch Exchange
PLMN	:	Public Land Mobile Network
PSDN	:	Public switched data network
PSTN	:	Public Switched Telephone Network
PSTN	:	Public Service Telephone Network
PTT	:	Provider of Telecommunication Training
PVC	:	Permanent virtual circuit
QoS	:	Quality of Service
RRN	:	Rural Radio Network
RSAS	:	Rural Service Access Switch
SCNet	:	Switched Circuit Network
SDH	:	Synchronous Digital Hierarchy
SHE	:	Safety, Health and Environmental Management
SMDS	:	Switched Multimegabit data services
SMME	:	Small, medium and micro enterprises
SONET	:	Synchronous Optical Network
SS7	:	Signaling System No. 7
STM	:	Synchronous Transfer Mode
SVC	:	Switch virtual circuit
		System
TAB	:	Totalisator Agency Board
TCP	:	Transmission control protocol
UBR	:	Unspecified bit rate
		Union-Telecommunications

V11	:	Software version number for EWSD
VBR	:	Variable bit rate
VCC	:	Virtual channel connection
VCI	:	Virtual channel identifier
VOIP	:	Voice over IP
VPC	:	Virtual path connection
VPI	:	Virtual path identifier
WAN	:	Wide Area Network

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Chapter One

Rural Scenario

1. Introduction

Provision of Rural telecommunication services is a complex process that involves consideration of both technical and socio-economic factors. It requires the development of infrastructure for rural telecommunications, assessment procedures for the evaluation of opportunities and strategic planning in terms of financial and infrastructure rollout, and special strategies for improvement of maintenance and repair activities.

The rural areas of most South African countries including South Africa and other countries such as Kenya, Tanzania, and Uganda have peculiar features such as:

- Low population density (typically 10-50 people per square kilometer). This requires deployment of technologies that can aggregate traffic from a large geographical area in a cost effective way.
- Low and seasonal individual incomes mainly from subsistence agriculture. This makes it necessary to ascertain the investment risk for this market.
- Very low provision of telecommunications infrastructure in rural areas. This is the crux of the matter. There is need to provide telecommunication services, but most the technologies available at present appear to be targeting areas where the traffic is naturally aggregated with reasonable number of customers per geographical areas to meet system commercial viability.

A combination of lack of geographical locations proximity to large population centers and low potential customer densities makes telecommunications service provision in rural areas a little more cumbersome than in urban areas. The challenge has always been the fact that the rural communities are not naturally aggregated enough as urban populations to enable deployment of high capacity networks. The KwaZulu Natal province in South Africa is the typical example of this under-provision of telecommunications service provision that is purely based on the urban/rural divide. [1]

1.1 Rural Telecommunications in South Africa

A rural area generally consists of scattered settlement, villages and small towns, and may be up to 200 kilometers from an urban center. Infrastructure such as telephone, electric power, piped water and all-weather roads are usually nonexistent. In South Africa the large distances argue against the direct importation of solutions from Europe and North America, where the number of customers per square kilometer together with their incomes are reasonable.

There are three main reasons why we need to provide telecommunications services to rural areas:

(i) A big proportion of the South African population lives in rural areas. For example, 54.8% of KwaZulu Natal population is rural.

(ii) There are a number of social-economic activities taking place in rural areas. For example, in the KwaZulu Natal province there were 7.7 million people in 1996 with 2.60% and 1.78% growth rates in the economies of the urban and rural areas respectively. [12] The rural population produced this growth rate despite being severely disadvantaged in terms of provisions of telecommunication and other basic services.

(iii) The link between telecommunications and development is well documented with a number of case studies conducted by the ITU and other bodies.- For example, the Maitland report (1982, ITU).

Table 1 shows the populations of urban and rural areas in different provinces of South Africa. Out of the nine provinces, five have over 50% of the population living in rural areas [2].

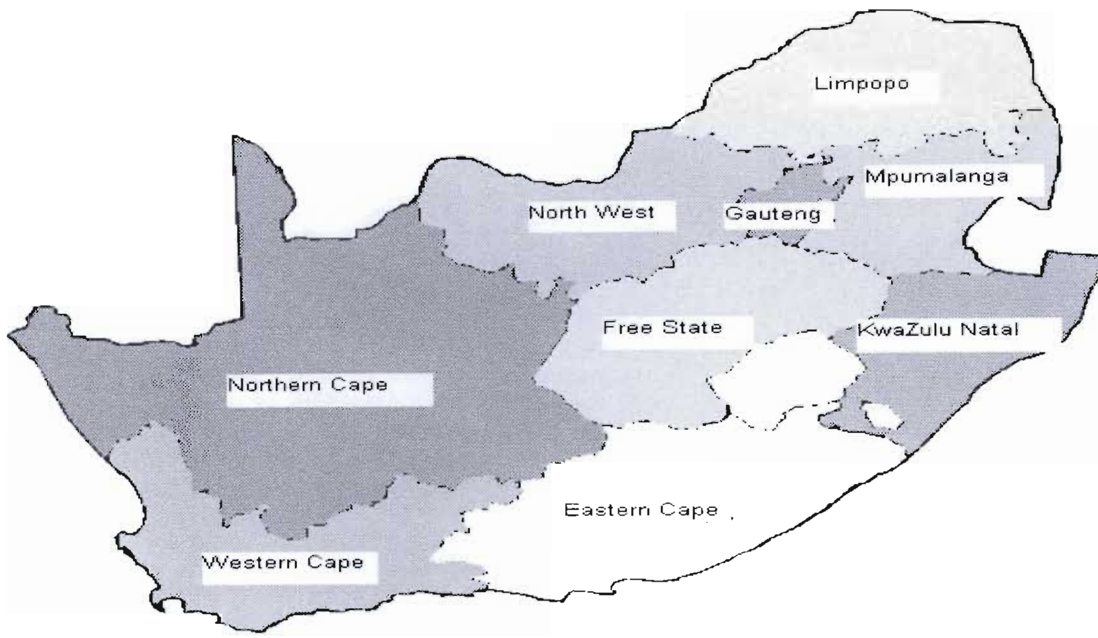

Figure 1: Map of South Africa

	Urban	%	Non-Urban	%	Total
Eastern Cape	2451449	38.1	3985314	61.9	6436763
Free State	2016014	74.5	690761	25.5	2706775
Gauteng	8506465	96.3	330713	3.7	8837178
KwaZulu Natal	4263416	45.2	5162600	54.8	9426017
Limpompo	549258	10.4	4724383	89.6	5273642
Mpumalanga	1222092	39.1	1900899	60.9	3122990
Northern Cape	663788	80.7	158939	19.3	822727
North West	1496812	40.8	2172538	59.2	3669349
Western Cape	4061232	89.8	463104	10.2	4524335
South Africa	25230526	56.3	19589251	43.7	44819776

Table 1: Census 2001 urban/non-urban (1996 classification) in South Africa

Source: Central statistical Office, RSA [2]

For a long time the question has been how service provision in rural areas of Africa could be done in a cost-effective way. This usually implies that the cost per connected exchange line in the rural areas should be in the same order of magnitude as in urban areas. For this to happen, it is generally accepted that wireless technologies offer the best hope for rural telecommunications in Africa, even though there are still a number of questions, both technical and financial on suitable network solution in terms of:

- Wireless applications to be provided.
- Wireless network planning and design optimization.
- Terminal equipment design.
- Characterization of wireless network application and robustness to Rural Radio channel variability.
- Financial and economic viability issues of Rural Telecommunication.

The main occupation in rural areas is agriculture but in some areas small-scale industries have been developed. The rural areas with their scattered population are the backbone of the national economies, producing food and raw material to feed industries that are normally located in the urban centers. The rural areas are in general, underprivileged as far as skilled manpower; electrical energy, transport, telecommunications infrastructure and other social facilities are concerned. As a result a problem of migration to areas with better-developed facilities, mainly in the cities, occurs at the expense of the rural agriculture labour force. This can only be redressed if economic development is given priority in rural areas. The Maitland report has shown that telecommunications is an enabler of economic development.

The most common tool for information exchange is telephone. The average telephone density in South Africa is 12% for every 100 people. The telephone density in the rural areas is 0.1% and in the urban areas is 14%. The scarcity of telecommunication facilities in developing countries is attributed partly to natural obstacles that make the required investment prohibitive [1]

1.2 Characteristics of rural areas in KwaZulu Natal Province

As already alluded to, the typical characteristics of the rural areas are as follows:

- The areas are sparsely populated, isolated, with poor or no power supply and hardly accessible by road.
- They have low population densities with low-income earnings. Consequently, there are a small number of potential subscribers per geographical area making it economically unattractive to provide services to such areas using conventional systems.
- They have hostile features such as steep and rough terrains, rivers and gorges, mountain ranges, plateaus and escarpments, harsh and weather conditions.

To illustrate the population sparcity, the model shown in figure 2 characterizes the residential areas in the rural environment. The gray area represents a typical location in rural. The population of the location is distributed among the tribal community clusters. The distance between clusters ranges from 1 km to 5km. The vegetation within a 1 km vicinity of a cluster is light and becomes heavy as you move further away from the cluster. In general, the clusters have two possible forms: concentrated clusters represented by yellow square and distributed cluster represented by pink circles. Most areas in rural areas are of 'distributed cluster' type except where there is some commercial farming, mining or other large-scale economic activity.

Figure 3 illustrates a concentrated cluster model in the rural area. There can be only one chief (Inkosi) in a cluster, who normally dwells in the center of the cluster. Nevertheless, these chiefs serve a unique and purposeful contribution to local governance. Their subjects are very loyal and almost follow to the letter instructions from the Inkosi. At present, the government is trying to include chiefs in the government structures because of the influence they have on rural populations.

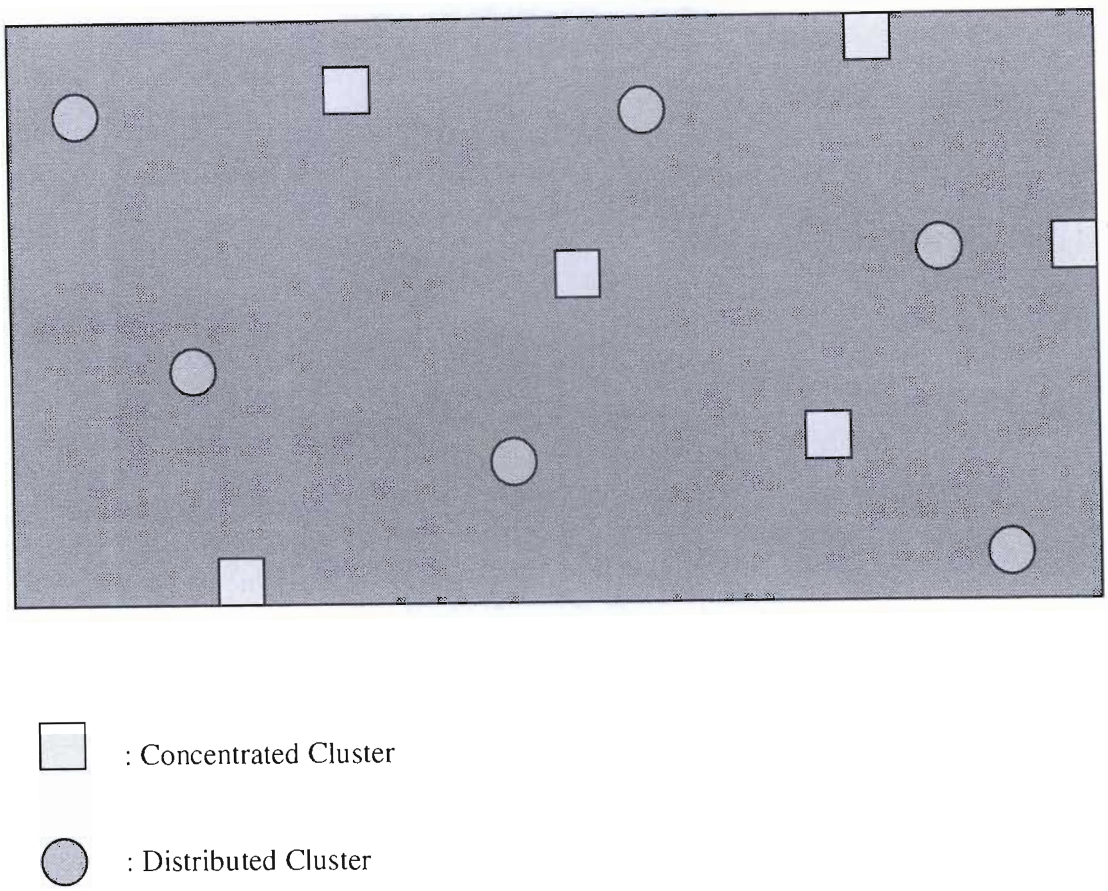

Figure 2: General rural settlement model in KwaZulu-Natal Province

The dimension of a 'concentrated cluster' ranges from 1 km to 3 km. About 50-100 families (with 5-10 people per family) reside in a cluster and are shown in the figure 3 below. Each family's territory is about 500m by 500m, as assigned by a chief. Spacing between different family's dwelling is about 100-500 m and the area is moderately vegetated.

Other types of clusters are less populated and are characterized by the distributed cluster model as shown in figure 4 As expected, the space between families is larger, ranging from 1 km to 3 km, and is heavily vegetated. Hilly areas are usually preferred for settlements because of their fertile productive soil and also historically, they form strategic vantage points easier to defend from intruders. It is very difficult and generally unacceptable to relocate from the areas where their ancestors have lived for generations. The bonding to ancestral land is very strong in most African communities. The features described here have a major impact on the choice of the telecommunication system that can efficiently and cost-effectively serve this area.

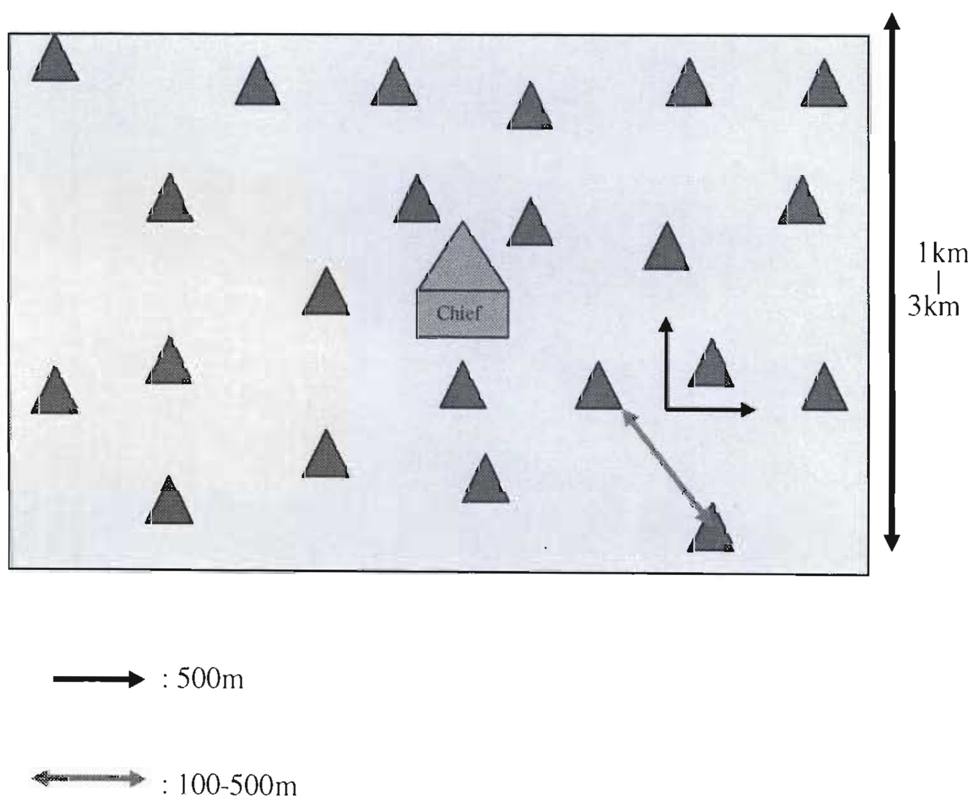

Figure 3: Concentrated Cluster Model of settlements in KwaZulu-Natal

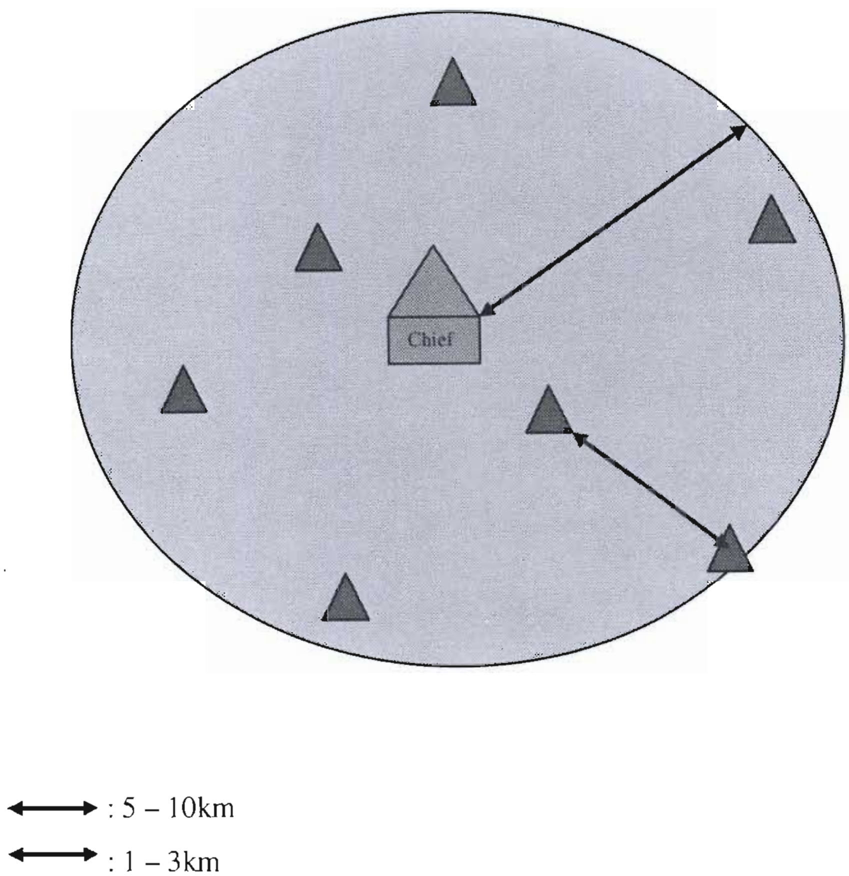

Figure 4: Distributed Cluster Model of settlements in KwaZulu-Natal

With these characteristics, provision of telecommunications services using traditional wired and centralized network architecture becomes economically prohibitive. Application of systems employing distributed network architecture as shown in figure 5, seems to provide cost effective solutions to suit the scenarios described.

The distributed switching network also known as the Rural Radio Network (RRN) was designed as a collaborative research between Universities of Warwick, Southampton and Dar Es Salaam [3]. The RRN system is a wireless network using distributed connectivity protocol.

A transceiver is a combination transmitter/receiver in a single package. The term applies to wireless communications devices such as cellular telephones, cordless telephone sets, handheld two-way radios, and mobile two-way radios. Occasionally the term is used in reference to transmitter/receiver devices in cable or optical fiber systems.
In a radio transceiver, the receiver is silenced while transmitting. An electronic switch allows the transmitter and receiver to be connected to the same antenna, and prevents the transmitter output from damaging the receiver. With a transceiver of this kind, it is impossible to receive signals while transmitting. This mode is called half duplex. Transmission and reception often, but not always, are done on the same frequency.

Some transceivers are designed to allow reception of signals during transmission periods. This mode is known as full duplex, and requires that the transmitter and receiver operate on substantially different frequencies so the transmitted signal does not interfere with reception. Cellular and cordless telephone sets use this mode. Satellite communications networks often employ full-duplex transceivers at the surface-based subscriber points. The transmitted signal (transceiver-to-satellite) is called the uplink, and the received signal (satellite-to-transceiver) is called the downlink.

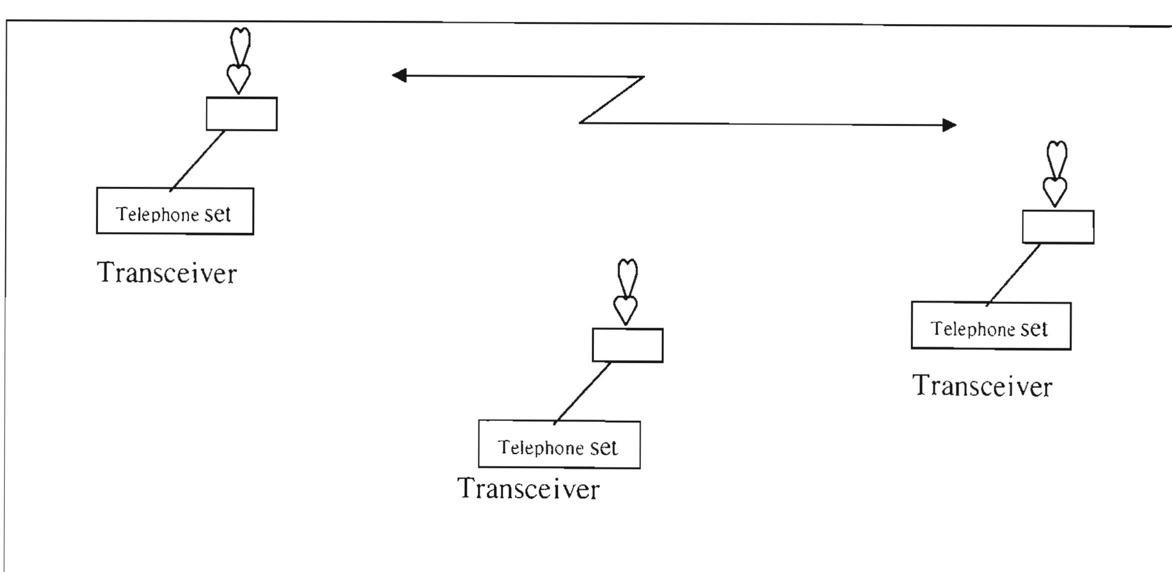

Figure 5: The Rural Radio Network (RRN)

1.3 Classification of Rural Areas

The term "Rural area" is the broad term, which covers different types of areas or settlements. It is proper to identify these settlements because they are of great importance when it comes to the provision of telecommunication services. The type of settlement determines the type of service to be provided. In the rural areas, there are four different types of settlements that might need different types of services. These are discussed in the following sections.

1.3.1 Informal settlement

Most people from this settlement are assumed to be unemployed; and even those who claim to be employed earn less than average such that they cannot afford the monthly charges for services. A person in this kind of settlement is not guaranteed to be settled there for a long period of time; It is expected that once a person gets more "developed" he/she moves away from that settlement. It is thus not advisable to give an individual service because it would be expensive.

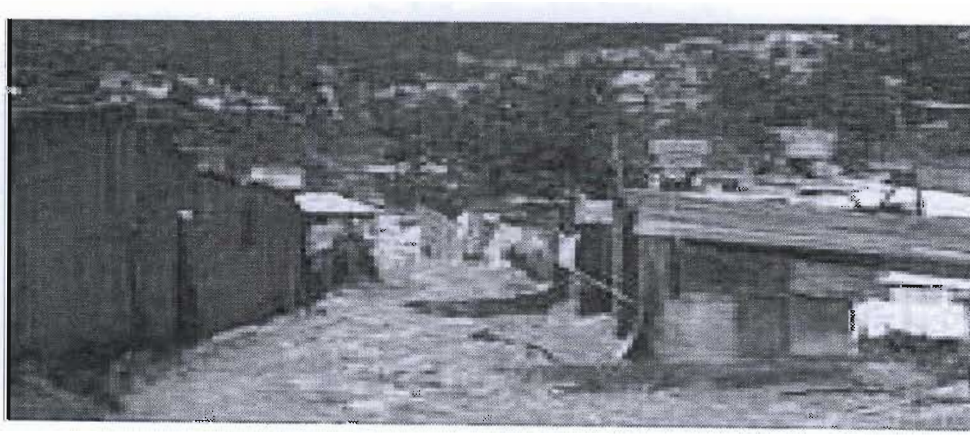

Figure 6: Typical informal settlement in KZN

1.3.2 Formal settlement

This is the type of convincing settlement that is guaranteed to be there for a long period of time, this kind of settlement can have a large enough population density, which will provide the telecommunication network a good coverage. Telecommunication services such as Internet and telephone are possible to this settlement.

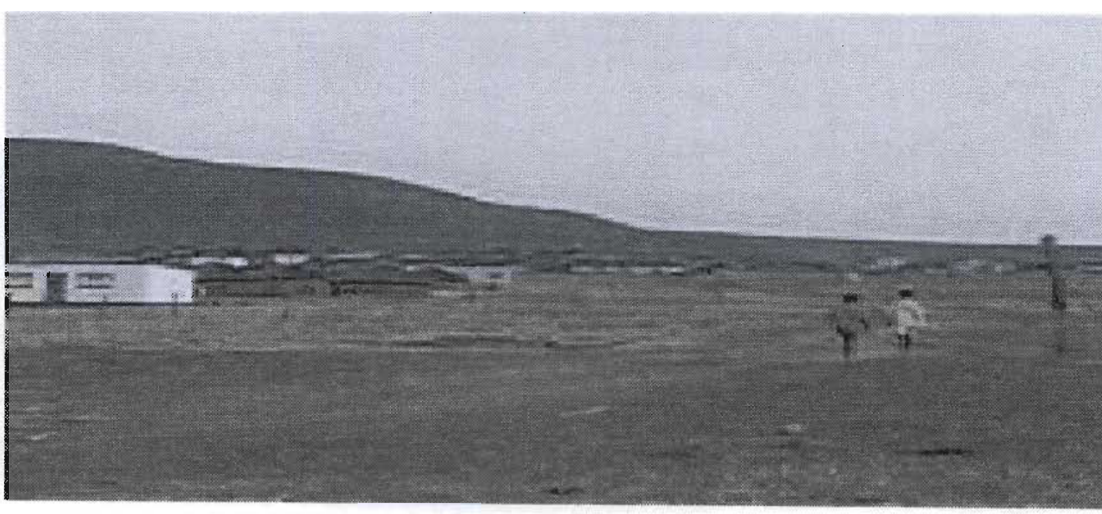

Figure 7a: Typical formal settlement in rural KZN

Figure 7b: Typical formal settlement in rural KZN

1.3.3 Farmers

A farming settlement includes a farmer and employees who are working; these employees often stay in premises within the settlement. This kind of settlement seems to require most telecommunication services like telephone, fax, e-mail. It is then obvious that for this particular settlement, there will be need for a little more bandwidth and a farmer might also need a guarantee quality of service (QoS).

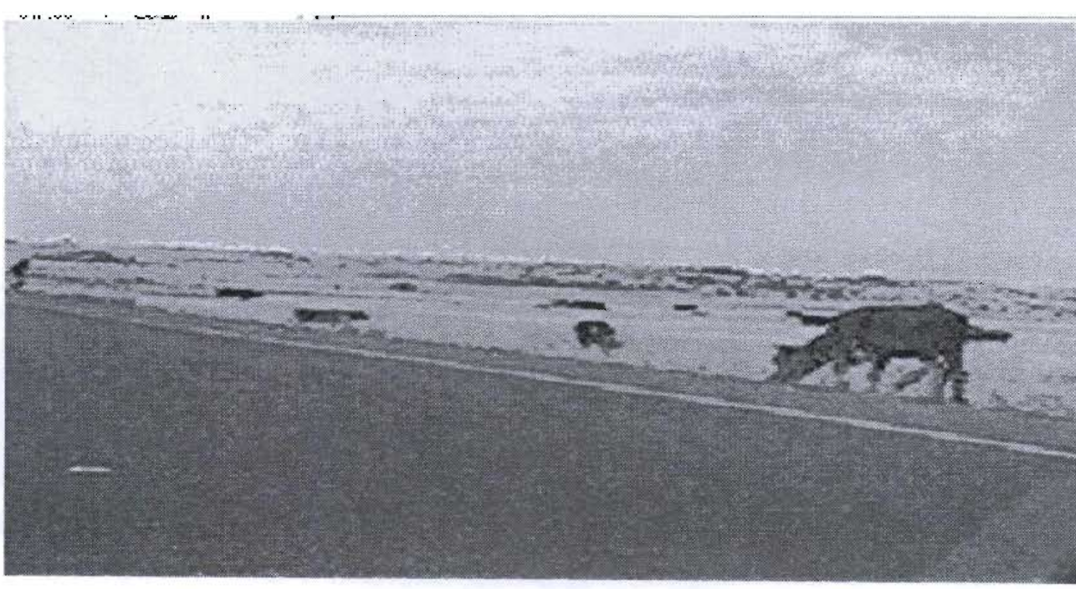

Figure 8: Farmer land

1.3.4 Country Lodge

This is a typical resting place for tourists from outside or within the country. Tourist firms, as well as social, academic and political workshop organizers often hire these places. Country Lodges are usually located or built in rural areas. Because of all these events, there is a need for the high-quality telecommunication services-for videoconferencing, Internet, E-mails, ATM machine and basic telephony. The only problem with this particular settlement is that these telecommunication services are not utilized all time; this means that a mechanism is needed that ensures the service is active only at the particular time required.

Figure 9: Country Lodge in rural KZN

Chapter Two

Wide area network (WAN) issues

2.1 What Is a WAN?

A wide area network (WAN) is a geographically dispersed telecommunications network. It is a voice, data, or video network that provides connection from one or more computers or network within an eligible school or library to one or more computer or networks that are external to such eligible school or library. A WAN is a data communications network that covers a relatively broad geographic area and that often uses transmission facilities provided by common carriers, such as telephone companies. In this particular scenario, the size of the wide area network is a region size.

The term distinguishes a broader telecommunication structure from a local area network (LAN). A wide area network may be privately owned or rented, but the term usually connotes the inclusion of public (shared user) networks. An intermediate form of network in terms of geography is a metropolitan area network (MAN).

WANs are built to provide communication solutions for organizations or people who need to exchange digital information between two distant places (in one country or in two different countries). Since the distance is long, the local telecommunication company is involved; in fact, WANs are usually maintained by the country's public telecommunication companies (PTT's - like AT&T, Sprint, BEZEQ, Telkom SA), which offer different communication services to the population [4].

2.2 Open System Interconnection (OSI) Model

The main feature or function of Asynchronous Transfer Mode is transport, and it is, therefore important to know or understand where ATM falls in the OSI model. One might think of ATM as transport, which is true and say it lies on the transport layer, but it is not; instead ATM lies on the Data Link layer. These few pages are looking at the Data Link Layer for completeness.

2.2.1 Data Link Layer

The main task of the data link layer is to take a raw transmission facility and transform it into a line that appears free of transmission errors in the network layer. It accomplishes this task by having the sender break the input data up into data frames (typically a few hundred bytes), transmit the frames sequentially, and process the acknowledgment frames sent back by the receiver. Since the physical layer merely accepts and transmits a stream of bits without any regard to meaning of structure, it is up to the data link layer to create and recognize frame boundaries. This can be accomplished by attaching special bit patterns to the beginning and end of the frame. If there is a chance that these bit patterns might occur in the data, special care must be taken to avoid confusion. The data link layer should provide error control between adjacent nodes.

Another issue that arises in the data link layer (and most of the higher layers as well) is how to keep a fast transmitter from drowning a slow receiver in data. Some traffic regulation mechanism must be employed in order to let the transmitter know how much buffer space the receiver has at the moment. Frequently, flow regulation and error handling are integrated, for convenience [4].

If the line can be used to transmit data in both directions, this introduces a new complication that the data link layer software must deal with. The problem is that the acknowledgment frames for A to B traffic compete for the use of the line with data frames for the B to traffic. A clever solution (piggybacking) has been devised. In most practical situations, there is a need for transmitting data in both directions. One way of achieving full-duplex data transmission would be to have two separate communication channels, and use each one for simplex data traffic (in different directions). If this were done, we would have two separate physical circuits, each with a "forward" channel (for data) and a "reverse" channel (for acknowledgment). In both cases the bandwidth of the reverse channel would be almost entirely wasted. In effect, the user would be paying the cost of two circuits but only using the capacity of one.

A better idea is to use the same circuit for data in both directions. In this model the data frames from A to B are intermixed with the acknowledgment frames from A to B. By looking at the "kind" field in the header of an incoming frame, the receiver can tell whether the frame is data or acknowledgment.

Although interweaving data and control frames on the same circuit is an improvement over having two separate physical circuits, yet another improvement is possible. When a data frame arrives, instead of immediately sending a separate control frame, the receiver restrains itself and waits until the network layer passes it the next packet. The acknowledgment is attached to the outgoing data frame. In effect, the acknowledgment gets a free ride on the next outgoing data frame. The technique of temporarily delaying outgoing acknowledgment so that they can be hooked onto the next outgoing data frame is widely known as piggybacking.

The data link layer provides reliable transit of data across a physical network link. Different data link layer specifications define different network protocol characteristics, including physical addressing, network topology, error notification, sequencing of frames, and flow control. Physical addressing (as opposed to network addressing) defines how devices are addressed at the data link layer. Network topology consists of the data link layer specifications that often define how devices are to be physically connected, such as in a bus or a ring topology. Error notification alerts upper-layer protocols that a transmission error has occurred, and the sequencing of data frames reorders frames that are transmitted out of sequence. Finally, flow control moderates the transmission of data so that the receiving device is not overwhelmed with more traffic than it can handle at one time.

The Institute of Electrical and Electronics Engineers (IEEE) has subdivided the data link layer into two sub-layers: Logical Link Control (LLC) and Media Access Control (MAC). Figure 19 illustrates the IEEE sub-layers of the data link layer.

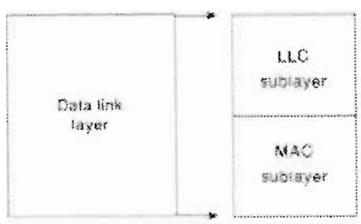

Figure 10: The Data Link Layer Contains Two Sublayers

The Logical Link Control (LLC) sublayer of the data link layer manages communications between devices over a single link of a network. LLC is defined in the IEEE 802.2 specification and supports both connectionless and connection-oriented services used by higher-layer protocols. IEEE 802.2 defines a number of fields in data link layer frames that enable multiple higher-layer protocols to share a single physical data link. The Media Access Control (MAC) sublayer of the data link layer manages protocol access to the physical network medium. The IEEE MAC specification defines MAC addresses, which enable multiple devices to uniquely identify one another at the data link layer [5].

2.2.2 Data Link Layer Addresses

A data link layer address uniquely identifies each physical network connection of a network device. Data-link addresses sometimes are referred to as physical or hardware addresses. Data-link addresses usually exist within a flat address space and have a pre-established and typically fixed relationship to a specific device.

End systems generally have only one physical network connection and thus have only one data-link address. Routers and other internetworking devices typically have multiple physical network connections and therefore have multiple data-link addresses. Figure 11 illustrates how each interface on a device is uniquely identified by a data-link address.

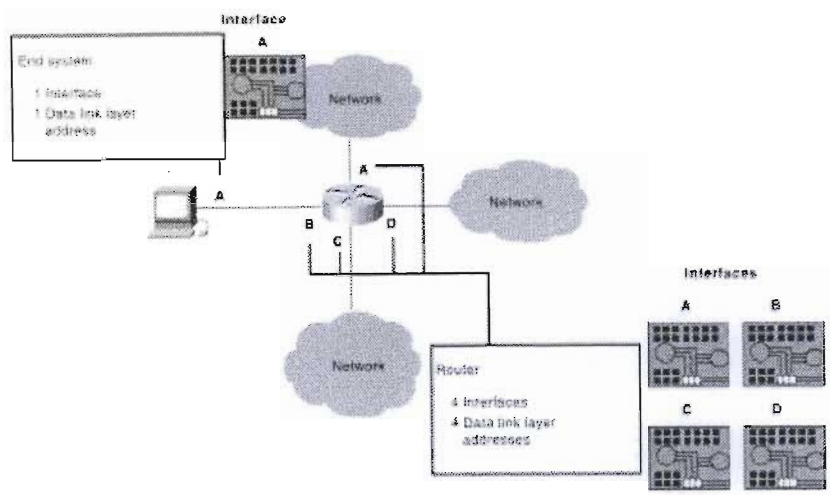

Figure 11: Each Interface on a Device Is Uniquely Identified by a Data-Link Address.

2.2.2.1 MAC Addresses

Media Access Control (MAC) addresses consist of a subset of data link layer addresses. MAC addresses identify network entities in LANs that implement the IEEE MAC addresses of the data link layer. As with most data-link addresses, MAC addresses are unique for each LAN interface. Figure 12 illustrates the relationship between MAC addresses, data-link addresses, and the IEEE sublayers of the data link layer.

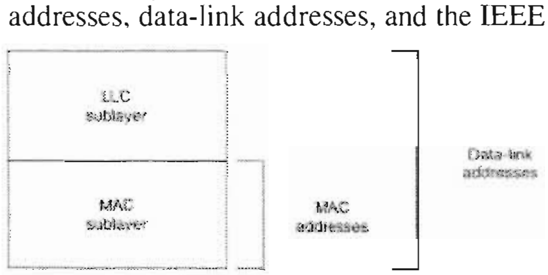

Figure 12: MAC Addresses, Data-Link Addresses, and the IEEE Sublayers of the Data Link Layer Are All Related

MAC addresses are 48 bits in length and are expressed as 12 hexadecimal digits. The first 6 hexadecimal digits, which are administered by the IEEE, identify the manufacturer or vendor and thus comprise the Organizationally Unique Identifier (OUI). The last 6 hexadecimal digits comprise the interface serial number, or another value administered by the specific vendor. MAC addresses sometimes are called burned-in addresses (BIAs) because they are burned into read-only memory (ROM) and are copied into random-access memory (RAM) when the interface card initializes. Figure 13 illustrates the MAC address format [4].

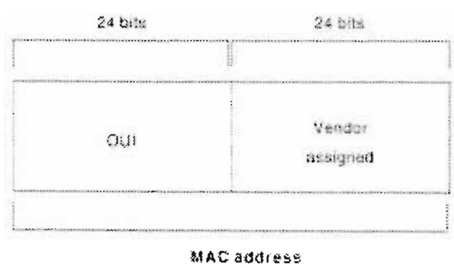

Figure 13: The MAC Address Contains a Unique Format of Hexadecimal Digits

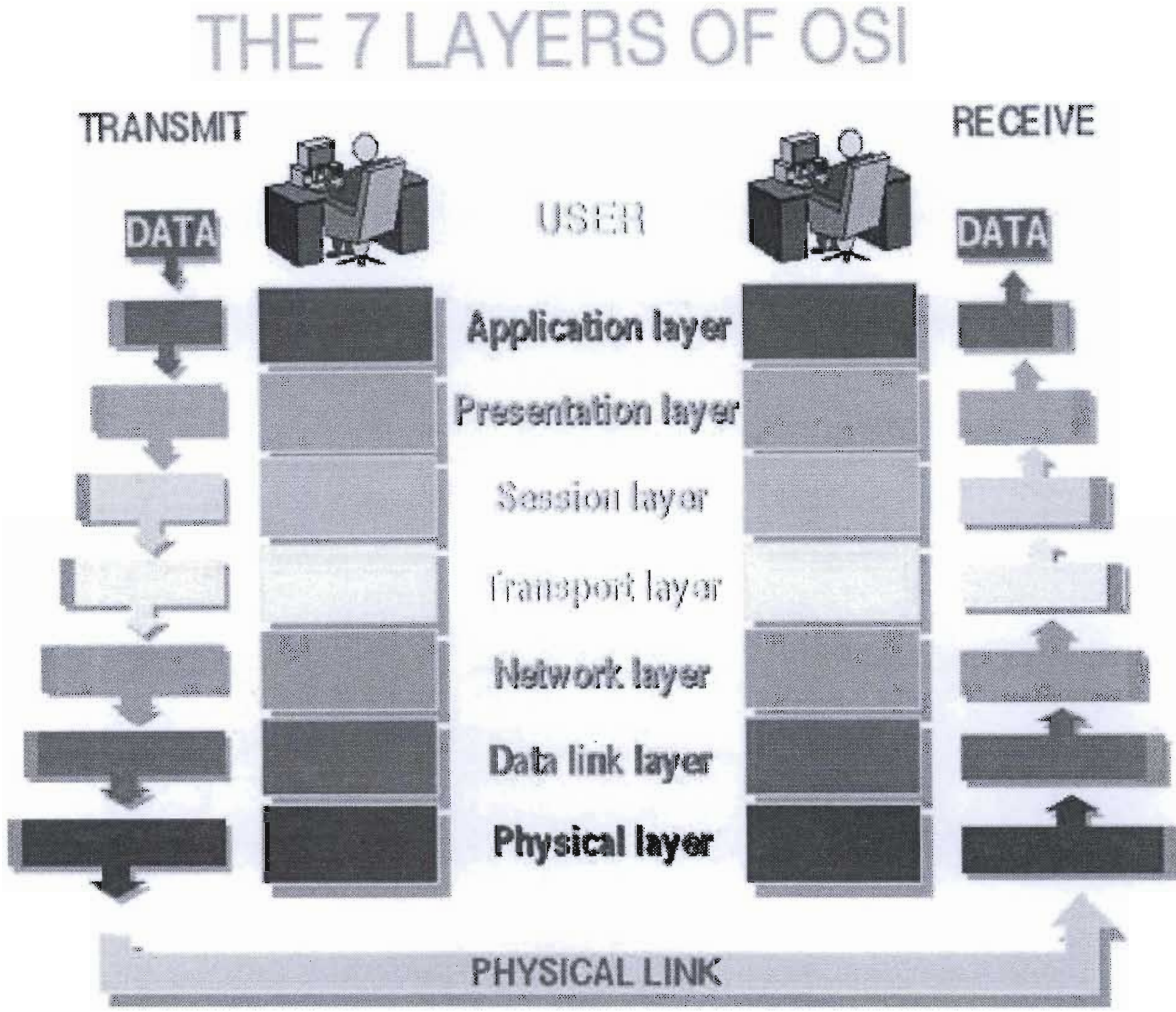

Figure 14: OSI layers

2.3 Significance of a WAN

The main purpose of a WAN is to provide reliable, fast and safe communication between two or more places (Nodes) with low delays and at low prices. WANs enable an organization to have one integral network between all its departments and offices, even if they are not all in the same building or city, providing communication between the organization and the rest of the world. In principle, this task is accomplished by connecting the organization (and all the other organizations) to the network nodes by different types of communication strategies and applications. Since WANs are usually developed by the PTT of each country, their development is influenced by each PTT's own strategies and politics.

WAN technologies generally function at the lower three layers of the OSI reference model: the physical layer, the data link layer, and the network layer. Figure 15: illustrates the relationship between the common WAN technologies and the OSI model.

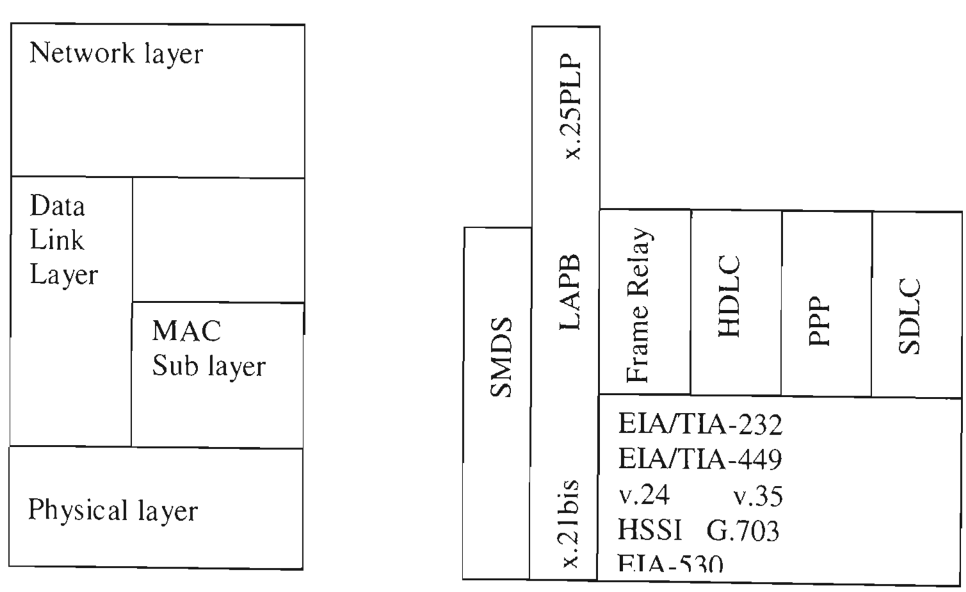

Figure 15: WAN Technologies Operate at the Lowest Levels of the OSI Model

2.4 The Basic of WANs

The basic WAN service which the PTT usually offers (for many years) is a Leased Line. A Leased Line is a point-to-point connection between two places, implemented by different transmission media (usually through PSTN Trunks), which creates one link between its nodes. A point-to-point link provides a single, pre-established WAN communications path from the customer premises through a carrier network, such as a telephone company, to a remote network. Point-to-point lines are usually leased from a carrier and thus are often called leased lines. For a point-to-point line, the carrier allocates pairs of wire and facility hardware to your line only. These circuits are generally priced based on bandwidth required and distance between the two connected points. Point-to-point links are generally more expensive than shared services such as Frame Relay (FR).

An organization whose networks are based on such lines has to connect each office with one line, meaning that each office is connected to as many lines as the number of offices it is connected to, as shown in the figure 16:

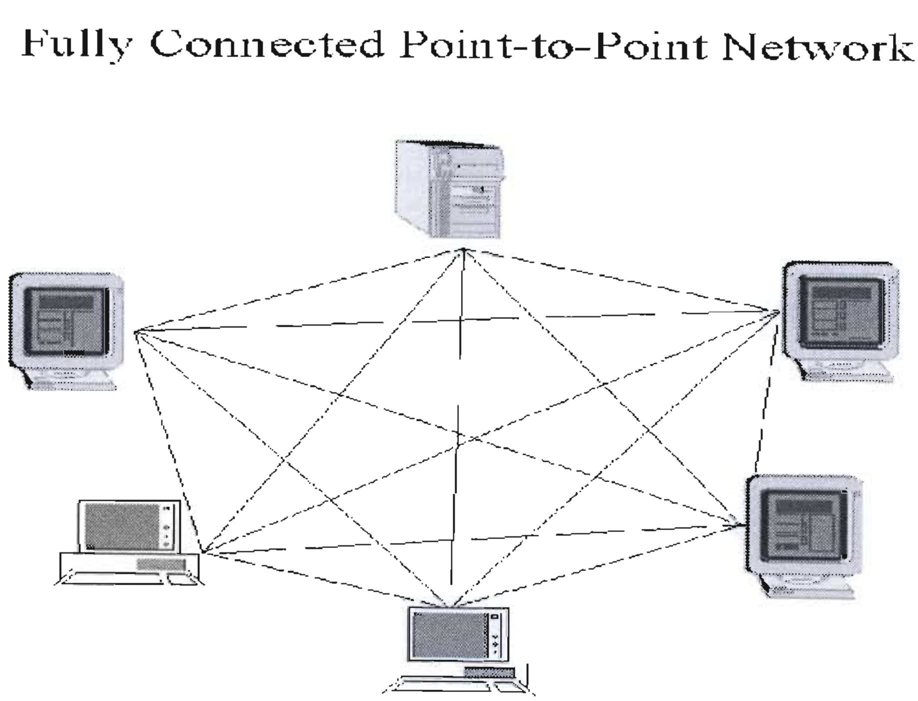

Figure 16: Point-to-Point Network

In the past, leased lines were just 4 wires connected between the two places, and the responsibility for communication fell on the organization and the good will of the PTT's personnel. These lines were not managed and often suffered from a lot of noise. Moreover, these lines consumed the PTT's bandwidth even when no transmission was occurring. Today, leased lines are usually point-to-point digital lines, which are implemented by creating a permanent channel, with known bandwidth, between the two nodes and transferring the data by a dedicated digital network, which enables automatic management on the line and minimizes noise interference[6].

For ages, the communication strategies of organizations were based on those lines and were usually built in a star configuration in order to minimize the amount of lines needed. It's easy to see that this configuration has a very weak point at its center.

In the 1970's, some PTTs built digital circuit switched communication networks which enabled creating a non permanent digital connection between two places (like telephone), but those networks did not provide the breakthrough in the communication technologies.

2.4.1 Circuit Switching

Switched circuits allow data connections that can be initiated when needed and terminated when communication is complete. This works much like a normal telephone line works for voice communication. Integrated Services Digital Network (ISDN) is a good example of circuit switching. When a router has data for a remote site, the switched circuit is initiated with the circuit number of the remote network. In the case of ISDN circuits, the device actually places a call to the telephone number of the remote ISDN circuit. When the two networks are connected and authenticated, they can transfer data. When the data transmission is complete, the call can be terminated.

2.4.2 Packet Switching

Packet switching is a WAN technology in which users share common carrier resources. Because this allows the carrier to make more efficient use of its infrastructure, the cost to the customer is generally much better than with point-to-point lines. In a packet switching setup, networks have connections into the carrier's network, and many customers share the carrier's network. The carrier can then create virtual circuits between customers' sites by which packets of data are delivered from one to the other through the network. The section of the carrier's network that is shared is often referred to as a cloud [6].

The Packet Switched WAN appeared in the 1960's, and defined the basis for all communication networks today. The principle in Packet Switched Data Network (PSDN) is that the data between the nodes is transferred in small packets. This principle enables the PSDN to allow one node to be connected to more than one other node through one physical connection. That way, a fully connected network, between several nodes, can be obtained by connecting each node to one physical link.

Some examples of packet-switching networks include Asynchronous Transfer Mode (ATM), Frame Relay, Switched Multimegabit Data Services (SMDS), and X.25. Figure 17: shows an example packet-switched network.

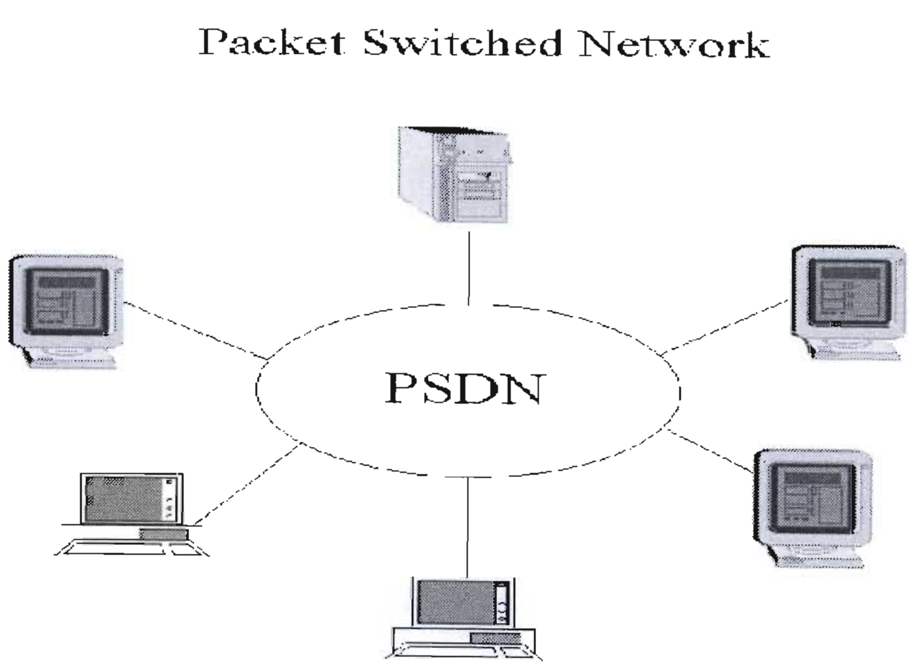

Figure17: Packet Switch Network

Another advantage for Packet Switching was the efficient use of resources by sharing the Network bandwidth among the users (instead of dividing).

2.5 WAN Virtual Circuits

A virtual circuit is a logical circuit created within a shared network between two network devices. Two types of virtual circuits exist: switched virtual circuits (SVCs) and permanent virtual circuits (PVCs).

SVCs are virtual circuits that are dynamically established on demand and terminated when transmission is complete. Communication over an SVC consists of three phases: circuit establishment, data transfer, and circuit termination. The establishment phase involves creating the virtual circuit between the source and destination devices. Data transfer involves transmitting data between the devices over the virtual circuit, and the circuit termination phase involves tearing down the virtual circuit between the source and destination devices. SVCs are used in situations in which data transmission between devices is sporadic, largely because SVCs increase bandwidth used due to the circuit establishment and termination phases, but they decrease the cost associated with constant virtual circuit availability [7].

PVC is a permanently established virtual circuit that consists of one mode: data transfer. PVCs are used in situations in which data transfer between devices is constant. PVCs decrease the bandwidth use associated with the establishment and termination of virtual circuits, but they increase costs due to constant virtual circuit availability. The service provider generally configures PVCs when an order is placed for service.

2.6 WAN Dialup Services

Dialup services offer cost-effective methods for connectivity across WANs. Two popular dialup implementations are dial-on-demand routing (DDR) and dial backup.

DDR is a technique whereby a router can dynamically initiate a call on a switched circuit when it needs to send data. In a DDR setup, the router is configured to initiate the call when certain criteria are met, such as a particular type of network traffic needing to be transmitted. When the connection is made, traffic passes over the line. The router configuration specifies an idle timer that tells the router to drop the connection when the circuit has remained idle for a certain period.

Dial backup is another way of configuring DDR. However, in dial backup, the switched circuit is used to provide backup service for another type of circuit, such as point-to-point or packet switching. The router is configured so that when a failure is detected on the primary circuit, the dial backup line is initiated. The dial backup line then supports the WAN connection until the primary circuit is restored. When this occurs, the dial backup connection is terminated [8].

2.7 WAN Devices

WANs use numerous types of devices that are specific to WAN environments. WAN switches, access servers, modems, channel service/ data service unit (CSU/DSUs), and ISDN terminal adapters are discussed in the following sections. Other devices found in WAN environments that are used in WAN implementations include routers, ATM switches, and multiplexers.

2.7.1 CSU/DSU

CSU/DSU stands for Channel Service Unit/Data Service Unit. The CSU is a device that connects a terminal to a digital line. Typically, the two devices are packaged as a single unit. The DSU is a device that performs protective and diagnostic functions for a telecommunications line. You can think of it as a very high-powered and expensive modem. Such a device is required for both ends of a T - 1 or T - 3connection, and the units at both ends must be set to the same communications standard.

2.7.2 ISDN

Abbreviation of integrated services digital network, an international communications standard for sending voice, video, and data over digital telephone lines or normal telephone wires. ISDN supports data of 64 Kbps (64,000 bits per second).

There are two types of ISDN:

- Basic Rate Interface (BRI) -- consists of two 64-Kbps B-channels and one D-channels for transmitting control information.
- Primary Rate Interface (PRI) -- consists of 23 B-channels and one D-channel (U.S.) or 30 B-channels and one D-channel (Europe).

The original version of ISDN employs baseband transmission. Another version, called B-ISDN, uses broadband transmission and is able to support transmission rates of 1.5 Mbps. B-ISDN requires fiber optic cables and is not widely available.

2.8 WAN Switch

A WAN switch is a multiport internetworking device used in carrier networks. These devices typically switch such traffic as Frame Relay, X.25, and SMDS, and operate at the data link layer of the OSI reference model. Figure 18: illustrates two routers at remote ends of a WAN that are connected by WAN switches.

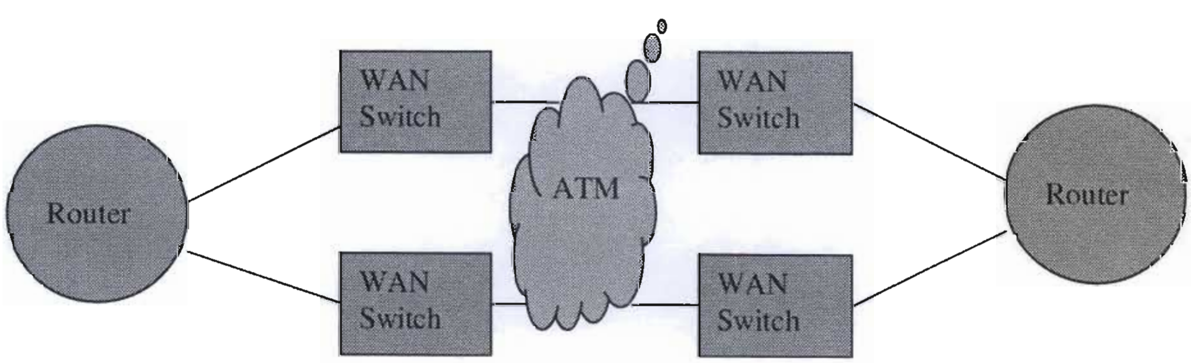

Figure18: WAN Switches can connect Two Routers at Remote Ends of a WAN

2.9 Modem

A modem is a device that interprets digital and analog signals, enabling data to be transmitted over voice-grade telephone lines. At the source, digital signals are converted to a form suitable for transmission over analog communication facilities. At the destination, these analog signals are returned to their digital form. Figure19: illustrates a simple modem-to-modem connection through a WAN.

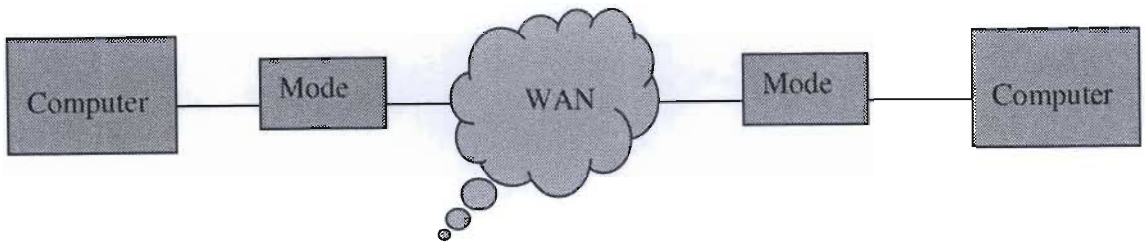

Figure 19: A Modem Connection through a WAN Handles Analog and Digital Signals

2.10 New Technologies

The communication target today is the ATM (and B-ISDN services). However, until applications and technologies for ATM become more developed, two main mid-time services are popularly used in the world today. The first service is Frame Relay, which is considered to be the next generation for X.25, and enables faster communication rate (up to T3/E3) and better communication protocol. Until all its standards will be completed, Frame Relay is mainly a point-to-point service and replaces the leased lines. The second network service is ISDN, which is a fully digitized service, enabling communication for most types of data (voice, computer data and images) at all the network nodes (meaning in every house). This service is at its peak today and is been implemented mostly in Europe.

Those two communication networks are not fully developed yet, and will be spread in the world in the next years.

2.11 Future WANs

The ATM network and B-ISDN services, which provide solutions for all types of data (including video) are been developed today and are beginning to be implemented.

But even today, new networks are been designed for future demands. Those new networks are aimed to work at enormous rates of Giga-bps, and are providing new challenges for their designers.

For example in a medium speed of 64Kbps, transferring a file of 10KBit over a distance of 3000Km will take 0.015625sec plus a minimum of 10 microseconds is needed for light to reach from 1 point to the other. In a Giga-Net of speed 10E+10bps, transferring that same file will take 1 microsecond (plus 10 microseconds for light), meaning that the file will reach the network before the first bit will reach its destination. This example and other issues make the next generation of WANs a very challenging one.

The WAN, has come a long way since the days of analog leased lines and is taking more and more tasks from the old separated networks into one integral network which enables good communication for any type of data or application.

Chapter Three

Asynchronous Transfer Mode (ATM)

3.1 Introduction

Changes in the structure of the telecommunications industry and market conditions have brought new opportunities and challenges for network operators and public service providers. Networks that have been primarily focused on providing better voice services are evolving to meet new multimedia communications challenges and competitive pressures. Asynchronous Transfer Mode (ATM) has been one of the hottest telecommunications topics for many years. Services based on asynchronous transfer mode (ATM) and synchronous digital hierarchy (SDH)/synchronous optical network (SONET) architectures provide the flexible infrastructure essential for success in this evolving market (see figure 20).

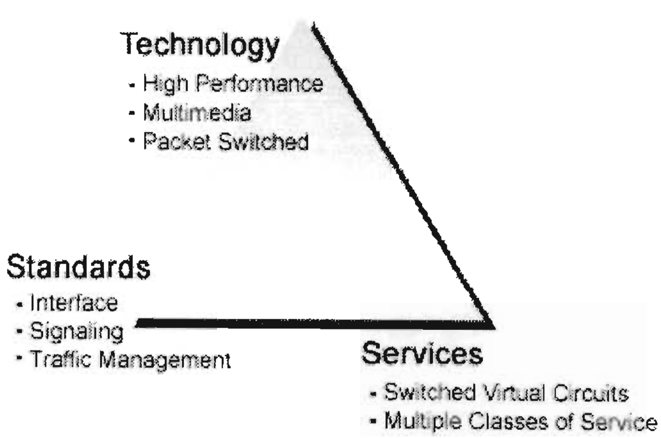

Figure 20: Evolving market of communication

ATM, which was once envisioned as the technology of future public networks, is now a reality, with service providers around the world introducing and rolling out ATM and ATM-based services. The ability to exploit the benefits of ATM technology within the public network successfully are providing strategic competitive advantage to carriers and enterprises alike.

In addition to revenue opportunities, ATM reduces infrastructure costs through efficient bandwidth management, operational simplicity, and the consolidation of overlay networks. Carriers can no longer afford to go through the financial burden and time required to deploy a separate network for each new service requirement (e.g., dedicating a network for a single service such as transparent LAN or frame relay). ATM technology allows core network stability while allowing service interfaces and other equipment to evolve rapidly.

This chapter will provide an overview about ATM to describe what it is, how it works, what its capabilities are, and some areas of current work.

3.2 Motivation

In a particular research in 1998 there was a response to the explosive increase in the number of mobile subscribers and ever-stronger demand for mobile multimedia services. The authors in [8] proposed introducing the ATM techniques for next generation mobile network infrastructures in order to handle a high volume of traffic and develop multimedia communication.

Firstly, the article clarified the mobile specific requirements for and advantage of applying ATM to mobile infrastructure networks. However, it is risky for network operators to replace the conventional STM- based infrastructure by ATM. Therefore that research showed a smooth evolution path for the mobile network infrastructure to convert from conventional STM to ATM as mobile multimedia service mature. Even in future mobile networks, the main traffic may still be voice communications, whose bit rate is too low for efficient use of the radio frequency band [10].

Applying ATM to such very-low-bit-rate mobile streams is inefficient due to the delay in filing out the payload of an ATM cell; this "packetization delay" degrades the quality of service.

Using a layered cell structure for the mobile ATM network can solve this problem.

This cell structure enables the efficient transfer of voice signals ranging from very-low - bit-rate signals to high-speed multimedia signals with little delay.

Mobile communication has penetrated so deeply into every day life that it is no longer surprising to see a person talking on the mobile phone in public. The maturing of conventional services in mobile communication networks has led to demands for more convenient and highly functional mobile multimedia services.

These demands require an infrastructure network that can provide the capacity needed for high traffic volumes as well as flexible types of communication. Studies currently concentrate on a third generation network, which will provide the multimedia services that will produce heterogeneous traffic ranging from low-bit-rate voice signals to high-bit-rate data and image communications. Moreover, basic research on the fourth generation system has already begun; this system will provide extra-high-bit-rate services comparable to broadband integrated services digital network. Asynchronous Transfer Mode (ATM) can efficiently transport heterogeneous traffic, such as high-speed multimedia services, in fixed environment [5].

3.3 Definition of ATM

Asynchronous transfer mode is a technology that has its history in the development of broad and ISDN in the 1970s and 1980s. Technically, it can be viewed as an evolution of packet switching. Like packet switching for data (e.g., X.25, frame relay, transmission control protocol [TCP/IP],) ATM integrates the multiplexing and switching functions, is well suited for bursty traffic (in contrast to circuit switching), and allows communications between devices that operate at different speeds. Unlike packet switching, ATM is designed for high-performance multimedia networking. ATM technology has been implemented in a very broad range of networking devices:

- PC, workstation, and server network interface cards
- Switched-Ethernet and token-ring workgroup hubs
- Workgroup and campus ATM switches
- ATM enterprise network switches
- ATM multiplexers
- ATM-edge switches
- ATM backbone switches

ATM is also a capability that can be offered as an end-user service by service providers (as a basis for tariff services) or as a networking infrastructure for these and other services. The most basic service building block is the ATM virtual circuit, which is an end-to-end connection that has defined end points and routes but does not have bandwidth dedicated to it. Bandwidth is allocated on demand by the network as users have traffic to transmit. ATM also defines various classes of service to meet a broad range of application needs.

ATM has a set of international interface and signaling standard defined by the International Telecommunication Union – Telecommunications (ITU-T) Standard sector (formally the CCITT). The ATM forum has played a pivotal role in the ATM market since its formulation in 1991. The ATM forum is an international voluntary organization composed of venders, service providers, research organizations, and users. Its purpose is to accelerate the use of ATM products and services through the rapid convergence of interoperability specifications, promotion of industry cooperation, and other activities. Developing multivender implementation agreements also furthers this goal [11].

3.4 Why was ATM first introduced?

ATM was introduced as the underlying technology of the developing Broadband ISDN. B-ISDN is being implemented currently and still developing as an extremely high bandwidth technology. The aim of B-ISDN is to support all forms of current and future telecommunications traffic, such as, but not limited to: telephone calls, videoconferences, television broadcasts and Internet services, within a single integrated network. With all these services in mind, ATM has been developed as a technology that embraces cell-switching technology. Cell switching has many benefits over circuit switching. Cell switching easily handles both constant rate and variable rate traffic at very high rates and importantly, it supports point-to-multipoint broadcasting, which is required for television distribution and cannot be provided by circuit switching [10].

3.5 ATM Architecture

The layered architecture of an ATM network is shown below in Figure 21. [12]

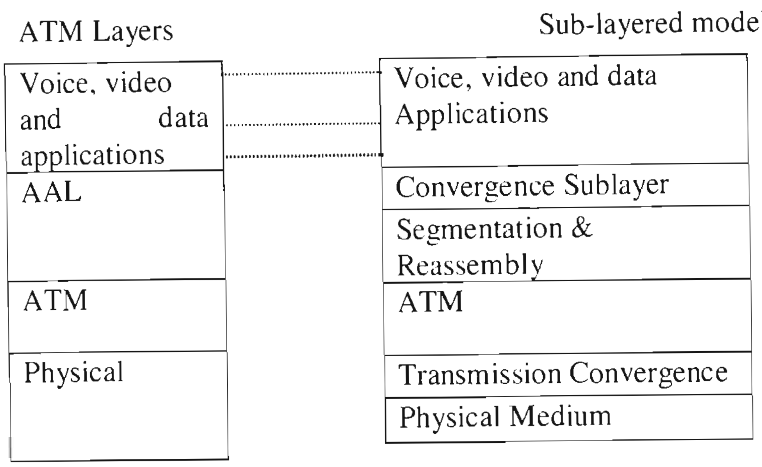

Figure 21: ATM protocol layers

The underlying physical layer defines the delivery of ATM cells between ATM entities. The ATM layer performs cell switching and multiplexing functions. The ATM adaptation layer (AAL) defines a set of service classes in order to accommodate different types of users. The AAL supports constant bit rate (CBR), real-time variable bit rate (rt-VBR), on-real-time variable bit rate (nrt-VBR), available bit rate (ABR) and unspecified bit rate (UBR) services [ITU-Ts 4]. Segmentation and reassembly is performed by the AAL. This entails processing higher layer data streams/frames into ATM cells to be passed to the ATM layer and conversely, reconstructing data streams for the higher layer from ATM cells [10]. ATM is based on a homogeneous network where all traffic is converted to fixed sized 53 byte cells, 48 byte payload plus 5-byte header. Header error control (HEC) is used to detect and correct single bit errors within the 5-byte header only. The HEC is seen as sufficient error control at the ATM layer, which has been developed for the optical fibre medium with low error rate (10-12) and the error pattern random [14]. The cell routing information contained within the header is not an exact address, thus ATM cell transport requires a connection to be established for communications. Connections can be point-to-point or point-to-multipoint and are composed of a series of switching and multiplexing units. Once established, a connection will have an associated virtual path identifier (VPI) and virtual channel identifier (VCI). The network units contain look-up tables to route cells along the established connection, based upon their header's routing field, which is a concatenation of a VPI and VCI. A virtual channel (VC) is a basic link between two switching points. A virtual channel connection is the concatenation of VCs defined by the look-up tables within the switching points. A virtual path (VP) connection can be observed as a lower layer connection containing multiple virtual channel connections, which are switched together as a single entity. Thus an ATM network can contain VP switches which observe the VPI only and VC switches which observe the whole routing field, VPI + VCI. This connection-oriented communication ensures ATM packets do not arrive out of order. Users communicating via ATM specify the quality of service they require when initiating a virtual circuit. The connection is only established if the ATM network has determined, to the best of its ability, that it can maintain the requested QoS. Guaranteeing QoS involves minimizing packet-dropping rates, packet delay and packet jitter. Packet delay refers to the time taken between a packet being generated at a terminal and its transmission from that terminal. Packet jitter refers to the time between consecutive packet transmissions from the same terminal. Packet dropping rate suffered by a terminal is the ratio of packets dropped, to packets generated by that terminal [13].

3.6 Current ATM Practice

In 1991 the ATM Forum (ATMF) was formed. The ATMF is an international organization consisting of over 600 member companies whose objective is to promote the use and awareness of ATM products and services through rapid convergence of interoperability specifications [9]. This is achieved through a technical committee, marketing committees and a user committee. The technical committee has several working groups to investigate different areas of ATM technology and promote a single set of specifications. This ensures interoperability between vendors as ATM products and services become available. Consisting of ATM end users, the user committee ensures the technical committee is meeting real-world user's needs. The International Telecommunications Union, telecommunications group (ITU-T) has produced several recommendations concerning ATM within their specifications, which are currently in use. Currently ATM is mainly used for high speed, high bandwidth network backbones, carrying large amounts of information quickly between cities and across continents [14]. ATM is not often the direct protocol used by the end user in this situation. Transmission Control Protocol (TCP) and Internet Protocol (IP) are used over the top of ATM. This configuration cannot take full advantage of the QoS provisions supplied by ATM as end users QoS demands are not represented within TCP/IP.

3.7 Benefits of ATM

The benefits of ATM are the following:

- High performance via hardware switching
- Dynamic bandwidth for bursty traffic
- Class-of-service support for multimedia
- Scalability in speed and network size
- Common LAN/WAN architecture
- International standards compliance

The high-level benefits delivered through ATM services deployed on ATM technology using international ATM standards can be summarized as follows:

- High performance via hardware switching with terabit switches on the horizon.
- Dynamic bandwidth for burst traffic meeting application needs and delivering high utilization of networking resources; most applications are or can be viewed as inherently bursty; data applications are LAN-based and are very bursty; voice is bursty, as both parties are neither speaking at once nor all the time; video is bursty; as the amount of motion and required resolution varies overtime.
- Class-of-service support for multimedia traffic allowing applications with varying throughput and latency requirements to be met on a single network.

- Scalability in speed and network size supporting link speeds of T1/E1 to OC-12 (622 Mbps) today and into the multi-Gbps range before the end of the decade; networks that scale to the size of the telephone network (i.e., as required for residential applications) are envisaged
- Common LAN/WAN architecture allowing ATM to be used consistently from one desktop to another; traditionally, LAN and WAN technologies have been very different, with implications for performance and interoperability
- Opportunities for simplifications via switched VC architecture; this is particularly for LAN–based traffic that today is connectionless in nature; the simplification possible through ATM VCs could be in areas such as billing, traffic management, security, and configuration management
- International standards compliance in central-office and customer-premises environments allowing for multivendor operation.

3.8 ATM Technology

In ATM networks, all information is formatted into fixed-length cells consisting of 48 bytes (8 bits per byte) of payload and 5 bytes of cell header (see Figure 22).

The fixed cell size ensures that long data frames or packets do not adversely affect time-critical information such as voice or video. The header is organized for efficient switching in high-speed hardware implementations and carries payload-type information, virtual-circuit identifiers, and header error check.

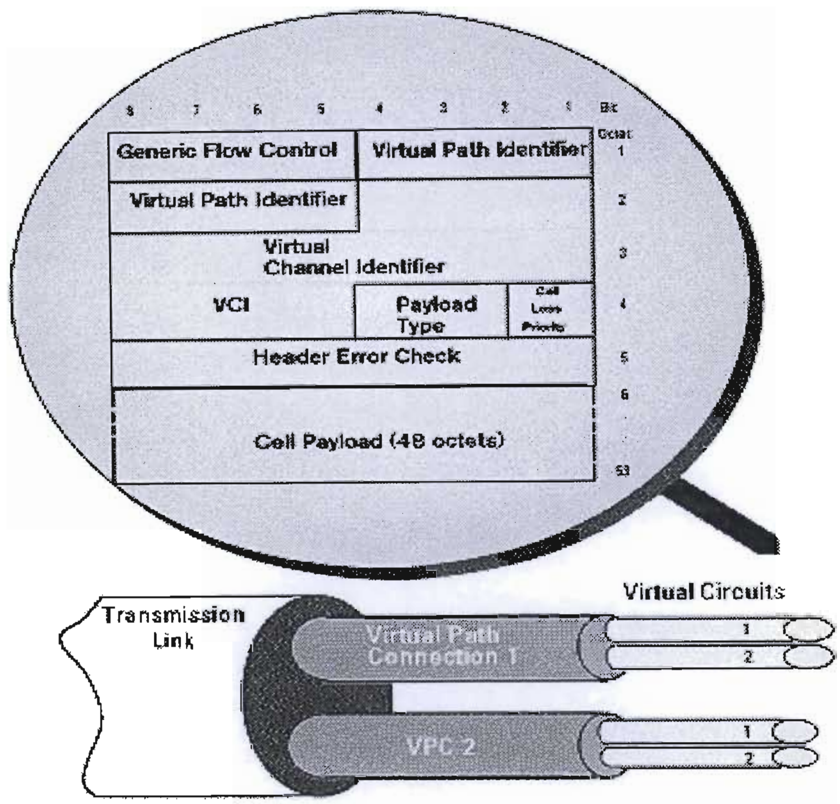

Figure 22: Fixed –Length Cells

ATM is connection oriented. Organizing different streams of traffic in separate cells allows the user to specify the resources required and allows the network to allocate resources based on these needs. Multiplexing multiple streams of traffic on each physical facility (between the end user and the network or between network switches) – combined with the ability to send the streams to many different destinations-enables cost savings through a reduction in the number of interfaces and facilities required to construct a network.

ATM standards defined two types of ATM connections: virtual path connections (VPCs), which contain virtual channel connections (VCCs). A virtual channel connection (or virtual circuit) is the basic unit, which carries a single stream of cells, in order, from user to user. A collection of virtual circuits can be bundled together into a virtual path connection. A virtual path connection can be created from end-to-end across an ATM network. In this case, the ATM network does not route cells belonging to a particular virtual circuit. All cells belonging to a particular virtual path are routed the same way through the ATM network, thus resulting in faster recovery in case of major failures.

An ATM network also uses virtual paths internally for the purpose of bundling virtual circuits together between switches. Two ATM switches may have many different virtual channel connections between them, belonging to different users. These can be bundled by the two ATM switches into a virtual path connection. This can serve the purposes of a virtual trunk between the two switches. This virtual trunk can then be handled as a single entity by; perhaps, multiple intermediate virtual path cross connects between the two virtual circuit switches.

Virtual circuits can be statically configured as permanent virtual circuits (PVCs) or dynamically controlled via signaling as switched virtual circuits (SVCs). They can also be point-to-point or point –to multipoint, thus providing a rich set of service capabilities. SVCs are the preferred mode of operation because they can be dynamically established, thus minimizing reconfiguration complexity.

3.9 ATM classes of services

ATM is connection oriented and allows the user to specify the resources required on a per-connection basis (per SVC) dynamically. There are the five classes of service defined for ATM (as per ATM Forum UNI 4.0 specification) [7]. The QoS parameters for these service classes are summarized in Table 2.

SERVICE CLASS	QUALITY OF SERVICE PARAMETER
Constant bit rate (CBR)	This class is used for emulating circuit switching. The cell rate is constant with time. CBR applications are quite sensitive to cell-delay variation. Examples of applications that can use CBR are telephone traffic (i.e., nx64 kbps), videoconferencing, and television.
Variable bit rate – non-real time (VBR-NRT)	This class allows users to send traffic at a rate that varies with time depending on the availability of user information. Statistical multiplexing is provided to make optimum use of network resources. Multimedia e-mail is an example of VBR-NRT.
Variable bit rate –real time (VBR-RT)	This class is similar to VBR-NRT but is designed for applications that are sensitive to cell-delay variation. Examples for real-time VBR are voice with speech activity detection (SAD) and interactive compressed video.
Available bit rate (ABR)	This class of ATM services provides rate-based flow control and is aimed at data traffic such as file transfer and e-mail. Although the standard does not require the cell transfer delay and cell–loss ratio to be guaranteed or minimized, it is desirable for switches to minimize delay and loss as much as possible. Depending upon the state of congestion in the network, the source is required to control its rate. The users are allowed to declare a minimum cell rate, which is guaranteed to the connection by the network.
Unspecified bit rate (UBR)	This class is the catch-all, other class and is widely used today for TCP/IP

Table 2: ATM Service Classes

3.10 ATM and Multicasting

ATM requires some form of multicast capability. AAL5 (which is the most common AAL for data) currently does not support interleaving packets, so it does not support multicasting.

If a leaf node transmitted a packet onto an AAL5 connection, the packet could be intermixed with other packets and be improperly reassembled. Three methods have been proposed for solving this problem: VP multicasting, multicast server, and overlaid point-to-multipoint connection.

Under the first solution, a multipoint-to-multipoint VP links all nodes in the multicast group, and each node is given a unique VCI value within the VP. Interleaved packets hence can be identified by the unique VCI value of the source. Unfortunately, this mechanism would require a protocol to uniquely allocate VCI values to nodes, and such a protocol mechanism currently does not exist. It is also unclear whether current SAR devices could easily support such a mode of operation.

A multicast server is another potential solution to the problem of multicasting over an ATM network. In this scenario, all nodes wanting to transmit onto a multicast group set up a point-to-point connection with an external device known as a multicast server (perhaps better described as a resequencer or serializer). The multicast server, in turn, is connected to all nodes wanting to receive the multicast packets through a point-to-multipoint connection. The multicast server receives packets across the point-to-point connections and then retransmits them across the point-to-multipoint connection but only after ensuring that the packets are serialized (that is, one packet is fully transmitted before the next is sent). In this way, cell interleaving is precluded.

An overlaid point-to-multipoint connection is the third potential solution to the problem of multicasting over an ATM network. In this scenario, all nodes in the multicast group establish a point-to-multipoint connection with each other node in the group and, in turn, become leaves in the equivalent connections of all other nodes. Hence, all nodes can both transmit to and receive from all other nodes. This solution requires each node to maintain a connection for each transmitting member of the group, whereas the multicast-server mechanism requires only two connections. This type of connection also requires a registration process for informing the nodes that join a group of the other nodes in the group so that the new nodes can form the point-to-multipoint connection. The other nodes must know about the new node so that they can add the new node to their own point-to-multipoint connections. The multicast-server mechanism is more scalable in terms of connection resources but has the problem of requiring a centralized resequencer, which are both a potential bottleneck and a single point of failure [7].

3.11 ATM Quality of Service

ATM supports QoS guarantees comprising traffic contract, traffic shaping, and traffic policing.

A traffic contract specifies an envelope that describes the intended data flow. This envelope specifies values for peak bandwidth, average sustained bandwidth, and burst size, among others. When an ATM end system connects to an ATM network, it enters a contract with the network, based on QoS parameters.

Traffic shaping is the use of queues to constrain data bursts, limit peak data rate, and smooth jitters so that traffic will fit within the promised envelope. ATM devices are responsible for adhering to the contract by means of traffic shaping. ATM switches can use traffic policing to enforce the contract. The switch can measure the actual traffic flow and compare it against the agreed-upon traffic envelope. If the switch finds that traffic is outside of the agreed-upon parameters, it can set the cell-loss priority (CLP) bit of the offending cells. Setting the CLP bit makes the cell discard eligible, which means that any switch handling the cell is allowed to drop the cell during periods of congestion [7].

3.12 ATM Traffic Management

Broadly speaking, the objectives of ATM traffic management are to deliver quality-of-service (QoS) guarantees for the multimedia applications and provide overall optimization of the network resources. Meeting these objectives enables enhanced classes of service and offers the potential for service differentiation and increased revenues, while simplifying network operations and reducing network cost.

ATM traffic management and its various functions can be categorized into three distinct element based on timing requirements.

Firstly, are nodal-level controls that operate in real time? These are implemented in hardware and include queues supporting different loss and delay priorities, fairly weighted queue-servicing algorithms, and rate controls that provide policing and traffic shaping. Well-designed switch-buffer architectures and capacity are critical to effective network operation. Actual network experience and simulation has indicated that large, dynamically allocated output buffers provide the flexibility to offer the best price performance for supporting various traffic types with guarantee QoS. Dynamically managing buffer space means that all shared buffer space is flexibly allocated to VCs on an as-need basis. Additionally, per virtual connection (VC) queuing enables traffic shaping, and early and partial packet-level discard have been shown to improve network performance significantly.

Secondly, network-level controls operate in near real time. These are typically, but not exclusively, implemented in software including connection admission control (CAC) for new connections, network routing and rerouting systems, and flow-control-rate adaptation schemes. Network-level controls are the heart of any traffic-management system. Connection admission controls support sophisticated equivalent-bandwidth algorithms with a high degree of configuration flexibility, based on the cell rate for CBR VCs, average cell rate plus a configurable increment for VBR VCs, and minimum cell rate for ABR VCs. Dynamic class-of-service routing standards define support for fully distributed link-state routing protocols, auto-reconfiguration on failure and on congestion, and dynamic load spreading on trunk groups.

Flow control involves adjusting the cell rate of the source in response to congestion conditions and requires the implementation of closed loop congestion mechanisms. This does not apply to CBR traffic. For VBR and UBR traffic, flow control is left as a CPE function. With ABR, resources management (RM) cells are defined, which allow signaling of the explicit rate to be used by traffic sources. This is termed rate-based flow control. ABR is targeted at those applications that do not have fixed or predictable bandwidth requirements and require access to any spare bandwidth as quickly as possible while experiencing very low cell loss. This allows network operators to maximize the bandwidth utilization of their network and sell spare capacity to users at a substantial discount while still providing QoS guarantees. To enhance the effectiveness of network-resource utilization, the ABR standard provides for end-to-end, segment-by-segment, and hop-by-hop service adaptation. [15]

Thirdly, network engineering capacities operating in non-real time support data collection, configuration management, and planning tools.

3.13 ATM Application

ATM technologies, standards, and services are being applied in a wide range of networking environments, as described briefly below (see figure 23)

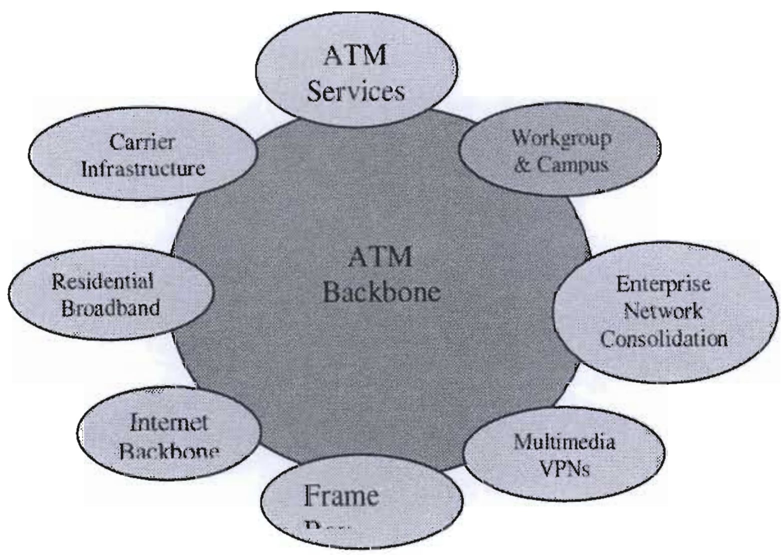

Figure 23: ATM Technologies, Standards, and Services

- **ATM services** _ Services providers globally are introducing or already offering ATM services to their business users.
- **ATM workgroup and campus networks** _ Enterprise users are deploying ATM campus networks based on the ATM LANE standards. Workgroup ATM is more of a niche market with the wide acceptance of switched-Ethernet desktop technologies.
- **ATM Enterprise network consolidation** _ A new class of product has evolved as an ATM multimedia network-consolidation vehicle. It is called an ATM enterprise network switch (ENS). A full-featured ATM ENS offers a broad range of in-building (e.g., video, voice, LAN, and ATM) and wide area interfaces (e.g., leased line, circuit switched, frame relay, and ATM at narrowband broadband

speeds) and supports ATM switching, voice networking, frame relay SVCs, and integrated multiprotocol routing.

- **Multimedia virtual private networks and managed services** _ Services providers are building in their ATM networks to offer a broad range of services. Examples include managed ATM, LAN, voice and video services (these being provided on a per-application basis, typically including customer-located equipment and offered on an end-to-end basis), and full-service virtual private-networking capabilities (these including integrated multimedia access and network management).
- **Frame relay backbones** _ Frame-relay service providers are deploying ATM backbones to meet the rapid growth of their frame relay services to use as a networking infrastructure for a range of data services and to enable frame relay to ATM service interworking services.
- **Internet backbones** _ Internet service providers are likewise deploying ATM backbones to meet the rapid growth of their frame-relay services, to use as a networking infrastructure for a range of data services, and to enable Internet class-of-service offerings and virtual private Internet services.

3.14 Advantages of ATM

The ATM has the following advantages.

1. Universal switching standard

Companies can set a connection to any location to transmit any type of information on demand.

2. Full support of multimedia

ATM provides communication at circuit speeds greater than 45MB and DS3.

3. Single network access

It handles voice, data and imaging transmission over multiple switch connection to many users via a single access to an ATM network.

4. Reduction in network delay

The use of short, fixed-length packets or "cells" which create a greater pipe lining and achieves greater efficiency over longer segments.

5. True bandwidth-on-demand

Users can dynamically allocate bandwidth required within a given call.

6. Optimization of network resource

It enables multiple users to share bandwidth more efficiency.

7. Technical longevity

It has been carefully designed to provide ultimate flexibility to support future application that may not be evident today.

8. Service integration

ATM enables the integration of a variety of services including ISDN, X.25 and Frame Relay on one network with a single mode of transmission and switching

3.15 Disadvantages of ATM

On the other hand, the following disadvantages have been identified.

1. Large overhead of cell header (5 bytes per cell)
2. Complex mechanisms for achieving QoS
3. Congestion may cause cell losses [8]

3.16 ATM deployment in South Africa

Telecommunication companies in South Africa, in particular Telkom started to deploy ATM switches in 1998/1999. The figure 24 below shows the layout of Telkom SA for its ATM network deployment. They put ATM switches in the big cities across South Africa, which resulted to an ATM ring. The most clients that Telkom gives services using ATM are corporate client.

Many specialized networks exist today in Telkom from the large voice network switches to frame relay routers and hubs. All offer different services and features and serve a host of various users. Each of these networks are managed individually and has unused capacity. ATM switching (Asynchronous Transfer Mode) is capable of offering voice, video, data, and LAN traffic on the same switching equipment. It manages the bandwidth better to allow a more dynamic bandwidth allocation. With a fully deployed ATM network in place, it can reduce the number of existing networks and offer new services. It also reduces network administration and makes network maintenance simpler. Taking all the existing networks and having one network able to do the work of many reduces cost to keep all those different networks operational. All this leads to better service for the customer [16].

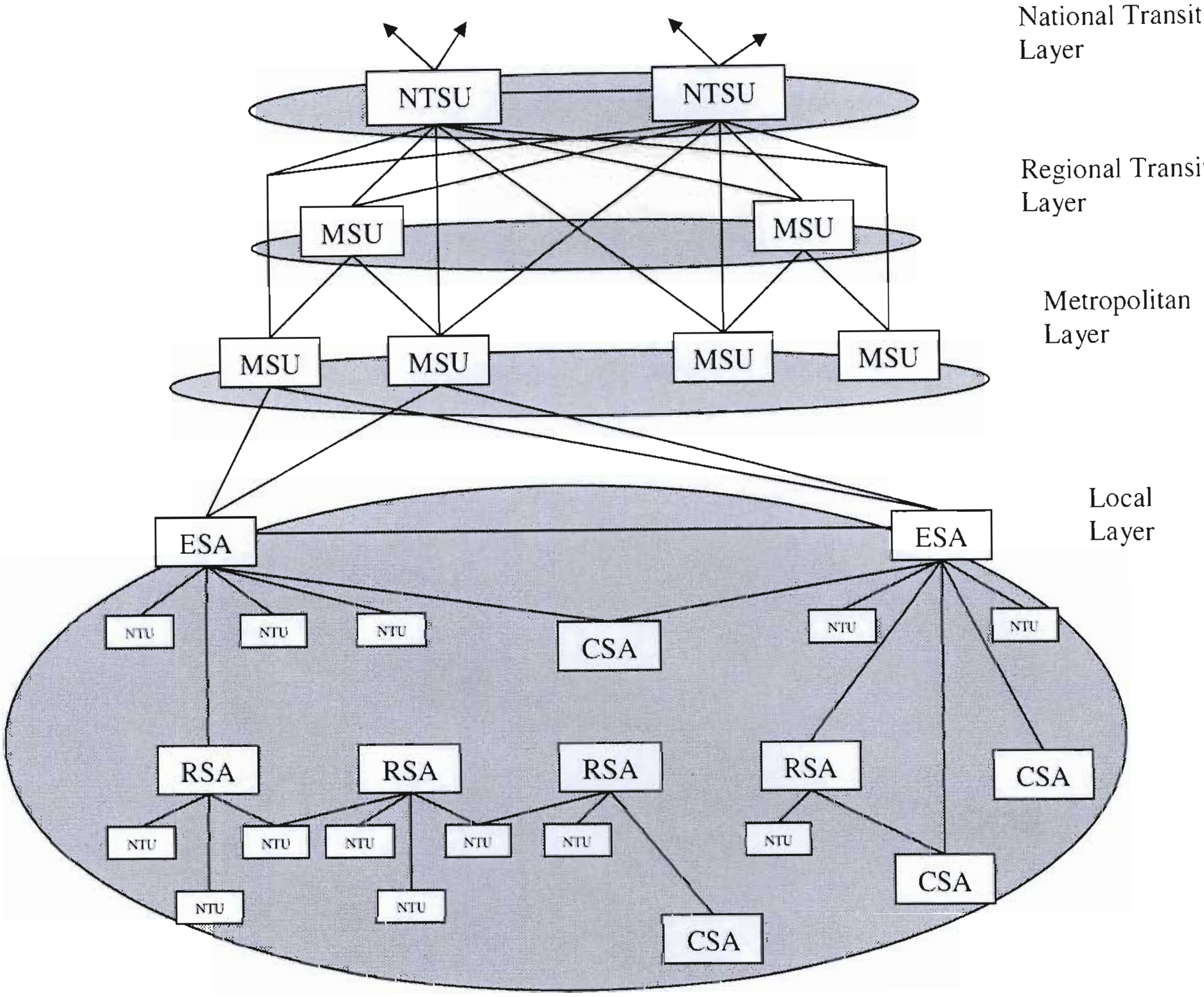

Figure 24: Telkom's ATM Network Architecture

Telkom's ATM's network will consist of 4 different layers. The four different layers will be:

- National Transit Layer
- Regional Transit Layer
- Metropolitan Layer
- Local Layer

3.17 Voice over IP (VoIP)

VoIP stands for Voice over Internet Protocol. As the term says VoIP tries to let go voice (mainly human) through IP packets and, in definitive through Internet. VoIP can use accelerating hardware to achieve this purpose and can also be used in a PC environment.

3.17.1 How does it work?

Many years ago it was discovered that sending a signal to a remote destination could have be done also in a digital fashion: before sending it, it has to be digitalized, with an ADC (analog to digital converter), transmit it, and at the end transform it again in analog format with DAC (digital to analog converter) to use it.

VoIP works like that, digitalizing voice in data packets, sending them and reconverting them in voice at destination.
Digital format can be better controlled: can be compress it, route it, convert it to a new better format, and so on; also it was seen that digital signal is more noise tolerant than the analog one (see GSM vs TACS).
TCP/IP networks are made of IP packets containing a header (to control communication) and a payload to transport data: VoIP use it to go across the network and come to destination.

Voice (source) - - ADC - - - - Internet - - - DAC - - Voice (destination)

3.17.2 What are the advantages using VoIP rather PSTN.

When you are using PSTN line, you typically pay for time used to a PSTN line manager company: more time you stay at phone and more you'll pay. In addition you couldn't talk with other that one person at a time.
In opposite with VoIP mechanism you can talk all the time with every person you want (the needed is that other person is also connected to Internet at the same time), as far as

you want (money independent) and, in addition, you can talk with many people at the same time.

If you're still not persuaded you can consider that, at the same time, you can exchange data with people are you talking with, sending images, graphs and videos [17].

Chapter Four

Rural Area Survey and Analysis

4.1 Introduction

The issue of cost effective telecommunication service provision in rural African countries has been receiving attention for a very long time in various quarters ranging from telecommunication researchers, telecommunication companies, governments and other stakeholders. There have been a lot of assumptions made about rural areas, especially in terms of economical viability; specifically, it is generally believed that people from rural areas are considered to be poor people; people who cannot afford to contribute to their development. It is true that poor people are found in rural areas, but these days evolving development and Government infrastructures have changed some of these notions. It is for that reason that an actual survey studying economical viability was done in the rural areas.

Recent developments in the deregulation of the telecommunication market along with formulation of policies and ICT strategies for socio-economic change in most African countries have not yet produced substantial results in terms of improvements in tele-densities in areas outside large cities and business centers. Table 1 shows the population densities in South Africa as ranging from 2 to 365 people per square kilometer. The lower the population density the more difficult and expensive it becomes to provide telecommunications infrastructure and services. There are some key reasons for adopting a data- centric area- wide network. Firstly, any modern network will be required to support a wide range of services including voice, data, e-mail and digital video. Secondly, in the African situation, the network will support large populations of infrequent users, spaced over a large geographical area. The economic viability of the service will consequently depend on the ability to effectively share the bandwidth and network equipment [14].

As part of the telecommunication market deregulation, a number of countries have promulgated specific policies to encourage investment in the telecommunication sector. For example, South Africa is in the process of licensing small, medium and micro enterprises (SMMEs) to specifically roll out networks in areas of the country with tele-density lower than 5% [1].

The question remains: what suitable technology is to be adopted to enable companies to offer competitive but affordable tariff structures and remain economically viable? It is anticipated that some service providers will deploy ATM technologies in the low tele-density areas for the following reasons (see chapter 3 on ATM advantages):

1. Technical longevity: It has been carefully designed to provide ultimate flexibility to support future applications that may not be evident today.
2. Reduction in network delay: The use of short, fixed-length packets or "cells" which create a greater pipe lining and achieving greater efficiency over longer segments.
3. Single network access: It handles voice, data and imaging transmission over multiple switch connection to many users via a single access to an ATM network [15].

Some service providers have anticipated deploying VOIP technologies. This could be seen as a preliminary step in a wider deregulation of VOIP as its use has the potential to reduce call rates especially for long distance calls which at the moment are quite expensive. VOIP networking can deliver low call rates compared to the traditional voice communication for a number of reasons, such as:

1. Data networking equipment is easily available at competitive pricing.
2. All links carry multiple voice and data packets on a per link basis enabling higher channel transmission resources.
3. The network can be modeled along the lines of the internet by interconnecting area-wide local networks called sub-nets in a flat topological structure with

interconnections running at different rates depending on the local resources and service requirements.

4. Packets are accepted even when network is busy. Delivery may slow down, but for delay sensitive services such as voice, priorities or other special provisions can be used. For example, we could segment wide area networks for different market segments in Africa based on population densities and proximity to a large business and commercial centers.

4.2 Traffic and Technology Statistics in KZN

In order to plan for appropriate communication technologies to be deployed in the rural areas, it is vital to study the traffic trends both originating from the rural area and terminating at the same time. This section therefore focuses on this, based on unpublished data from Telkom SA, for 2004/2005.

Traditionally, to be able to deploy any kind of technology to any kind of an area, one has to know the existing technologies, whether they efficient or not and the demand forecast for the particular technology. It is for those reasons that we have try to identify the rural KZN into different kind of zones. In this work, three zones with different penetrations have been identified: these are Ulundi, Nkandla and Babanango zones. Ulundi is an area under the Empangeni district and is located in the North-eastern region of KZN. Ulundi has been identified because it has governmental offices, some schools that utilize computers and a large community hospital, but the fact remains that it is surrounded by rural communities. Ulundi Central has got a telecommunication access point called the digital secondary switching unit (DSSU) which the main Exchange. Ulundi has other small exchanges at Ulundi North and Ulundi South.

The traffic pattern for the originating and terminating traffic has been generated. This traffic will help in terms of understanding and analyzing the need for the deployment of ATM in rural areas of KZN. As highlighted before the traffic is different among these zones simply because the capacity is also different.

4.2.1 Ulundi Central (NULU) Traffic Statistics

Figures 25 below indicate the originating, terminating and GSM traffic at Ulundi Central Exchange.

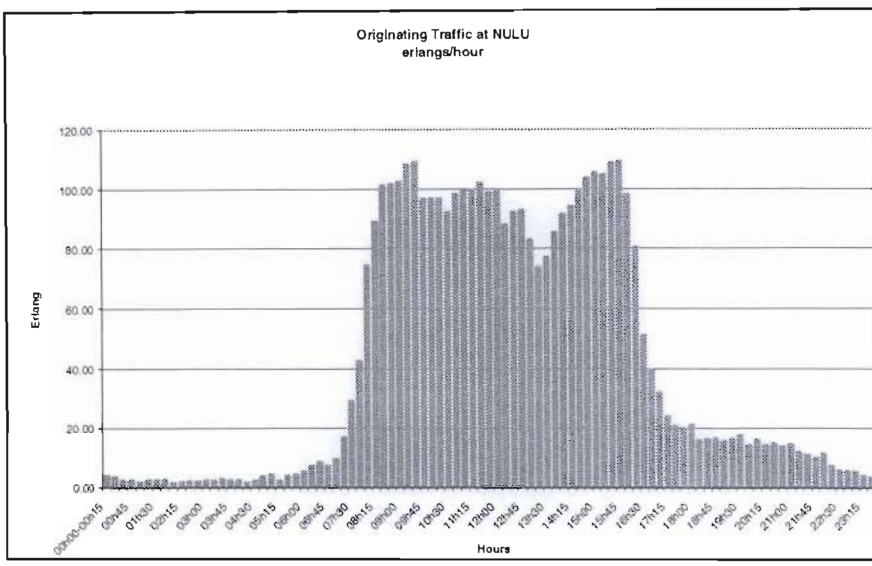

Figure 25a: Typical Pattern of originating traffic at Ulundi Central Exchange

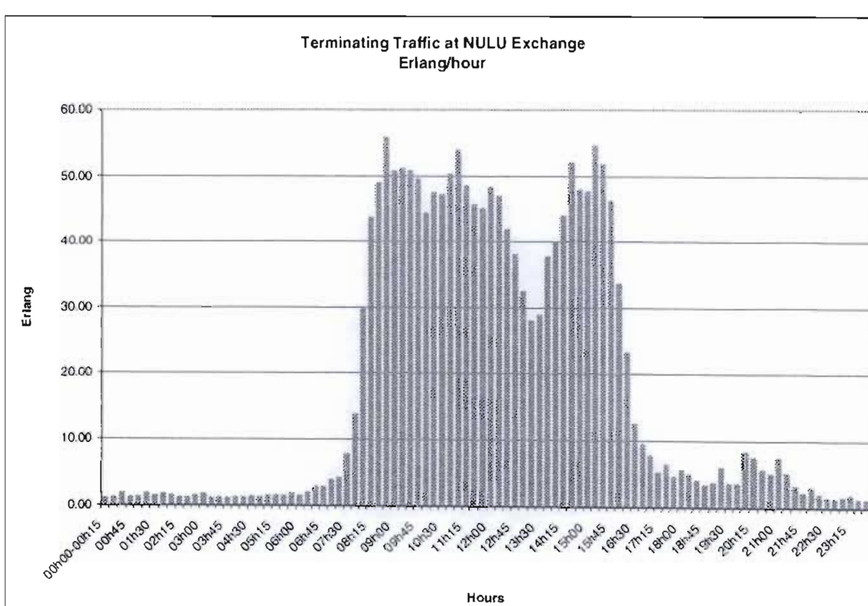

Figure 25b: Typical pattern of terminating traffic at Ulundi Central Exchange

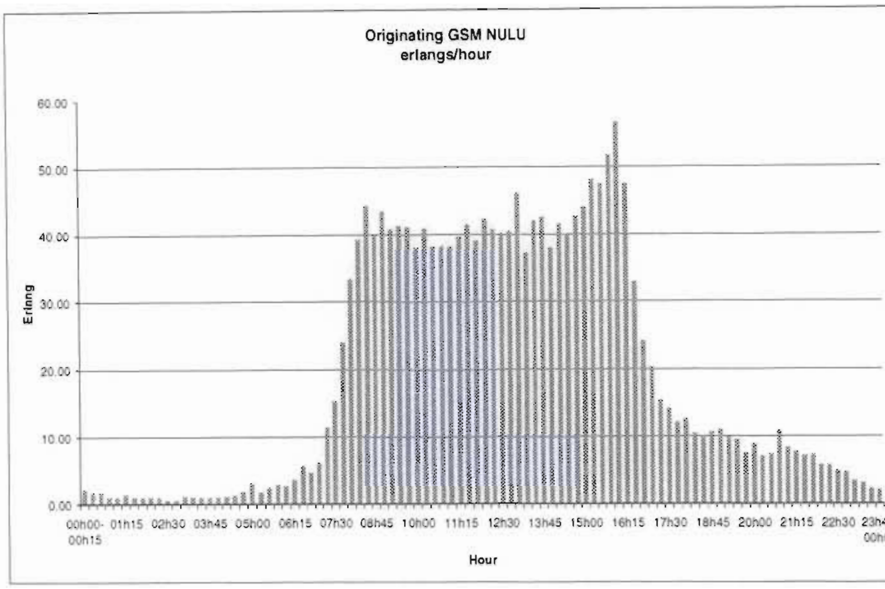

Figure 25c: Typical pattern of originating GSM traffic at Ulundi Central Exchange

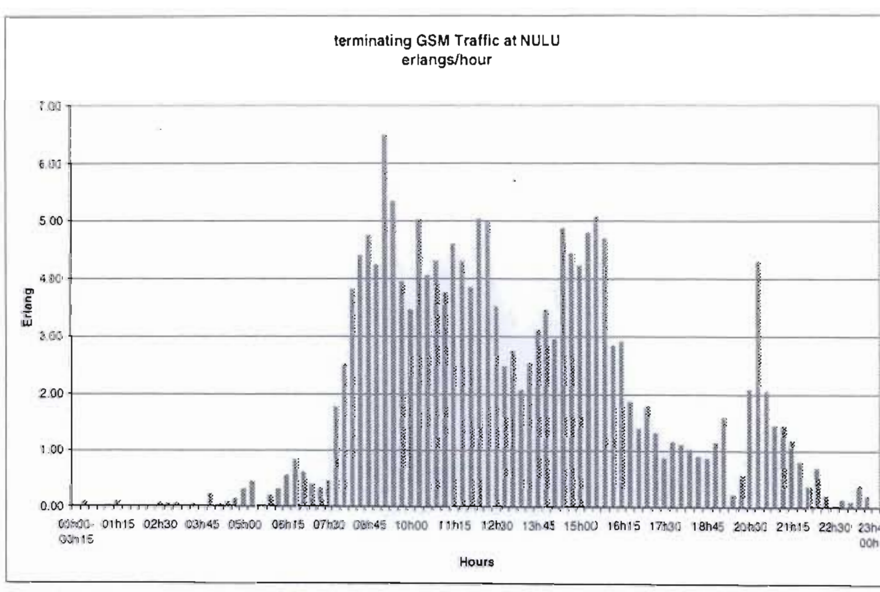

Figure 25d: Typical pattern of terminating GSM traffic at Ulundi Central Exchange

It is observed that there is higher originating than terminating GSM traffic, between 08H00 and 16H00 hrs, with a ratio of almost 10:1. For non-GSM traffic, the ratio is 2:1.

4.2.2 Ulundi South (NULZ) traffic statistics

Ulundi South Exchange serves the southern rural part of Ulundi. Figures 26 show the originating, terminating and GSM traffic characteristics in Ulundi South exchange. Note that this exchange does not have an ATM node.

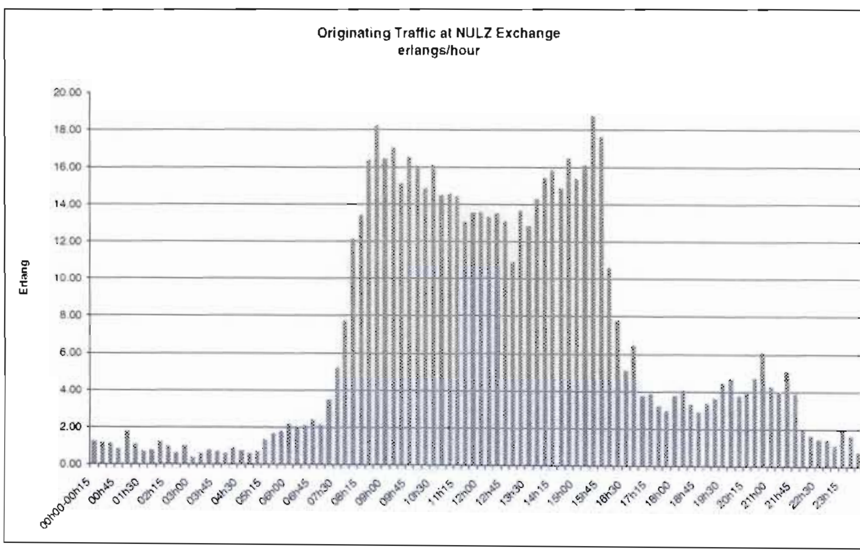

Figure 26a: Typical Pattern of originating traffic at Ulundi South Exchange

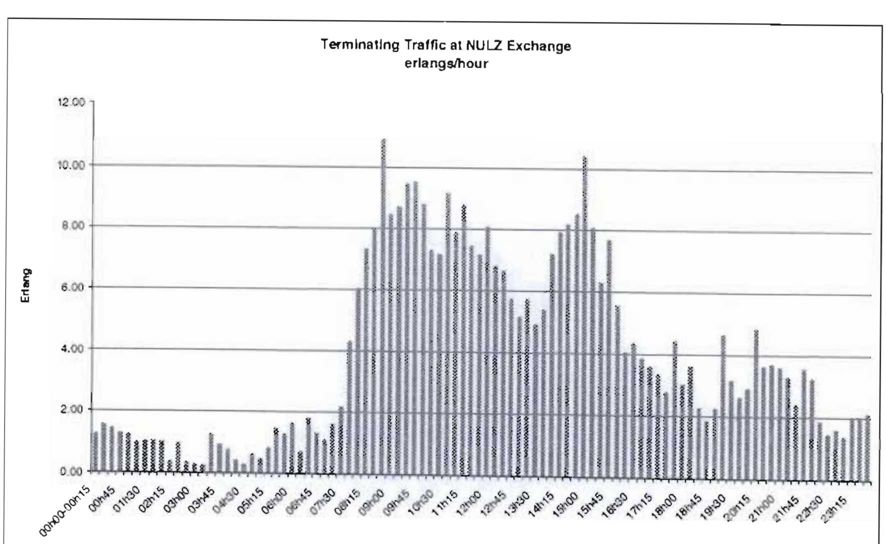

Figure 26b: Typical pattern of terminating traffic at Ulundi South Exchange

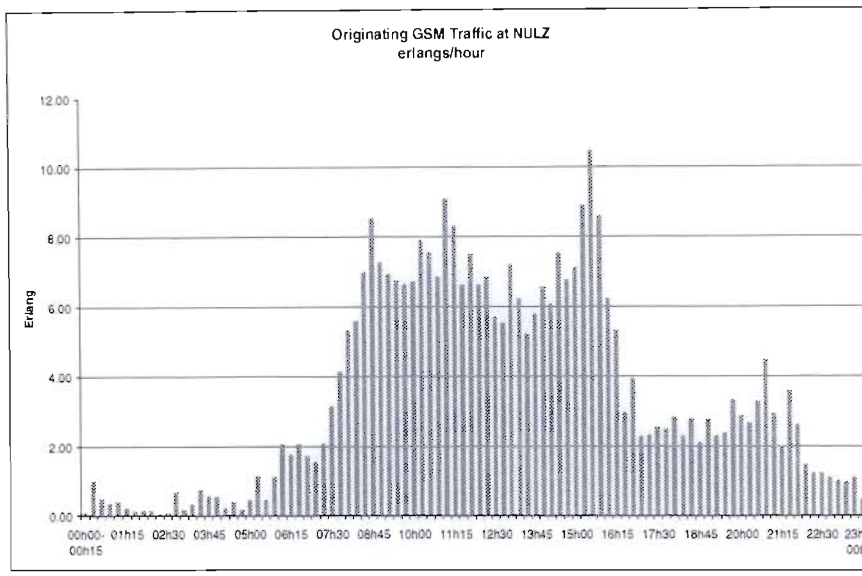

Figure 26c: Typical pattern of GSM originating traffic at Ulundi South Exchange

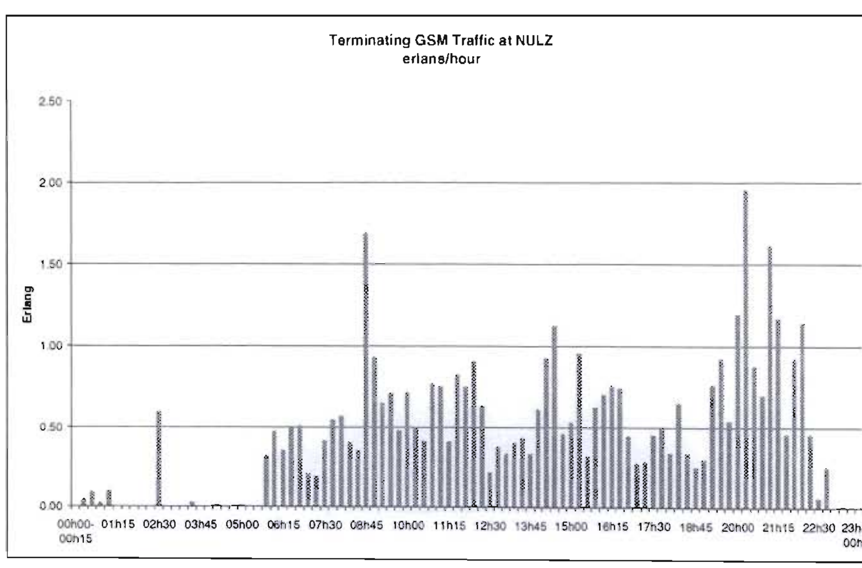

Figure 26d: Typical pattern of GSM terminating traffic at Ulundi South Exchange

One again observes higher originating than terminating GSM traffic, especially between 08H00am and 16H00pm, with a ratio of almost 7:1. On the other hand, for non-GSM traffic, the ratio of originating to terminating traffic is about 2:1.

4.2.3 Ulundi North (NULN) traffic statistics

Ulundi North Exchange serves the northern rural part of Ulundi. Figures 27 show the originating, terminating and GSM traffic characteristics in Ulundi North exchange. Note that this exchange also does not have an ATM node.

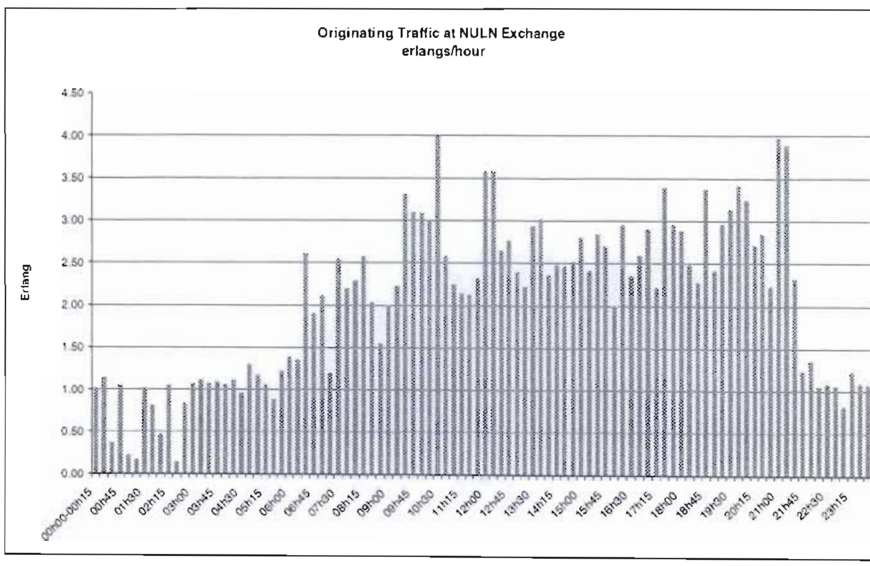

Figure 27a: Typical Pattern of originating traffic at Ulundi North Exchange

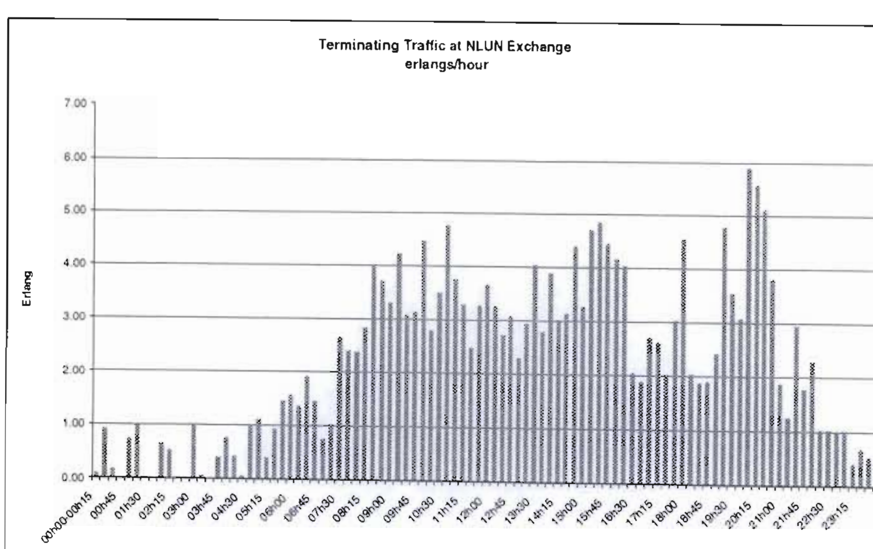

Figure 27b: Typical pattern of terminating traffic at Ulundi North Exchange

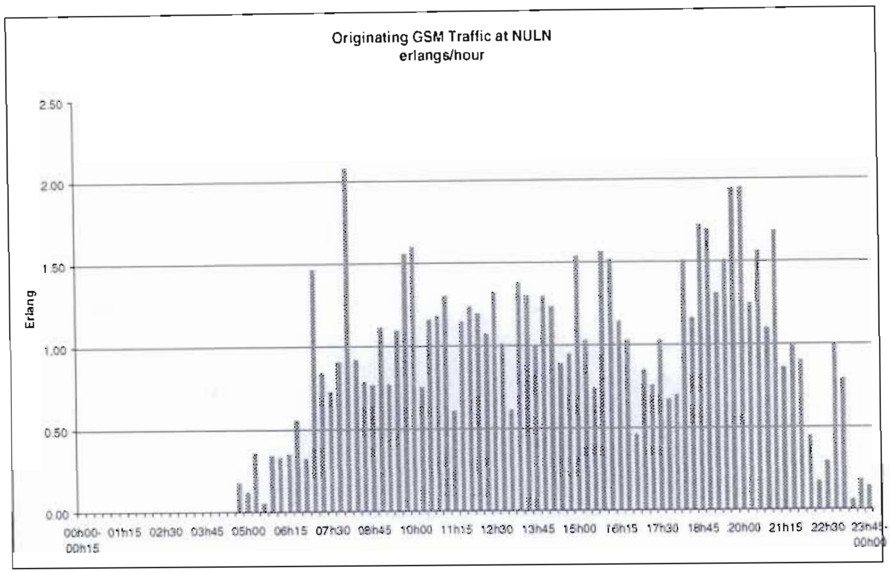

Figure 27c: Typical pattern of GSM originating traffic at Ulundi North Exchange

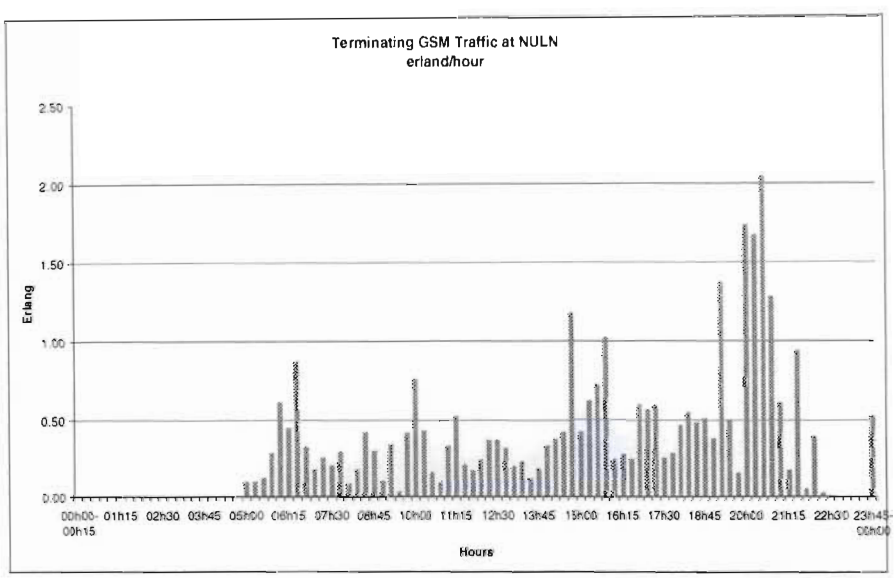

Figure 27d: Typical pattern of GSM terminating traffic at Ulundi North Exchange

One here observes slightly higher originating than terminating GSM traffic, especially between 08H00am and 16H00pm, with a ratio of almost 3:1. On the other hand, for non-GSM traffic, the ratio of originating to terminating traffic is now about par 1:1.

4.2.4 Nkandla (NNKL) traffic statistics

Nkandla is also a typical rural outpost that is situated in the central KwaZulu Natal. Nkandla is hilly with a sprinkle of vegetation. It has an estimated area of 35 x 40 square kilometres and a population of about 250 000 people. Most residents do not have access to telecommunication facilities; they therefore have to go to nearby centres where the services are available. Figures 28 below show the originating, terminating and GSM traffic at Nkandla Exchange.

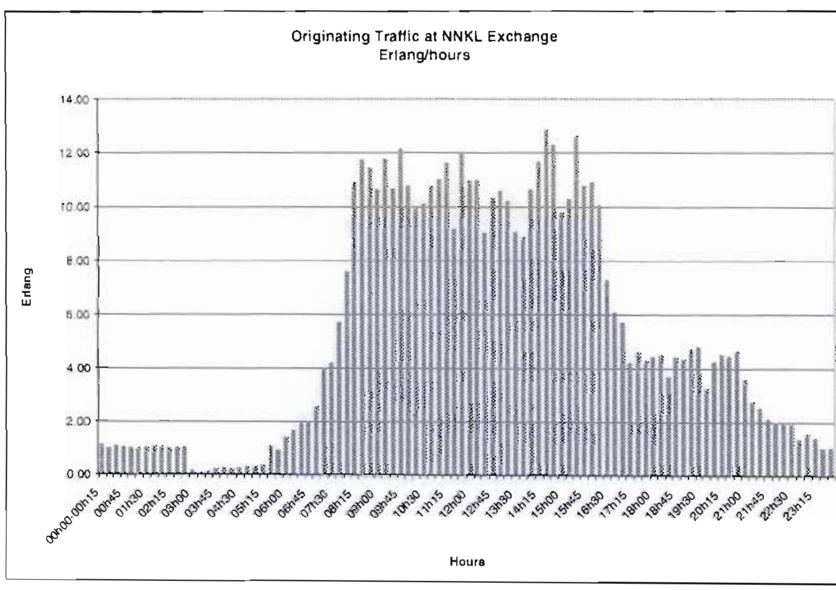

Figure 28a: Typical pattern of originating traffic at Nkandla Exchange

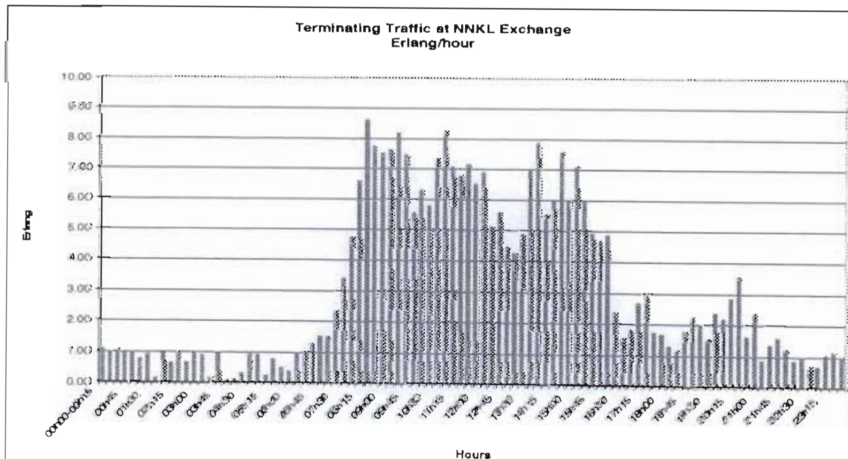

Figure 28b: Typical pattern of termination traffic at Nkandla Exchange

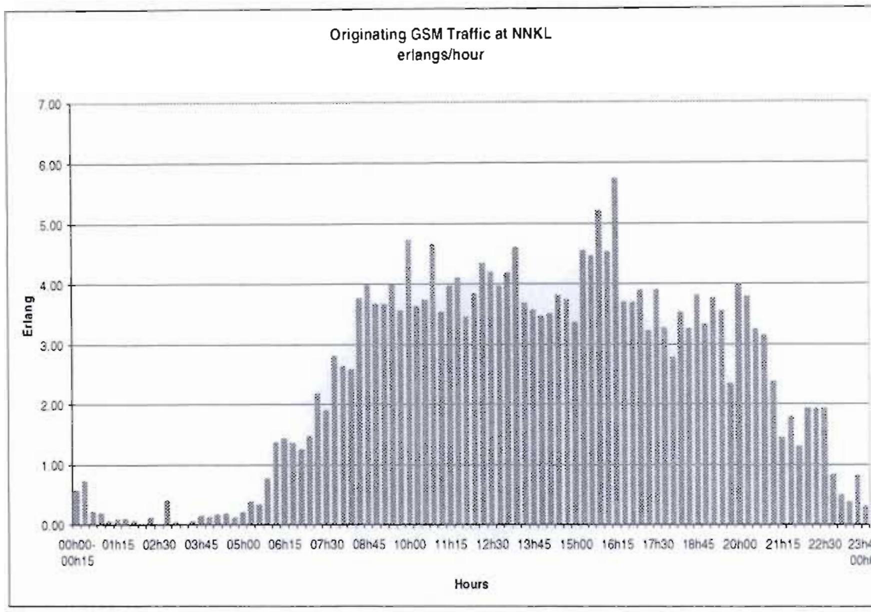

Figure 28c: Typical pattern of originating GSM traffic at Nkandla Exchange

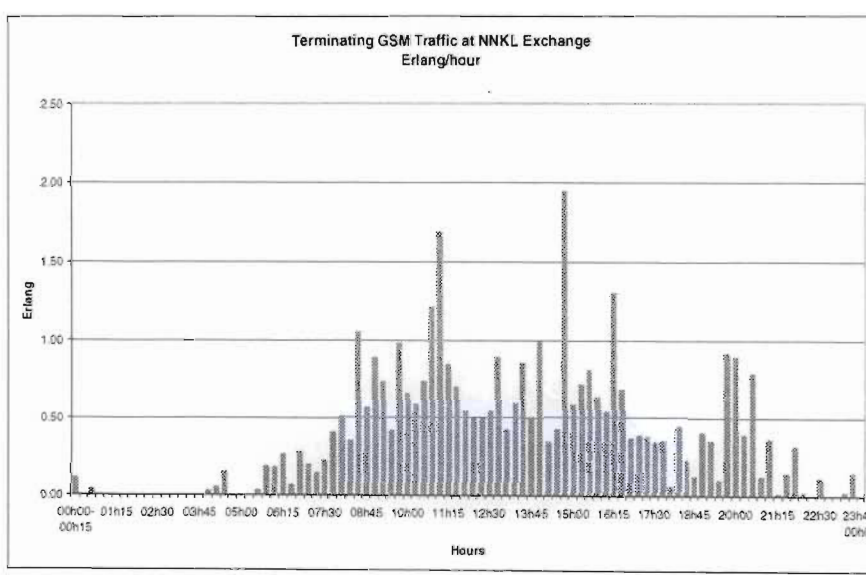

Figure 26d: Typical pattern of terminating GSM traffic at Nkandla Exchange

Again, it is observed that the originating GSM traffic is higher than the terminating GSM traffic at Nkandla with the ratio of about 5:1 during the period 08H00am to 16H00pm. For the non-GSM traffic, the ratio of outgoing to incoming is about 2:1.

4.2.5 Babanango (NBAB) traffic statistics

Babanango is a rural area that is dominated by large-scale commercial farmers. It is situated about 45 km from Nkandla in Central KZN. This area is a hilly place with immense vegetation; it is thus very difficult to deploy telecommunication infrastructure, especially underground and overhead facilities like optic fiber and copper. Traditionally radio systems are a better solution for this type of terrain. Figures 29 below indicate the originating, terminating and GSM traffic at Babanango Exchange.

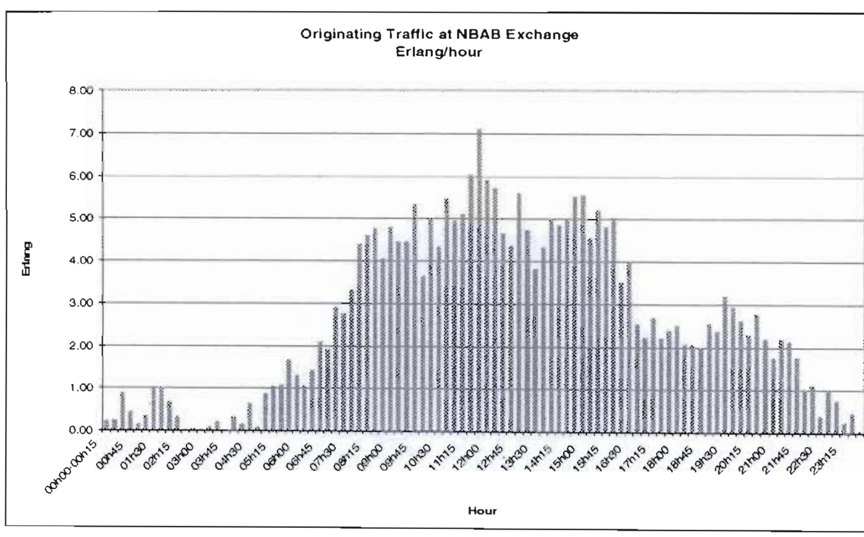

Figure 29a: Typical pattern of originating traffic at Babanango Exchange

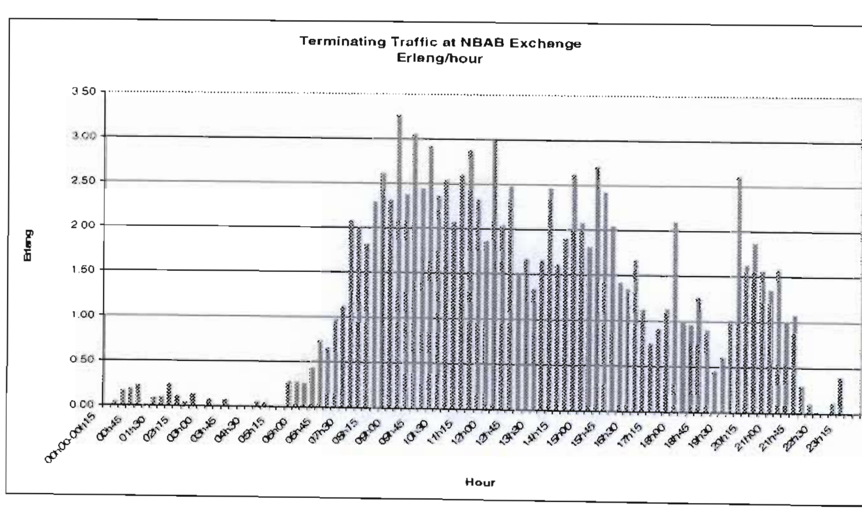

Figure 29b: Typical pattern of terminating traffic at Babanango Exchange

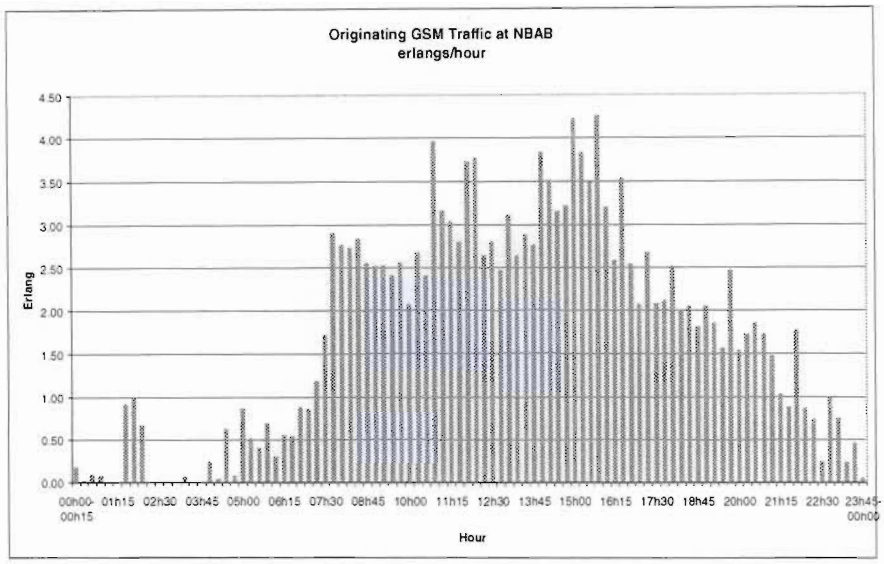

Figure 29c: Typical Pattern of originating GSM traffic at Babanango Exchange

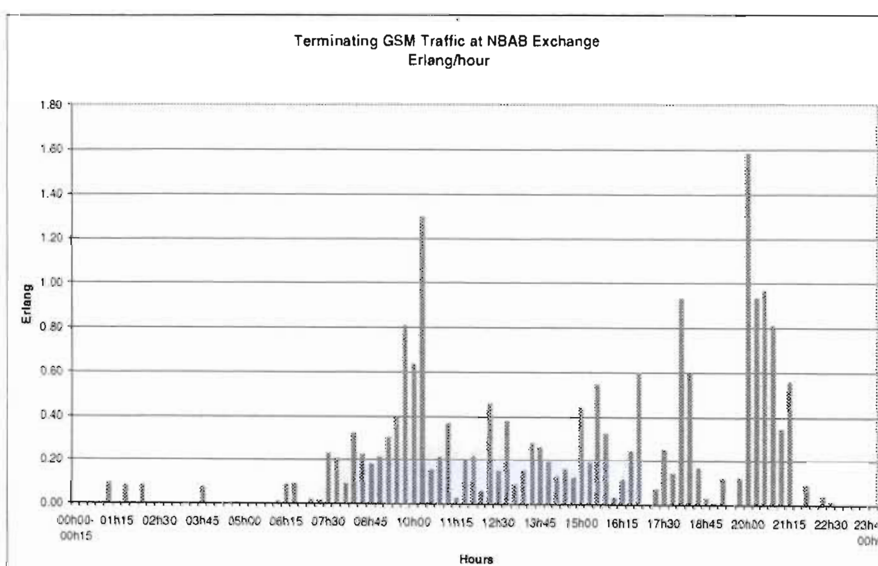

Figure 29d: Typical Pattern of terminating GSM traffic at Babanango Exchange

Again, it is observed that the originating GSM traffic is higher than the terminating GSM traffic at Babanango with a ratio of about 5:1 during the period 08H00am to 16H00pm. For the non-GSM traffic, the ratio of outgoing to incoming is again about 2:1.

4.2.6 Nqutu traffic statistics

We have also included the results that were physically obtained by the author through a survey at a place called Nqutu, which is not far from Nkandla and Babanango. Although the statistics are not as detailed as these other areas, the data obtained have been used to estimate the total average traffic. From the graph in Figure 30 it can be seen that the peak hour is from 13h00 to 14h00. At this time about 35 people were utilizing the phone, with an average holding time calculated to be 5.54 minutes.

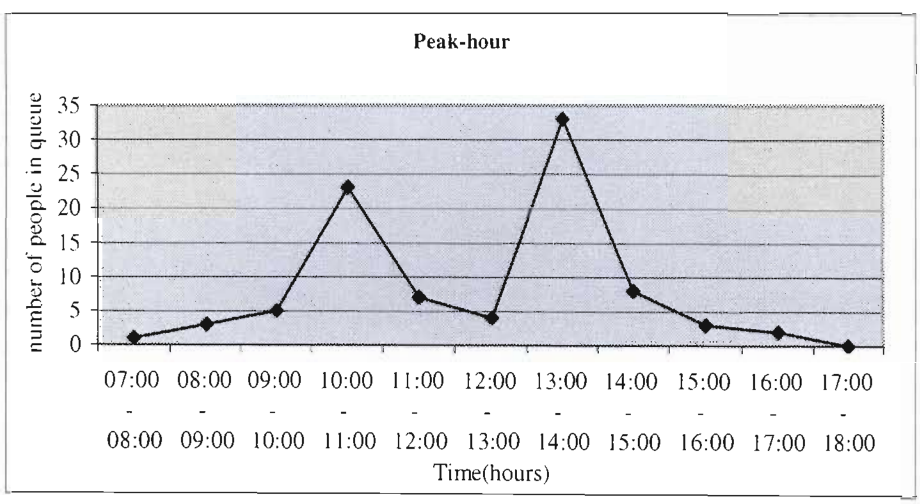

Figure 30: Typical daily traffic pattern in Nqutu

4.2.7 Five-Year Traffic Projection

The total forecast demand for the years 2005-to-2009 is displayed in Figure 31, for the five areas considered earlier. The figure shows a steady linear service demand growth at these areas over the five-year period - this is because of the projected development in terms of infrastructure, education sector, agriculture, and other areas of the economy. The detailed information for the forecast statistics is also shown in tables in Appendices.

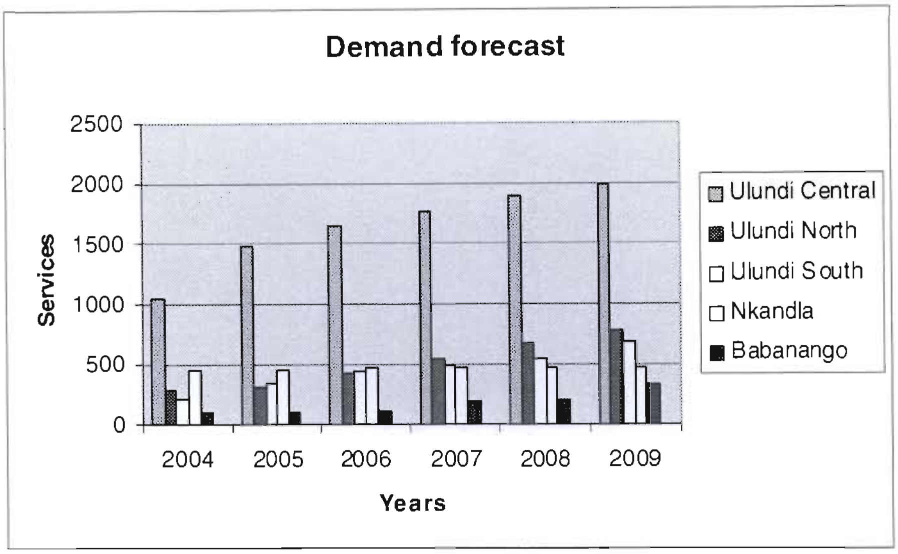

Figure 31: Typical telecommunication demand forecast for rural areas in KZN

(Source: Unpublished data, Telkom SA)

4.3 Further Projections for Measurements in Nqutu

The analysis that follows for Nqutu is due to the fact that a physical survey was actually done in this area by the author and the findings. The survey was undertaken to obtain some fine details with regard to rural subscriber tendencies. Figure 32 shows the average calls per month per person in total, which can also be calculated as shown below. We can obtain the average calls as follows.

$$\text{Average calls per month} = \sum_{i}^{N} X_i P_i$$

Where P_i is the probability of X_i calls.

X_i is the number of calls per month in range

$i = 1,2,3\ldots N$ where N is the size of range (here N= 13)

Therefore the average = 7.8606 calls per month/person ~ 8 calls per month/person

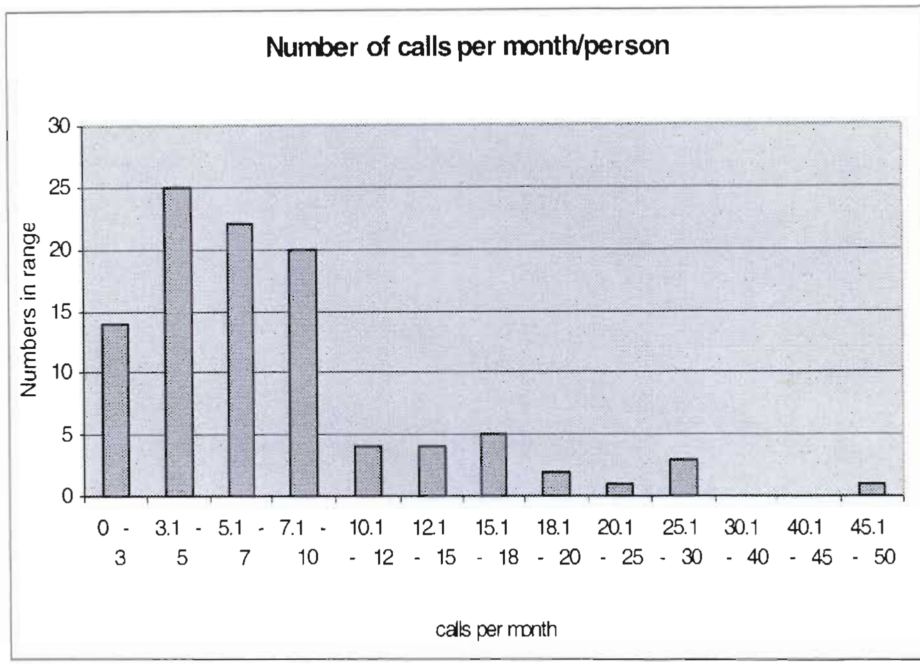

Figure 32: Number of calls per month/person

Using the same procedure used in Figure 32, one obtains the average minutes per call per person in this survey, based on Figure 33. That is,

Average minutes per call = 5.544554 minutes ~ 5.54 minutes per call

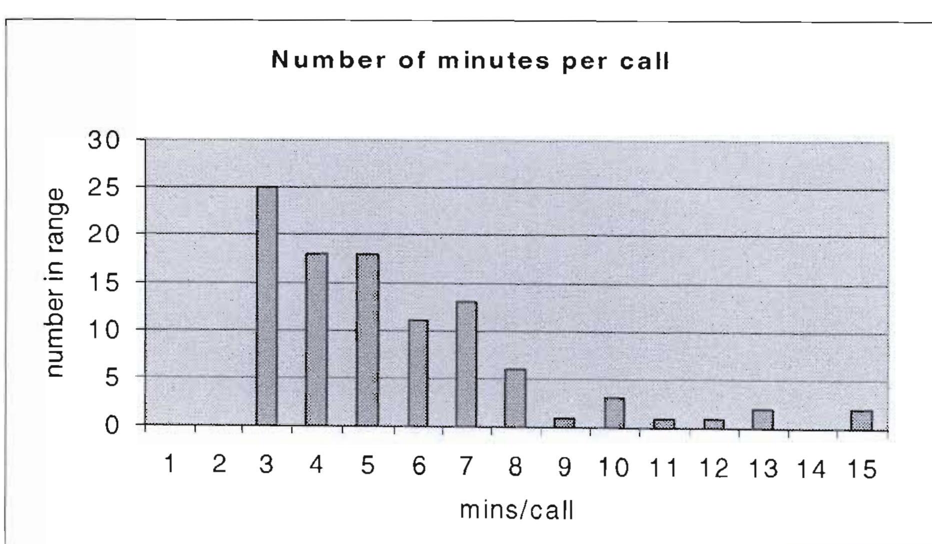

Figure 33: Number of minutes per call

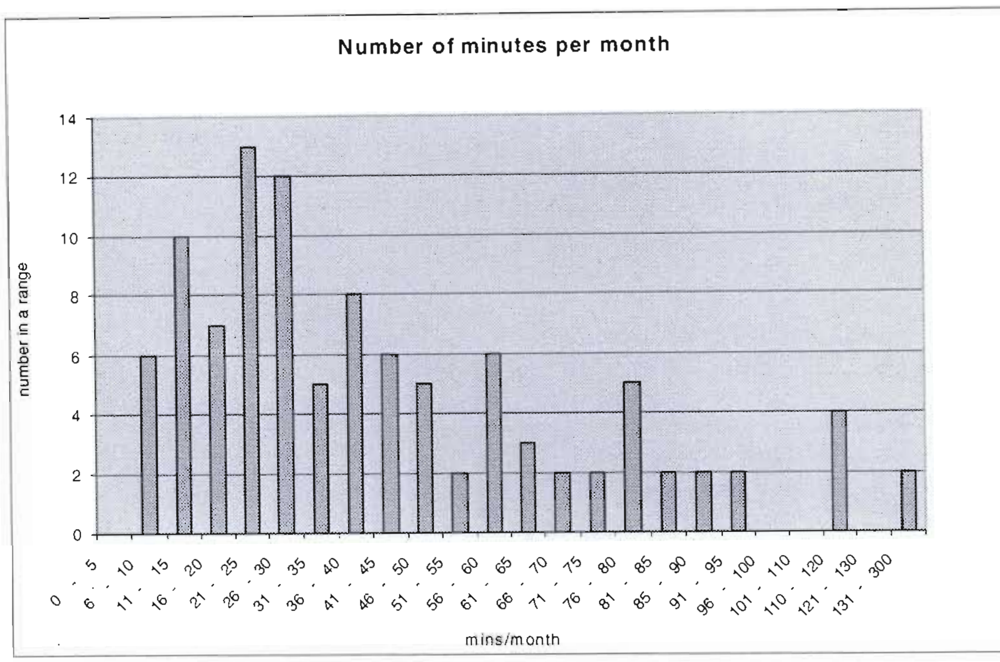

Figure 34: Number of minutes per month

Next, we obtain the call minutes per person per month, as shown in Figure 34. This becomes:

Average call minutes per month = 44.60577 minutes ≈ 45 minutes

Similarly, we analyze the average costs per call per person as shown in Figure 35. This becomes:

Average cost per call = 6.45099 R ~ R6.45[c]

Finally, since bills are paid monthly, the estimation for the economic projection is calculated on a monthly basis. The variation is displayed in Figure 36. Using the procedure used above, we have an estimated average cost per month per person. It means that the average amount that each person spends is:

Average monthly expense per person = R57.54545 ~ R57.55[c]

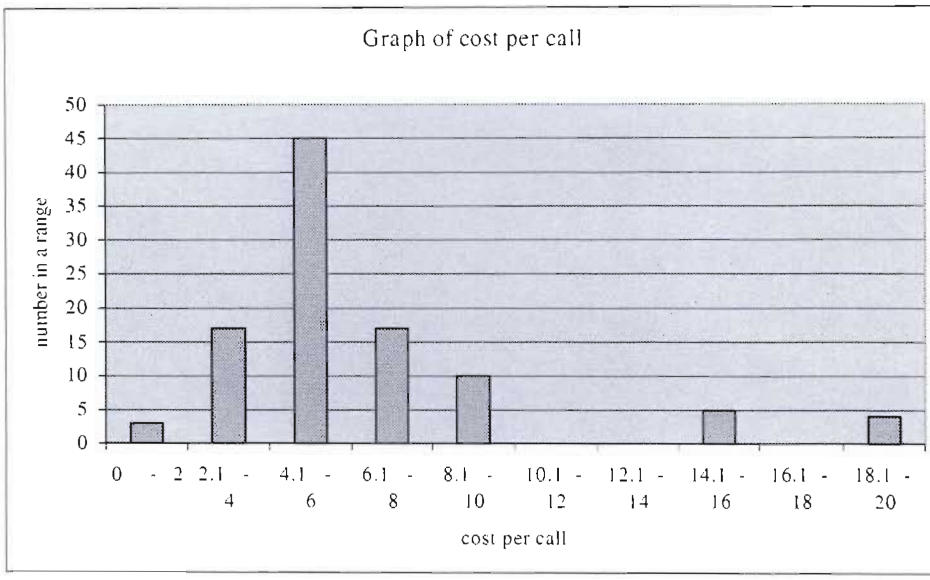

Figure 35: Cost per call

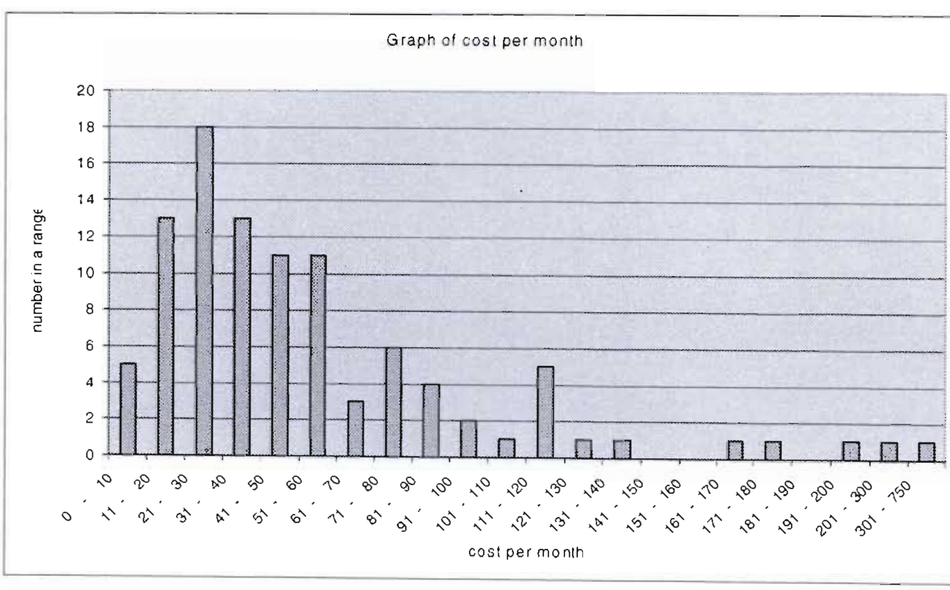

Figure 36: Total Cost expenditure per subscriber per month

4.4 ATM Nodes in KZN

Table 3 and the map in Figure 37 below show several areas in KZN that have ATM nodes. These areas are very densely populated, and therefore have many communication services. It therefore makes sense to run such traffic on ATM transport.

The areas highlighted with pink dots are the ones with the ATM nodes, with each node serving the surroundings that are close by, at approximate radius of about 20 km. Additional areas of interest to this study have been added to the map as dots (these are Nkandla, Babanango and Nqutu). Note that Ulundi North and Ulundi South are not identifiable separately due to their proximity to Ulundi Central, where the ATM node is.

Figure 37 : Map of KwaZulu Natal, showing ATM Nodes

Key:

Nkandla : ●

Babanango : ○

Nqutu : ●

ATM Node : ●

Table 4 shows the different technologies currently utilized in the provision of telecommunication services in each of the above rural areas in KZN.

REGION	ATM Node	Description
Eastern	NBAH:A1	Durban Beach
Eastern	NCNG:A1	Congella Durban
Eastern	NDN+:A1	Durban Central
Eastern	NDNG:A1	Durban New Germany
Eastern	NDNN:A1	Durban North
Eastern	NDTM:A1	Durban Taj Mahal
Eastern	NDVT:A1	Overport Durban
Eastern	NEPI:A1	Empangeni
Eastern	NGVX:A1	Greyville Durban
Eastern	NIO+:A1	Isipingo Durban
Eastern	NLYS:A1	Ladysmith
Eastern	NMLV:A1	Malvern
Eastern	NNGY:A1	New Germany Durban
Eastern	NNWC:A1	Newcastle
Eastern	NPHX:A1	Phoenix Durban
Eastern	NPMB:A1	Pietermaritzburg
Eastern	NPS+:A1	Port Shepstone
Eastern	NPWN:A1	Pinetown Durban
Eastern	NRGH:A1	Rossburgh Durban
Eastern	NULU:A1	Ulundi
Eastern	NWEM:A1	Westmead Durban
Eastern	NWTE:A1	Westville Durban

Table 3: ATM Nodes in KwaZulu Natal

TECHNOLOGY\ZONE	ULUNDI	NKANDLA	BABANANGO
OFDC	X	X	
RURTEL	X	X	X
VSAT UMC	X		
DECT	X	X	X
MGW	X	X	
ATM	X		

Table 4: Technologies versus Zones

Ulundi is the only centre among those mentioned that has an ATM node; this means that the other zones do not currently have ATM deployment. This arises from the fact that ATM is advantageous in areas that handle high traffic intensity. Since these zones are not close (some as far as 100 km apart), they cannot share an exchange. Since telecommunications service providers charge each line per distance, it is therefore costly to have a switching or billing equipment as far as more than 100 km from the client. The proposal for the ATM deployment should therefore consider these facts. It would be recommended to have ATM switch in each of these zones and thus make it easier to extend the routing by ATM remote terminals to reach even the furthest rural centre.

Most telecommunication service providers are currently providing trunk capacity according to the subscribers' needs as specified in the license given by Independent Communication Authority of South Africa (ICASA). For example, Telkom SA provides pipes of 2 Mbps, 34Mbps 155 Mbps, etc. So when there are many customers in a common area, they are integrated into a single street distribution box (SDC), then several SDC are integrated into a bigger pipe that is subsequently terminated in the exchange. If an SDC has sufficient bandwidth requirement such that it is deemed worth, for example, 2 Mbps, then such a pipe is provided. Table 5 below shows the services and the capacities of each technology currently deployed in KZN.

TECHNOLOGY	**CAPACITY** (Megabits per second)	**SERVICES**
ATM	2Mbps, 34Mbps, 155Mbps	SABC broadcast, corporate inter-connection, Banks, Video Conferences
SDH	2Mbps	Telephone line, computer, Banks, internet
OFDC	64, 128, 512Kbps	Telephone line, computer, internet
DECT	64Kbps	Only telephone line
RURTEL	64, 128Kbps	Telephone line, fax
MGW	64,128, 512Kbps	Telephone line, fax, computer, e-mails

Table 5: Technologies versus Capacities currently deployed in KZN

4.5 Summary

Since the objective of this thesis is to investigate the feasibility of implementing ATM in a rural area of KZN, constraints of that are the cost-effectiveness and the economic viability for such a network. In this section, we have presented the traffic characteristics for five rural areas of KZN; in addition, we have reported on a survey carried out in Nqutu, a rural area without an exchange. From the results of the traffic data as well as the survey analysis, one can draw conclusions based on the estimation. Ulundi Central, which has an ATM node, has outgoing non-GSM traffic of about 100 Erlangs, and corresponding incoming traffic of about 45 Erlangs, thus resulting in a total traffic of 145 Erlangs. The corresponding total GSM traffic is about 85 Erlangs (sum of terminating and originating GSM traffic). On the other hand, the total average outgoing non-GSM traffic for Ulundi South, Ulundi North, Nkandla, and Babanango is 35 Erlangs, while the corresponding incoming traffic is 22 Erlangs, thus giving a total of about 60 Erlangs. The corresponding GSM traffic for the four rural areas is 18 Erlangs (both outgoing and incoming). Now, we also consider the average amount that each potential subscriber can afford monthly, which is about R58.00. We bear in mind that the statistics exclude other governmental sectors like organizational offices, welfare offices, farmers, schools and hospitals that can contribute a lot towards traffic and therefore enhance the performance of this network. These traffic data, coupled with the calculations done for Nqutu, will therefore form a basis in the next section for determining the sustainability of installing ATM remote terminals at these five stations.

Chapter Five

Economic Viability of ATM in Rural KwaZulu Natal

5.0 Introduction

We have previously presented traffic and survey data with regard to telecommunications services in rural KZN. In this chapter, we start by highlighting areas or sectors that would benefit from greater telecommunication services in rural Kwazulu-Natal. Then we discuss the implementation strategies which involve aggregating traffic from adjacent rural areas in order to ensure adequate traffic for the ATM node at Ulundi Central. Thereafter, we perform an economic analysis to understand the viability of this approach.

5.1 Motivation for Rural Telecommunications Access

5.1.1 Clinics and Telecommunications

With the emergence of serious health challenges, including HIV/AIDS, clinics in rural areas are carrying a very heavy load. It is therefore doubtless that telecommunication facilities thus need to be improved in such clinics, as we have many clinics with poor health facilities in rural areas, which should be in constant touch with major hospitals in cases of serious illnesses and emergencies. The best way to do that is to have good telephones, fax machines and e-mail access. Noting that the majority of people in rural areas are poor, it is economically sensible for the patients' families to make follow-up telephone calls to enquire about the conditions of their patients rather than traveling personally, which is much more costly. In addition to the clinic's official telephones, public telephones within the clinics' vicinities are also vital for the patients to be able to call their relatives from time to time.

The ever-increasing rate of spread of the HIV/AIDS pandemic has called for radical educational awareness campaigns by all relevant institutions and individuals involved.

Clinics are one of the most reliable institutions in these awareness programmes and therapeutic activities in rural areas. Considering that most of the awareness campaign programs are screened in television as video tapes, it is important to have provisions for tele-video and video tape machines in rural clinics.

5.1.2 Farm Sector and Telecommunications

The farm sector is often neglected and has remained marginal in terms of development, particularly in improving telecommunication facilities. This sector constitutes an important group (farmers and farm workers) with distinct telecommunication needs. Current global demands have given rise to the urgent need for farmers' access to the Internet. In order for the farmers to be effective and competitive in the commercial arena, they need to have access to the relevant support information via the Internet, where most advertisements are now placed. Certain transactions require more than the Internet and e-mail, and therefore the fax machine certainly becomes an answer. Such documentations may range from invoices, requisitions for particular goods, etc.

Some farm workers stay in the farm compounds. Most of them cannot afford to buy entertainment facilities, and therefore farmers must create central entertainment centres, of which video machines and televisions become crucial components. It goes without saying that where people stay in numbers, as in such areas, telephones are certainly needed. Advancing modern technology is pushing away the traditional communication facilities, which are often time consuming and less effective. This implies that even in farms, people should at least have access to good telecommunication facilities.

5.1.3 Traditional Leadership (Amakhosi) and Telecommunications

Traditional leaders operate in Tribal Courts. Tribal Courts are therefore central operational venues in rural areas. Tribal meetings are also held in Tribal Courts. Pension grants are also facilitated in either Tribal Courts or local shops. Other structures existing in rural areas mostly operate in Tribal Courts due to unavailability of alternative venues. All of these factors are a clear indication that Tribal Courts deserve improved telecommunication facilities, due to the incessant gatherings therein. The roles, functions and status of the traditional leaders and Amakhosi in particular are under scrutiny. This scrutiny has given rise to the argument that Amakhosi should have central roles in development activities. In order for the traditional institution to be truly effective and productive in development ventures, good telecommunication and infrastructural facilities need to be put in place.

5.1.4 Tuck-shops and Telecommunications

Tuck-shops also serve as a meeting point for many rural dwellers. As mentioned earlier on, people receive their pension grants either in shops or in Tribal Courts. This is also an indication that telephones are necessary in tuck-shops. People involved in any business including tuck-shops may certainly need fax machines, as has been mentioned earlier on, trading business may require certain documentations to be faxed. Some business people do install televisions in their shops to make their business flourish.

5.1.5 The Tele-Education

In South Africa, there is a shortage of science and language teachers. This problem creates a situation whereby there is no interest in this vital area from the scholars or learners, both now and in coming generations. Now, the only remedial measure that can be instituted in the mean time is to introduce tele-education. This means that a teacher in one location can teach students from different places at the same time. Demonstrations, laboratory work and other experiments can also be done through the same medium. This interactive kind of application will require a big bandwidth to carry this volume of information and at the same time at a high speed as a real-time service. The same tele-education can be used in the clinics, farming estates and other areas where one centrally-placed expert can train workers from the respective sectors.

The above information has shown that modern lifestyle in all sectors of life certainly need telecommunication facilities, not as luxury but as an integral part of our lives. If all communities are to become part of the global network, telecommunication facilities are the answer. Development of infrastructure and telecommunication facilities in particular is the only way of breaking the urban -rural divide created by the disadvantages of the past.

5.2 Traffic Considerations for ATM Network

5.2.1 Total Average Traffic

Table 6 below shows the average traffic based on the data shown in Chapter 4. In the next sub-section, we focus on calculating in detail the total traffic emanating from and terminating at each station.

STATION/ EXCHANGE	NON-GSM TRAFFIC (ERLANGS)		GSM TRAFFIC (ERLANGS)	
	Outgoing	Incoming	Outgoing	Incoming
Ulundi Central	100	45	40	4.5
Ulundi North	3	4	1.5	0.5
Ulundi South	16	8	7	0.7
Nkandla	11	7	4	0.8
Babanango	5	3	3	0.6
Nqutu	3.2	2.8(est)	1.5(est)	0.5 (est)

Table 6: Average Hourly Traffic for Rural KZN, 0800-1700 hours

5.2.2 Analysis of Individual Stations

5.2.2.1 Ulundi Central :

A. The total non-GSM traffic originating from and terminating at Ulundi Central Exchange:

Originating ~ 100 Erlang

Terminating ~ 45 Erlang

Therefore, total non-GSM traffic = 145 Erlang

B. The total GSM traffic originating from and terminatig at Ulundi Central Exchange:

Originating ~ 40 Erlang

Terminating ~ 4.5 Erlang

Therefore, total GSM traffic ~45 Erlang

C. Total Traffic (GSM + non-GSM) ~190 Erlangs

5.2.2.2 Ulundi North :

A. The total non-GSM traffic originating from and terminating at Ulundi North Exchange:

Originating ~ 3 Erlang

Terminating ~ 4 Erlang

Therefore, total non-GSM traffic = 7 Erlang

B. The total GSM traffic originating from and terminating at Ulundi North Exchange:

Originating ~ 1.5 Erlang

Terminating ~ 0.5 Erlang

Therefore, total GSM traffic ~2 Erlang

C. Total Traffic (GSM + non-GSM) ~ 9 Erlangs

5.2.2.3 Ulundi South :

A. The total non-GSM traffic originating from and terminating at Ulundi South Exchange:

Originating ~ 16 Erlang

Terminating ~ 8 Erlang

Therefore, total non-GSM traffic = 24 Erlang

B. The total GSM traffic originating from and terminating at Ulundi South Exchange:

Originating ~ 7 Erlang

Terminating ~ 0.7 Erlang

Therefore, total GSM traffic ~8 Erlang

C. Total Traffic (GSM + non-GSM) ~ 32 Erlangs

5.2.2.4 Nkandla :

A. The total non-GSM traffic originating from and terminating at Nkandla Exchange:

Originating ~ 11 Erlang

Terminating ~ 7 Erlang

Therefore, total non-GSM traffic = 18 Erlang

B. The total GSM traffic originating from and terminating at Nkandla Exchange:

Originating ~ 4 Erlang

Terminating ~ 0.8 Erlang

Therefore, total GSM traffic ~5 Erlang

C. Total Traffic (GSM + non-GSM) ~ 23 Erlangs

5.2.2.5 Babanango :

A. The total non-GSM traffic originating from and terminating at Babanango Exchange:

Originating ~ 5 Erlang

Terminating ~ 3 Erlang

Therefore, total non-GSM traffic = 8 Erlang

B. The total GSM traffic originating from and terminating at Babanango Exchange:

Originating ~ 3 Erlang

Terminating ~ 0.6 Erlang

Therefore, total GSM traffic ~4 Erlang

C. Total Traffic (GSM + non-GSM) ~ 12 Erlangs

5.2.2.6 Nqutu:

A. The total non-GSM traffic originating from and terminating at Nqutu Exchange:

Originating = 35*5.54/60 ~ 3 Erlang

Terminating ~ 3 Erlang (Estimate)

Therefore, total non-GSM traffic = 6 Erlang

B. The total GSM traffic originating from and terminating at Ulundi North Exchange:

Originating ~ 1.5 Erlang (Estimate)

Terminating ~ 0.5 Erlang (Estimate)

Therefore, total GSM traffic ~2 Erlang

C. Total Traffic (GSM + non-GSM) ~ 8 Erlangs

5.2.3 Perspective on the Traffic Patterns

Ulundi is the most rural of all the stations in Table 3 with ATM nodes in KZN. The traffic at Ulundi Central exchange is 190 Erlangs. However, since this node was installed at least five years ago, it is therefore reasonable to estimate that a minimum traffic of at least 100 Erlang is necessary for an ATM node to be sustainable at a station. The combined traffic of the other stations in Table 6 (adding GSM and non-GSM traffic) is 84 Erlangs. As highlighted earlier on, the growth in terms of traffic is increasing at about 10% per annum through the duration of the forecast; it is therefore clear that in three or four years to come, the traffic will have grown to the extent that an independent exchange should exist in the area that will then require the deployment of an ATM node to support the traffic between the exchanges. For the time being, we propose a system of traffic aggregation using ATM remote terminals (RTs).

ATM is in place right now; it is available all over South Africa as a ring passing through all major centers with reasonable traffic intensity; it can thus be utilized for the above requirements in rural areas. A schematic diagram of the designed deployment for the particular survey is therefore shown in the Figure 38. Based on this traffic, the analyses of the ATM network performance can be done. There are many ways or possible solutions that can be suggested for the ATM network to serve a low-density area efficiently, taking into consideration the fact that it's a rural area, with the following three main characteristics:

I. Sparsely populated
II. Traffic is expected to be low

III. Low income

This obviously creates problems for an ATM network, especially when the traffic is low, because of the delay in filling out the payload of an ATM cell. This "packetization delay" degrades the quality of service (QoS). Therefore, this thesis proposes a possible design that will aggregate the low traffic to be transmitted efficiently. Two options are envisages, namely:

I. Multiplexing several low-bit rate streams into an ATM cell: This reduces packetisation delay, and by so doing, it makes the network to be efficient.
II. Multiplexing a low-bit- rate and higher bit rate streams: for example a rural area and a nearest urban area with high bit rate, as this will also make the network efficiently.

5.3 System Design Considerations

5.3.1 General

For each station in the design, this simulation makes the following assumptions:

a. Simulation runs for 10 years.

b. Roll-out of network from year 0 to year 10.

c. Average tax rate is 30%.

d. Cost of capital is 12%. (Average interest rate to borrow money)

5.3.2 Service Categories

Two service categories are envisaged, namely, business services and public payphone services.

A. Business Lines

For business services, we assume that:

a. Every business line generates R 1000.00 per month for calls and R 120.00 for line rental.

b. Average cost per call minute is R 0.90 – total call minutes per annum is 6,666. Number of busy day in the year is 250.

c. 10% of calls are in the busiest time of the day. Traffic per line = 6,666 / (250 * 60) * 1/10 = 0.0444 erlang.

d. To estimate number of businesses in each area, we assume that half of the traffic observed is generated by businesses and the other half by payphone users.

B. Payphone Service

For payphone services, the following assumptions are made:

a. Every person that uses the service generates R60.00 per month.

b. Tariff per call minute is R1.20. Total call minutes per annum is 60/1.20 * 12 = 600. Number of busy days per year is 250.

c. 10% of calls are in the busiest time of the day. Average traffic per person is 600 / (250 * 60) * 1/10 = 0.004 erlang.

5.3.3 Payphone units

With regard to payphone units, we make the following assumptions:

a. We need one payphone for every 50 users who actually use the payphone service

b. Capital cost is R10,000.00 per unit.

c. Physical lifetime is 10 years.

5.3.4 Remote Terminals (RTs)

For remote terminals in the network, we assume that:

a. Every RT has a unit capacity of 10 lines.

b. The farthest point from town is 30km. We need one RT every 3 km. If we want to deploy RTs in a ring we need at least 30/3 *2 = 20 RTs.

c. Two scenarios are investigated: RT with SDSL backbone at R 20,000 each and RT with WiFi backbone each at R 25,000 each.

These remote terminals use ATM cards; these ATM cards are slotted in the shelves inside. The RT box then becomes an ATM switch. SDSL and WiFi chips identify the use of wire line or wireless access, respectively.

5.3.5 Copper access

With regard to copper access, we make the following assumptions:

a. Copper access links cost R 3,000 per km. (Correctly modelling the copper access network cost is a major undertaking)

b. Access lines from the RTs to the telephones are on average 1.5 km long.

c. Backbone links are 3km long on average for the SDSL scenario. If WiFi RTs are deployed, no backbone copper links are required.

5.3.6 Interconnect Issues

With regard to call termination, we make the assumption that most calls made from this network terminate on either a cellular network, or a fixed operator's network. To accept our calls and carry them to their destination we pay the fixed operator R 0.27 per call minute on average.

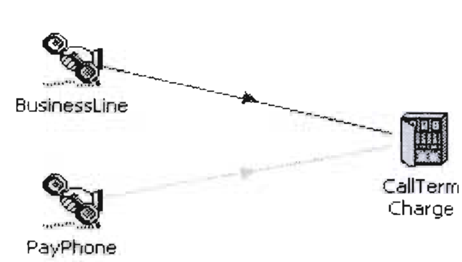

Figure 38: Call termination charges

5.4 Network Design

5.4.1 Overview

The proposed designed network layout is shown in Figure 37. The traffic comes from different areas, as shown. The diagram provides a view of the total network related part of the model, and Fig.39 is the schematic representation of the same network. This kind of network will collect enough traffic from different rural areas as indicated from the diagram and terminate the traffic at Ulundi Central where there is an ATM node. The proposed network is cost-effective in sense that there will be no nodes in all these zones but only the master remote terminals that will take the aggregated traffic to the ATM node at Ulundi Central. In each zone there are several small remote terminals (RTs) depending on the particular traffic, and they sustainable for low traffic.

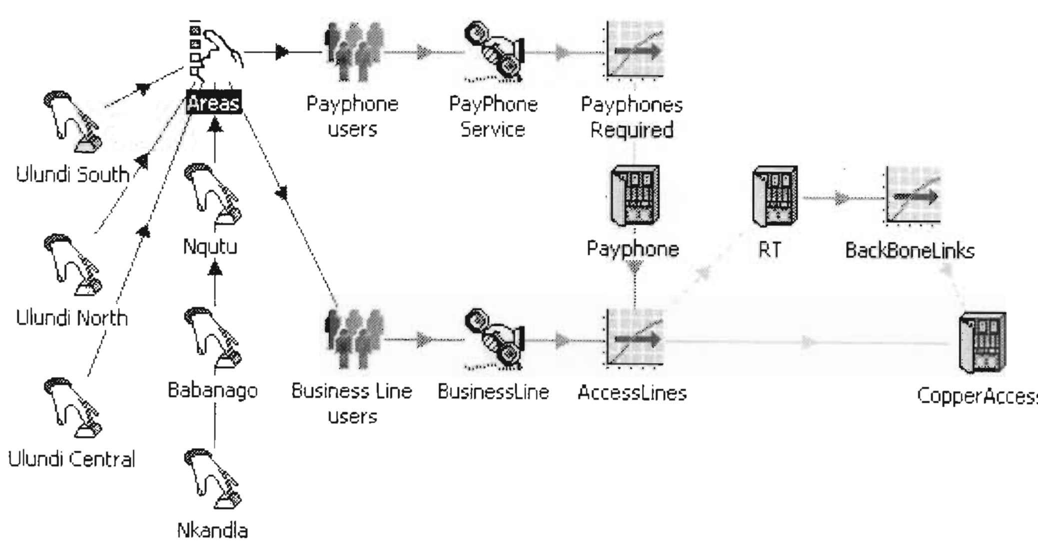

Fig. 39: Software Design Layout for all stations

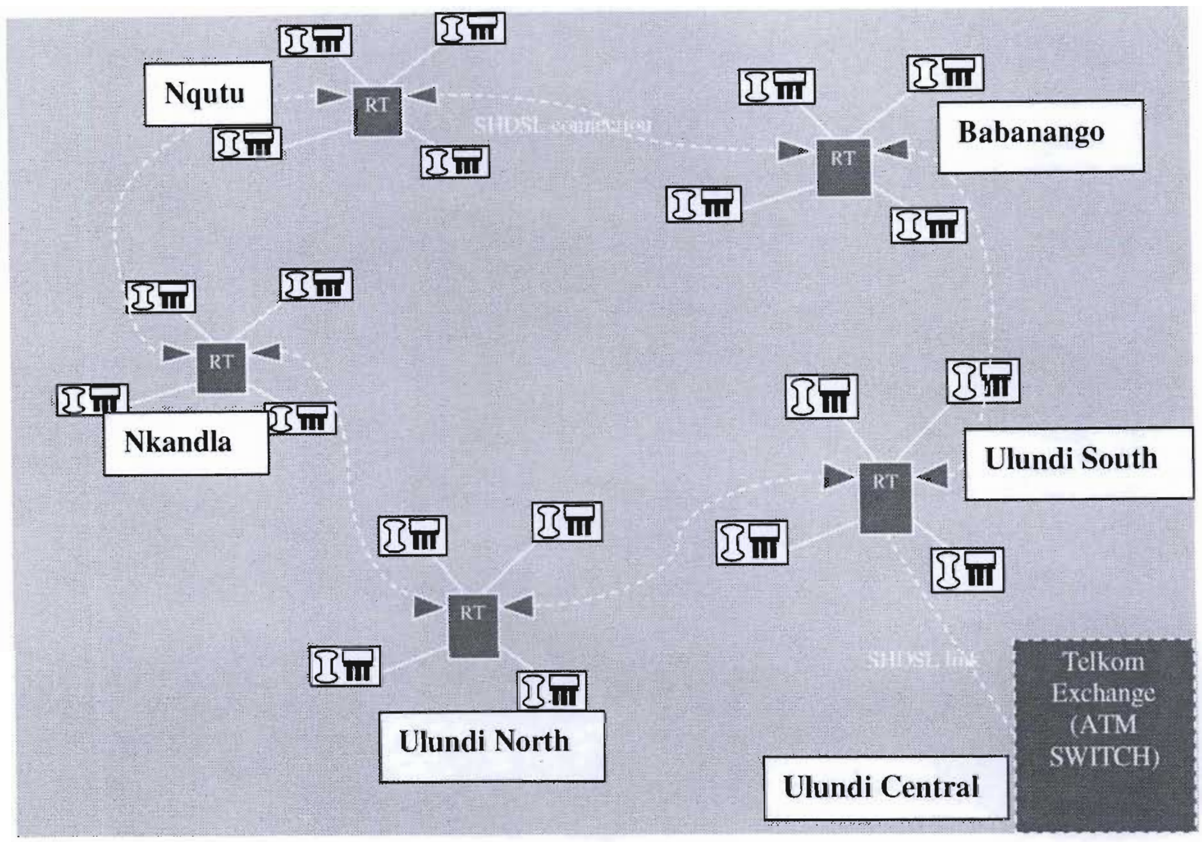

Fig. 40: Schematic ATM-based Design Layout for Rural KZN

5.5 Operations

5.5.1 Operational Overview

Figure 40 below gives an overview of the operations cost calculation, with various cost components, including technician and vehicle costs for maintenance.

5.5.2 Technicians

With regard to technicians required for network maintenance we make the following assumptions:

a) Technicians have a capacity of 2,000 hours (250 days, 8 hours) of work each per annum. A maximum of 75% of this can be utilised effectively.

b) Average annual salary is R 72,000.

c) Maintenance hours per network element:

i. Per kilometer of copper access: 1.0 faults per annum that takes 8 hours to fix = 8 hours per annum per km.

ii. Payphone: 1 hour per day to collect the money and correct faults.

iii. RT: 10 hours per annum for preventative maintenance and rectifying faults as they appear.

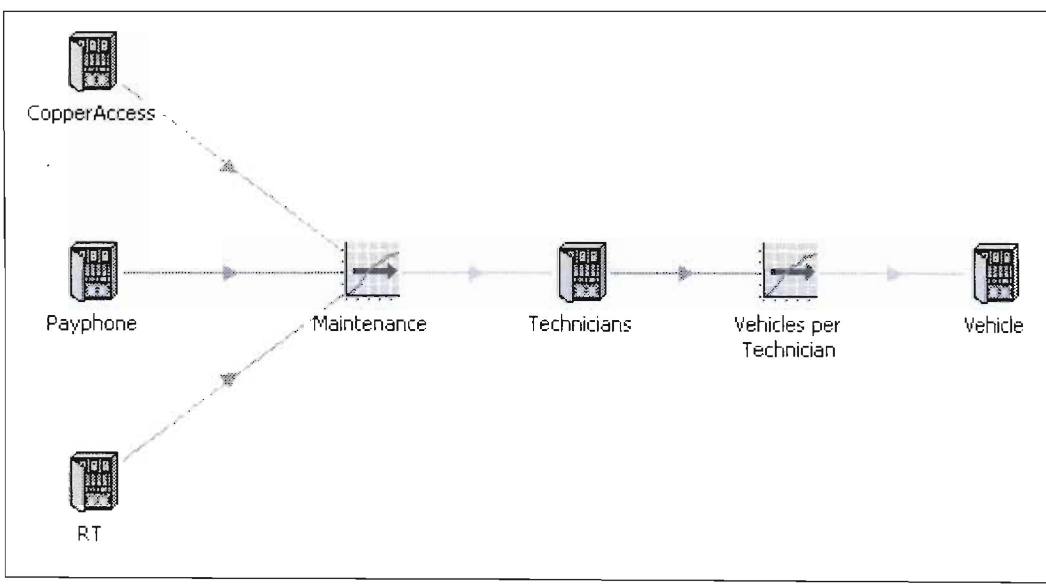

Figure 41: Operational Schematic

II.

5.5.3 Vehicles

For maintenance vehicles, we require that:

a) Capital cost per vehicle: R 120,000. Cost per month to operate the vehicle is R1,500.

b) Ratio of maintenance vehicles to technicians is 0.5.

5.4 Design Simulation Results

5.4.1 Service rollout

5.4.1.1 Access Lines

Table 7 below shows the simulated lines in service. This was derived as follows. Taking Nqutu in year one as an example, the traffic total observed is 8 Erlang. It is assumed that one half of the traffic is generated by payphone users, with the other half generated by business and other users. It is further assumed that the average traffic generated per user in the busy hour is 0.004 erlang, with 50 users per payphone. Thus 4 erlang at 0.004 per user results in 1,000 users. This therefore gives (1,000 users/50) or 20 payphones. Similarly, the number of business phone users is calculated as follows: 4 erlang / 0.0444 erlang per user = 90.1 users, which is rounded up to give 91 users. Therefore the access lines required are 20 + 91 = 111 lines. This is the number of lines required for Nqutu. Similar calculations are performed for Babanango, Nkandla, Ulundi South, Ulundi North, and Ulundi Central.

From the table, the average access line growth rate from year-to-year is as follows: 11.4% for year 1 to year 2; 10% from year 2 to year 3; 9% from year 3 to year 4; 8.5% from year 4 to 5; 7.5% from year 5 to 6; 7% from year 6 to 7; 6.5% from year 7 to 8; 6.2% from year 8 to 9; and 5.7% from year 9 to 10. These growth rates are in accordance with empirical results acquired over the years for the type of region in question.

Access Lines	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Nqutu	111	125	137	149	161	174	186	198	210	222
Babanago	166	186	204	222	241	259	277	296	314	332
Nkandla	318	353	389	424	460	495	530	566	601	635
Ulundi South	441	491	540	589	638	687	736	785	834	882
Ulundi North	125	139	153	166	181	194	208	222	236	249
Ulundi Central	2,615	2,906	3,197	3,488	3,779	4,068	4,359	4,650	4,941	5,230

Table 7: Access Lines in service over 10 years

5.4.1.2 Total Traffic Generated

The corresponding traffic generated, as earlier discussed, are displayed in Table 8. These conform with the data in Table 6 and discussions in Section 5.2.2.

Traffic in Erlangs	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Nqutu, PayPhone Service	4	4	5	5	6	6	7	7	8	8
Nqutu, BusinessLine	4	5	5	5	6	6	7	7	8	8
Babanago, PayPhone Service	6	7	7	8	9	9	10	11	11	12
Babanago, BusinessLine	6	7	7	8	9	9	10	11	11	12
Nkandla, PayPhone Service	12	13	14	15	17	18	19	20	22	23
Nkandla, BusinessLine	12	13	14	15	17	18	19	21	22	23
Ulundi South, PayPhone Service	16	18	20	21	23	25	27	28	30	32
Ulundi South, BusinessLine	16	18	20	21	23	25	27	29	30	32
Ulundi North, PayPhone Service	5	5	6	6	7	7	8	8	9	9
Ulundi North, BusinessLine	5	5	6	6	7	7	8	8	9	9
Ulundi Central, PayPhone Service	95	106	116	127	137	148	158	169	179	190
Ulundi Central, BusinessLine	95	106	116	127	137	148	158	169	180	190

Table 8: Total traffic generated during the busy hour over 10 years

5.4.1.3 Call Minutes (Thousands per Annum)

In order to determine the total annual call minutes, we again take Nqutu as an example. Traffic from payphone users is 4 erlang during the busy hour. Call minutes in the busy hour is determined as (4 erlang * 60 minutes) = 240 minutes. Since we consider the proportion of call minutes in the busy hour is 10% as shown in section 5.3.2, the call minutes per day from payphone users are 2,400 minutes. Given our earlier assumption that the number of busy days per annum is 250, the call minutes per annum is 2,400 * 250 = 600,000 minutes for Nqutu.

The call minutes from business users are slightly more due to the fact that the results are based on the rounded up number of business phone customers (i.e. 91 instead of the calculated 90.09). Similar calculations are performed for Babanango, Nkandla, Ulundi South, Ulundi North, and Ulundi Central. The results are displayed in Table 9.

Call Minutes (Thousands)	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Nqutu, PayPhone Service	600	634	701	767	834	900	967	1034	1100	1167
Nqutu, BusinessLine	606	643	713	779	846	912	979	1046	1112	1179
Babanago, PayPhone Service	900	950	1050	1150	1250	1350	1450	1550	1650	1750
Babanago, BusinessLine	906	959	1062	1162	1262	1362	1462	1562	1662	1762
Nkandla, PayPhone Service	1725	1821	2013	2204	2396	2588	2780	2971	3163	3354
Nkandla, BusinessLine	1732	1828	2021	2214	2408	2601	2794	2987	3180	3370
Ulundi South, PayPhone Service	2400	2534	2800	3067	3334	3600	3867	4134	4400	4667
Ulundi South, BusinessLine	2404	2541	2811	3077	3343	3610	3876	4143	4409	4675
Ulundi North, PayPhone Service	675	713	788	863	938	1013	1088	1163	1238	1313
Ulundi North, BusinessLine	679	719	796	869	946	1022	1096	1172	1249	1322
Ulundi Central, PayPhone Service	14250	15042	16625	18209	19792	21375	22959	24542	26126	27709
Ulundi Central, BusinessLine	14252	15045	16630	18215	19800	21382	22964	24549	26134	27716

Table 9: Call minutes (in thousands) over 10 years

5.4.1.4 Revenue per Service

In order to determine the generated revenue, we note in section 5.3.2 that the payphone tariff per call minute is R1.20. On the other hand, every business call generates R0.90 per minute, with a monthly rental of R120. Table 10 shows the total revenue obtained for each of the areas. This can be further broken down to specific services and aspects of services, as shown in Table 11 for Nqutu.

(Thousands of Rand)	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Nqutu	1,276	1,350	1,495	1,636	1,777	1,918	2,059	2,200	2,341	2,482
Babanago	1,912	2,021	2,236	2,447	2,659	2,871	3,082	3,294	3,506	3,717
Nkandla	3,660	3,863	4,271	4,678	5,086	5,493	5,900	6,308	6,715	7,119
Ulundi South	5,087	5,373	5,940	6,505	7,070	7,634	8,199	8,763	9,328	9,892
Ulundi North	1,434	1,515	1,676	1,833	1,993	2,153	2,311	2,471	2,631	2,789
Ulundi Central	30,184	31,862	35,217	38,572	41,927	45,279	48,632	51,987	55,342	58,694

Table 10: Total service revenue generated in thousands of Rand

(Revenue in Thousands of Rand)	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
PayPhone Service Usage Revenue	720	760	841	921	1,000	1,080	1,160	1,240	1,320	1,400
BusinessLine Rental Revenue	11	12	13	14	15	16	18	19	20	21
BusinessLine Usage Revenue	545	578	641	701	761	821	881	941	1,001	1,061

Table 11: Annual Service Revenue Breakdown for Nqutu

5.4.2 Network Rollout

In this section results from the actual rollout of the network is analyzed, based on the discussions in sections 5.5.2 and 5.5.3. Table 12 shows the cumulative number of elements installed in the network, for Nqutu only. The table allows the analysis of the impact of different network architectures (in this case between different backbone strategies).

Units Installed	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Payphone	20	23	25	27	29	32	34	36	38	40
RT	20	20	20	20	20	20	20	20	21	23
SDSLBackBone CopperAccess (km)	227	248	266	284	302	321	339	357	378	402
WiFiBackBone CopperAccess (km)	167	188	206	224	242	261	279	297	315	333

Table 12: Network Rollout for Nqutu over 10 years

Table 13 shows the planned capital expenditure per area. (Once again only Nqutu is shown for brevity). A telecommunications operator would use a similar table with projected capital requirements to request financing for the project.

Units	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
SDSLBackBone/Nqutu	1,641	93	74	194	74	447	74	194	223	132
WiFiBackBone/Nqutu	1,561	93	74	74	194	447	74	74	219	244

Table 13: Capital Expenditure for Network Rollout over 10 years for Nqutu

5.4.3 Operations rollout

5.4.3.1 Requirements for Technicians and Vehicles

Having an installed network is not sufficient to provide service in any given area. The network needs to be maintained and operated as well. For this simulation a very simplistic support and maintenance arrangement have been assumed, with only the technicians performing direct maintenance and their vehicles being considered. Table 14 shows the technicians and vehicles required in the Nqutu area.

Units	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Technicians	5	6	6	7	7	8	8	9	9	10
Vehicle	3	3	3	4	4	4	4	5	5	5

Table 14: Technicians and Vehicles for operation in Nqutu

The total operational costs associated with operating the network is thus shown in Table 15.

(R 000)	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Technicians Operating Costs	360	432	432	504	504	576	576	648	648	720
Vehicle Operating Costs	108	108	108	144	144	144	144	180	180	180

Table 15: Operational Costs for Network Installed in Nqutu

5. 5 Profitability indicators

In order to obtain financing or for financial management purposes in the organisation, it would be required to show that investing in this project would be profitable. A number of profitability indicators are in general use. A popular indicator is the Net Present Value (NPV) analysis where all future cash flows are discounted to their present values. If the sum of discounted cash flows is bigger than zero it is assumed that the project is viable. Figure 40 shows the NPV curves for all the areas considered in this network, with an SDSL backbone.

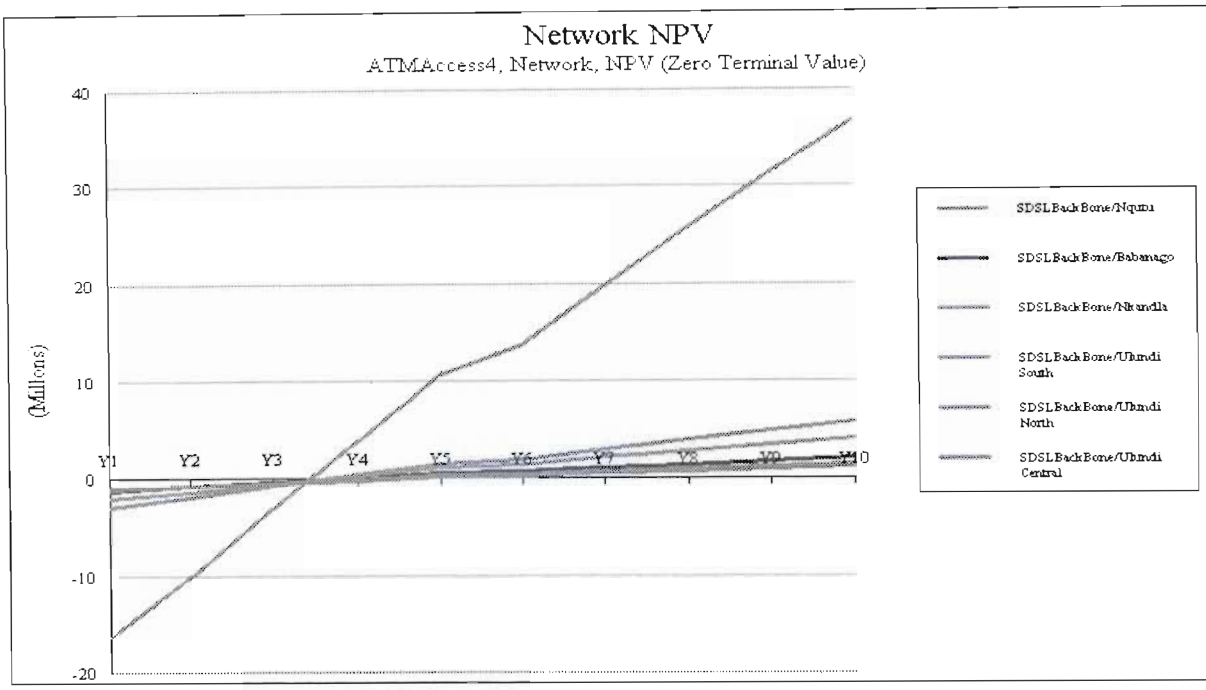

Figure 42: NPV curves for the six areas

The curves are to be interpreted as follows: In the initial years, the project requires huge investment to connect the initial subscribers, but not much revenue is being received as yet. At the end of year four the discounted values of all revenues received are larger than the discounted values of all outflows. If an investor is willing to risk money for more than four years, any of these areas would be a good investment.

Another way to look at investing in these projects is to calculate a rate of return value. An investor would then be able to compare this rate of return with interest rates he can obtain by investing money in, for example, a fixed deposit or shares, versus investing it into financing the project. The graph in Figure 41 shows Internal Rate of Returns (IRR) for all areas. The graph shows that if the investor is willing to wait 10 years, he will have received returns equivalent to an investment yielding a return of 50% per annum if he invests in Ulundi Central. It also shows that investment in a smaller area like Nqutu is still profitable, at a return of 32% per annum, indicating, as expected, that much lower returns can be obtained from an investment there than in an investment in Ulundi Central.

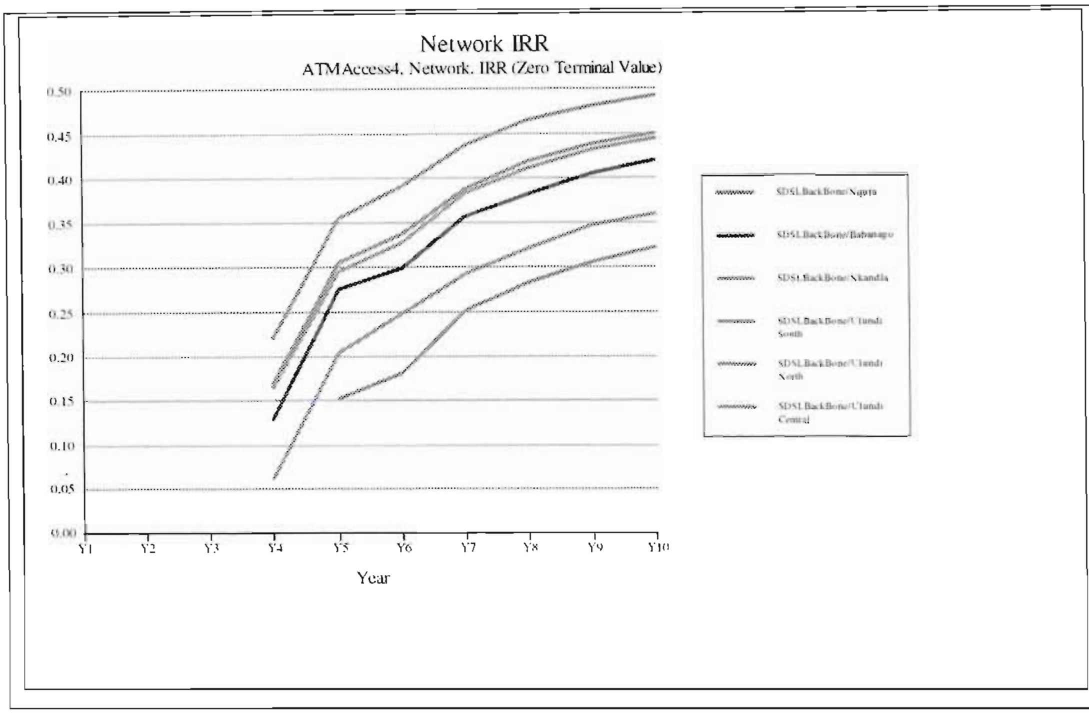

Figure 43: IRR curves for all areas

In order to optimise revenues, management in a telecommunications company would typically like to know the profit margin (ratio of revenues to income) for each service in the total basket of services. This will allow them to identify and get rid of unprofitable services (or rectify problems by adapting pricing, for example) while nurturing profitable services. The graph in Figure 42 shows the operating profit margin for the two services (payphone and business line services) that were modelled. In this case there are not major differences in the margins of the two services.

Operations managers are always looking at ways to minimise costs. A useful tool is to identify the elements that contribute the most costs to the service and try to optimise those cost elements first. Table 16 shows the operating charge per element for the Business Line service in Nqutu. The same can be replicated for the other regions. The table shows that the biggest costs associated with the service are the call termination fees paid over to other operators and the technicians performing maintenance on the network. Finally, Table 17 shows the overall income statement for Nqutu.

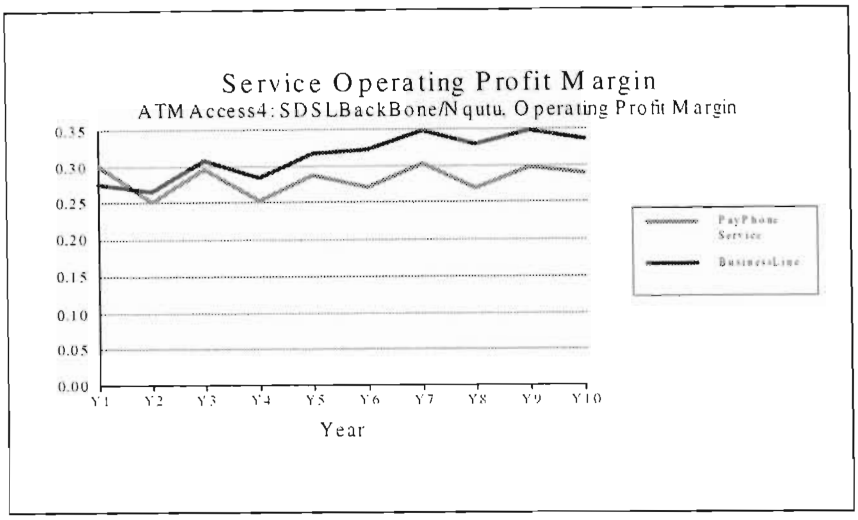

Figure 44: Service profit margin for Nqutu

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Call Terminating Charge	1,798	1,701	1,718	1,725	1,730	1,735	1,739	1,743	1,746	1,749
Copper Access	307	298	291	286	281	277	273	270	270	272
RT	360	320	292	268	248	230	215	202	200	207
Technicians	1,448	1,492	1,346	1,430	1,312	1,354	1,259	1,324	1,250	1,323
Vehicle	507	435	393	477	437	395	367	429	405	386

Table 16: Cost elements for Business Line service in Nqutu

(Thousands)	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Revenue	1,276	1,350	1,495	1,636	1,777	1,918	2,059	2,200	2,341	2,482
Depreciation	166	172	177	206	210	216	221	250	257	266
Amortisation	0	0	0	0	0	0	0	0	0	0
Operating Costs	740	831	868	994	1,029	1,137	1,173	1,299	1,335	1,443
Operating Profit	371	348	450	437	537	564	665	651	749	773
Interest Income	0	0	0	4	33	66	104	161	218	288
Interest Expense	45	78	43	10	0	0	0	0	0	0
Pre-Tax Profit	326	270	407	431	571	630	769	812	968	1,061
Tax Charge	98	81	122	129	171	189	231	244	290	318
Net Profit	228	189	285	301	399	441	538	569	677	742
Dividends Declared	46	38	57	60	80	88	108	114	135	148
Retained Profit	182	151	228	241	320	353	430	455	542	594

Table 17: Income Statement for Nqutu

5.6 Summary

In this chapter, we have used the traffic statistics of chapter 4 to design an-ATM-based rural network which aggregates traffic via ATM remote terminals to the ATM node at Ulundi Central. The remote terminals are located at Nqutu, Nkandla, Babanango, Ulundi North, and Ulundi South. We have determined the required access lines for each region, the corresponding number of remote terminals, the total traffic generated during the busy hour, the call minutes carried per annum,and the resulting annual revenue generated in the network. We have then determined the expenses arising from network rollout and the operational costs, taking into account both technicians and vehicles. From the analysis of the profitability of the network, it has been seen that, assuming an SDSL backbone, the network breaks even only at the fourth year of deployment. Thereafter, the network operates profitably, even for an investor who ventures in a small region such as Nqutu, Babanango, or Ulundi North. Nevertheless, as expected, the ATM network still performs best in high-traffic zones such as Ulundi Central. We also note that the most expensive cost elements for a business line would be the call termination costs and manpower deployments (technicians). With regard to the profitability of payphone service and business lines, it is observed that the service operating profit margin is only slightly higher for the latter. Thus, in terms of client choice, an investor could not discriminate between one or the other.

Chapter six

Conclusion

While it could probably be argued that ATM is not the optimal technology for voice or video or data or image traffic alone, ATM is, however, currently viewed as an optimal technology available for integrating voice, video, data, and image traffic on a single network infrastructure. The ATM applications of today are relatively modest compared to the potential of the future, and the total promise is still some years away. In South Africa, ATM is receiving excellent support from the service provider and equipment vendor community; most LECs and IECs are offering, or intend to offer, an ATM service, while available products include routers, ADSUs, campus and wide area switches, and protocol analyzers. We note that legacy networks still exist and are not being recovered as long as they are operational at a profit hence the ATM backbone currently in South Africa can also be well utilized to serve rural areas like KwaZulu Natal.

In this thesis, we have proposed a wide area network for low-density traffic areas, typical in rural and underserved remote areas in South Africa. The advantage of this approach for an Africa-wide network is the fact that mapping physical wide area network to cover large geographical areas is a matter of logical extension of a local network. The network scales easily from both coverage and capacity perspectives and local networks can operate at their desired capacity without affecting other networks. The network should be dimensioned and segmented in such a way that an autonomous area network interconnects several networks within a physical area based on distances over which business is transacted. Since traffic might be aggregated based on villages or small towns, there is need for large coverage access nodes to minimize capital costs. This will thus be part of the task ahead, namely, to specify strategies and technologies for access, switching, routing, billing and other related issues for this network topology.

Since Telkom SA has invested a lot of money in ATM, it would be a hard sell just to ditch ATM altogether. From our analyses, we have investigated the minimum requirement for ATM to be sustainable in a rural setting; we have also seen the typical traffic pattern of different rural areas in KZN. One of the investigated areas (Ulundi) has shown that aggregating the traffic from the other outlying rural areas increases the traffic which therefore requires additional trunks. It is therefore, proposed in this thesis that if possible, all the generated traffic for different settlements in an area should be aggregated to a remote terminal (RT) armed with an ATM chip. These multiples of RTs are then also aggregated to a master remote terminal, from which the traffic would be fed to the ATM Node at Ulundi Central. The master terminals are in a ring topology - this topology being essential in terms of alternative routing when there is a fault in the network. From the analysis of the profitability of the simulated network, it has been seen that, assuming an SDSL backbone, the network breaks even at the fourth year of deployment. Thereafter, the network operates profitably, even for an investor who ventures in a small region such as Nqutu, Babanango, or Ulundi North. Nevertheless, as expected, the ATM network still performs best in high-traffic zones such as Ulundi Central.

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