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VOIP INVESTIGATION AND CHALLENGES

– Case: Ethiopian Telecommunications

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VOIP INVESTIGATION AND CHALLENGES

VOIP stands for Voice over Internet Protocol. It makes voice or data transmit over an internet protocol. Sound waves travel across the data network instead of the phone company's network. Today's communication benefits a great deal from VOIP technology mainly because it reduces phone costs and offers more features for calling, ease of use and, versatility. The benefits are not limited to cost. VOIP has come up with different services which the old system cannot provide. VOIP deployed in countries with good ICT infrastructures and loose regulations.

The Ethiopian Telecommunication is the only Internet service provider (ISP) in Ethiopia. Due to many factors, which this thesis is going to investigate, VOIP barely exists in Ethiopia. The aim of this thesis is to introduce and discuss the working principles of VOIP, its challenges in Ethiopia, to study other African and European countries experiences and to suggest alternate solutions that might help users in Ethiopia to enjoy the fruit of VOIP technology. The thesis is not limited to VOIP. It tries to discuss Telephony and Internet fundamentals in general, voice transmission over IP network in particular.

KEYWORDS:

(VOIP, ISP, Ethiopian Telecommunications)

FOREWORD

For Nebi who received most of my VoIP calls.

1

Abbreviations

VOIP   Voice over Internet Protocol

PSTN   Public Switched Telephone Network

ISP   Internet Service Provider

ADSL   Asymmetric Digital Subscriber Line

IXP   Internet Exchange Point

CDMA   Code Division Multiple Access

ISO   International Standard Organisation

QoS   Quality of Service

UDP   User Datagram Protocol

CONTENTS

PICTURES

Picture 1. VSAT antenna

FIGURES

Figure 1. Map of Ethiopia

Figure 2. Fiber Optic backbone.

Figure 3. ADSL Topology

Figure 4. WoredaNET Satellite based Network Structure.

Figure 5. VOIP Mechanisms.

Figure 6. Encoding Decoding Phase.

Figure 7. ISO model and Internet protocol correspondence.

TABLES

1 PROBLEM STATEMENT

Ethiopia has been a good example of a country where a digital divide exists. VOIP as an emerging business in Ethiopia has suffered the most mainly because of lack of proper infrastructure, inadequate broadband backbone and monopoly over internet services. The main aim of this thesis is to investigate VOIP implementation difficulties in Ethiopia. While doing so, it tries to see in depth what comprises Ethiopian internet and suggest what has to be done to improve VOIP service.

It is very crucial to understand how Internet and Telephony business operate in order to proceed with the investigation. All kinds of internet service in Ethiopia are examined to enable wise recommendations. Without an appropriate knowledge of VOIP fundamentals, the thesis would look like a machine deprived of power source.

In the end, the thesis investigates other African countries experiences and attempts to recommend to Ethiopian Telecommunications Corporation what needs to be improved in order to make VOIP flourish.

2 INTERNET AND TELEPHONY SERVICE IN ETHIOPIA

2.1 General Information Ethiopia

Ethiopia is the ninth largest country in Africa and is located in the northeastern region, popularly referred to as the Horn of Africa. As a landlocked country, Ethiopia is bound to the east by Djibouti and Somalia, to the north and northeast by Eritrea, to the south by Kenya and to the west by the Sudan. The total land area is 440,284 miles (1.1 million square kilometers). There are ten major rivers (7000 km long) and lakes (7400 sq. km. in area). (Website, Ethiopian Government official)

Figure 1. Map of Ethiopia

2.2 Ethiopian Telecommunication Corporation (ETC)

Ethiopian Telecommunication Corporation (ETC) is the oldest operator in Africa. It is under the supervision of the Ministry of Post and Communications. It is believed to be

King Menelik who brought telecommunications first time to Ethiopia. Ethiopia's main network is constituted from a variety of microwave, satellite and PANAFTEL terrestrial microwave network, connecting Ethiopia to other Southern and Eastern African countries via links to some neighboring countries. (Union, 2012)

Ethiopia is connected to the rest of the world with submarine gateways buried beneath the sea. There are about 1318 submarine gateways. ETC has also installed a fiber optic cable throughout the country to be able to deliver good service in digital radio, TV, internet and multimedia services.

Ethiopia has the lowest rates of mobile and internet penetration on the continent due to poor infrastructure and a government monopoly on the telecommunications. The ETC and the regulator, Ethiopian Telecommunication Agency (ETA) have an exclusive right to provide public switched communication, internet, data communication and GSM mobile communication.

While dealing with voice communications over IP network, a good fiber optic backbone has a great deal of importance towards that goal.

Much of ETC's current strategy, as directed by the government is to roll out voice services to every district in the country

2.3   ICT Infrastructure

ICT infrastructure is plays a major role in communication. Pure flow of information across the internet is achieved with good infrastructure. ICT infrastructure is a broad term used to describe the hardware used to interconnect users and networks. It includes fiber cables, satellite and antennas, television cables, routers etc. that regulate the dynamics of the communication.

ICT infrastructure is among the core ICT indicators in forming a global information society.

A UN report (UN, April 2008) publicized a core ICT indicator index based on

- ICT infrastructure and access

- Access to, and use of, ICT by households and individuals

- Use of ICT by businesses20

- The ICT sector and trade in ICT goods

The ICT infrastructure and access index measures using different indicators such as the number of fixed line subscribers, mobile users, computer users, internet subscribers etc. Table 1 shows the number of subscribers on internet and telephone.

Table 1. Subscribers of Internet and Telephone

Indicator	Population	Subscribers
Fixed(Wired) Broadband	87,302,819	6,772,000
Mobile-cellular telephone	87,302,819	14,126,659
Fixed Telephone	87,302,819	797,501

2.4 Market share

Ethiopian Telecommunication Agency (ETA) licensed ETC to provide the major telecom services. Other services that need ETA's license include:

- TV Receiver only

- Radio Communication

- Resale(Telephone, Fax or internet services separately)

- Tele center.

- In-house or building cable installation.

- Outside cabling or wire local loop lines installation or maintenance.

- Telecommunication exchange installation or maintenance.

- Satellite telephone service. (ETA)

Major services like fixed-line (Domestic and International), mobile services, international gateway, internet services, domain names etc. are under the monopoly of ETC.

2.5   Internet in Ethiopia

Apart from the normal telephony service, ETC has offered its customers a variety of internet connections. This thesis lists the services with their respective price lists in 2013. Compared to other African countries, the prices are not very high. The problem is with the quality of service.

The internet services provided by ETC are as follows:

- Dial-up Internet

- Asymmetric digital subscriber line(ADSL)/ Broadband wired Internet

- CDMA 2000 1X data only

- CDMA 2000 1X data + voice

- EVDO data only

2.6   Dial up Internet

Dial-up Internet access is a form of Internet access that uses the facilities of the Public Switched Telephone Network (PSTN) to establish a dialed connection to an Internet Service Provider (ISP) via telephone lines. The user's computer or router uses an attached modem to encode and decode Internet Protocol packets and control

information into and from analogue audio frequency signals, respectively. It has a downloading speed of up to 56 kb/s. (Ethio Telecom Web Page)

Internet which comes from a very slower connection like Dial-up will degrade voice quality. Table 2 below shows ETC's complete Dial-up service. The dial up internet has least preference with customers. It takes hours to compose and send an e- mail in this type of connection. VOIP cannot be implemented in this type of internet connection. ETC classified Dial-up internet in the narrowband internet services.

Table 2. ETC Dial-up package

Type of fee	Amount in birr/Ethiopian currency
Subscription fee	101,74
Minimum usage charge	40,00
Minimum utilization	600min
Utilization charge(in birr)	
Peak hour	0,1
Off peak hour	0,07
Peak Hour (> 1300 Minutes)	0,07
Off Peak Hour (> 1300 Minutes)	0,04
PSTN Dial Up Connection	Free
Mobile Internet Charge : 0,04/100kbs	

2.7 Code Division Multiple Access(CDMA)

CDMA service users transmit over the same communication channel. CDMA employs a special coding mechanism to be able to reduce any interference between users.

ETC's CDMA 2000 1X supports packet data speeds up to 153Kb/s. This narrowband internet is least preferable as Dial-up internet. VOIP cannot be implemented in this type of service.

2.8 Broadband Internet

Broadband internet is a relatively fast Internet service provided through wired and wireless connections with a speed level from 256Kbps for surfing, e-mail access, Ecommerce etc. (Ethio Telecom Web Page)

ETC has understood the benefits of broadband internet quite late. In March 2010 ETC signed a contract with SEACOM, an African owned submarine fiber optic cable system, to provide broadband fiber connectivity via a backhaul link through Djibouti.

Broadband internet is the back bone of excellent communication. In addition to VOIP, a reliable broadband internet used for:

- High speed web surfing

- Online education

- Video conferencing

- Cloud Computing, gaming

- Reduction of cost communication etc.

The national fiber backbone has been built by a Chinese owned company, ZTE. This 10,000km fiber optic cable connects 78 towns across the country with different connectivity speed. According to Hamilton (2009), Ethiopia is in the lowest rank within the sub-Saharan African countries.
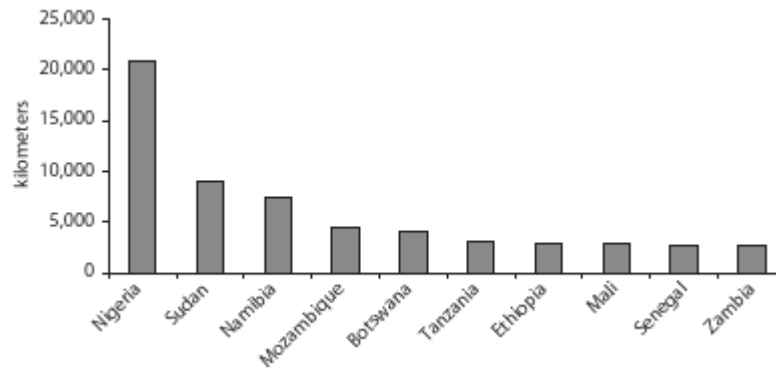
Figure 1. Fiber Optic backbone (Hamilton,2009)

2.9   Asymmetric Digital Subscriber Line (ADSL)

ADSL is a data communication technology that enables data to transfer faster through copper telephone lines by utilizing frequencies that are not used by the voice (Wikipedia).

This is the most reliable type of internet service ETC provides. It is a high speed reliable internet at an affordable price of 400birr which is approximately 15 euros.

VOIP can be well implemented with broadband internet with 256Kps and above speeds. Therefore, ETC's ADSL type Internet best suits for the implementation of VOIP.

For the purpose of comparison, in Finland a 10mps upload and 10mps download broadband ADSL connection costs around 25 euros without any restriction on the amount of data.

Table 3. ADSL Package of ETC

Speed	Bundle	Monthly Charge	Rate	Subscription fee

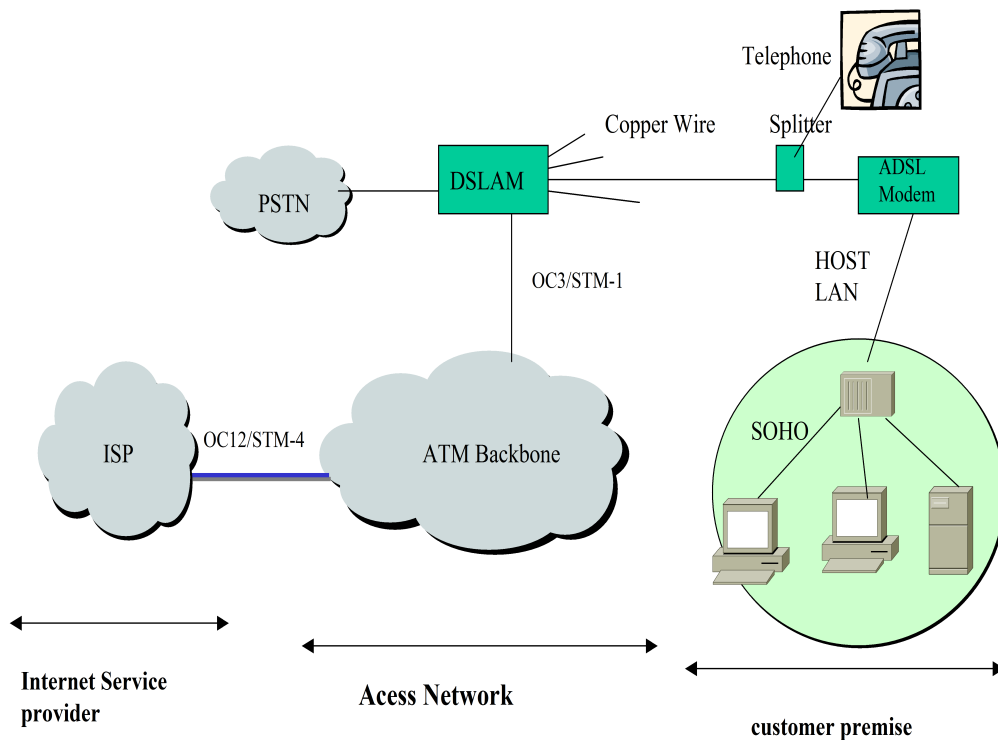|		in birr		in birr
512kbs	2GB	250,00	0,23	280
1mps	4GB	400,00	0,23	280
2mps	6GB	550,00	0,23	280

Figure 2.ADSL Topology (SchoolNET Ethiopia)

2.10 Wireless Broadband internet

ETC provides wireless internet service through different access methods.

AIRONET- This wireless technology supports 54mps downloading capacity near the source.

VSAT- This wireless technology supports 2mbps downloading capacity.

EV-DO- This service is most used with customers because it has a mobile nature. It can provide an internet speed level of 300Kbps-700Kbps. Since the introduction of EVDO, the number of internet subscribers doubled.

2.11 Web hosting

ETC provides web hosting services. Web hosting helps customers with providing server spaces to store their files. Surprisingly the, majority of functional websites are hosted abroad, in Europe and America.

It is the author's personal opinion that ETC or the government has intentionally degraded the level of internet connectivity to control the grey market revenue and fear of national security.

The Ethiopian government strategy was to implement a specific sector of public to benefit from ICT. Schools, government districts (Woredas) and agricultural units are among the targets.

2.12 SchoolNET

SchoolNET is a satellite based (VSAT) network aimed to provide secondary schools in the entire country with internet and TV-broadcasts. More than 550 schools are benefiting from this network. SchoolNET brought about unified and qualified education to students all over the country equally. In addition to this the satellite dish(as shown in Picture 1) can be used both for national and international traffic.

Picture 1. VSAT antenna

2.13 WoredaNET

WoredaNET is a terrestrial and satellite-based network primarily aimed to provide ICT services for various federal, government and regional districts. It connects more than 611 districts. WoredaNET through its videoconferencing facilities assists the Federal Supreme Court and district courts.

3. Satellite based Network Structure
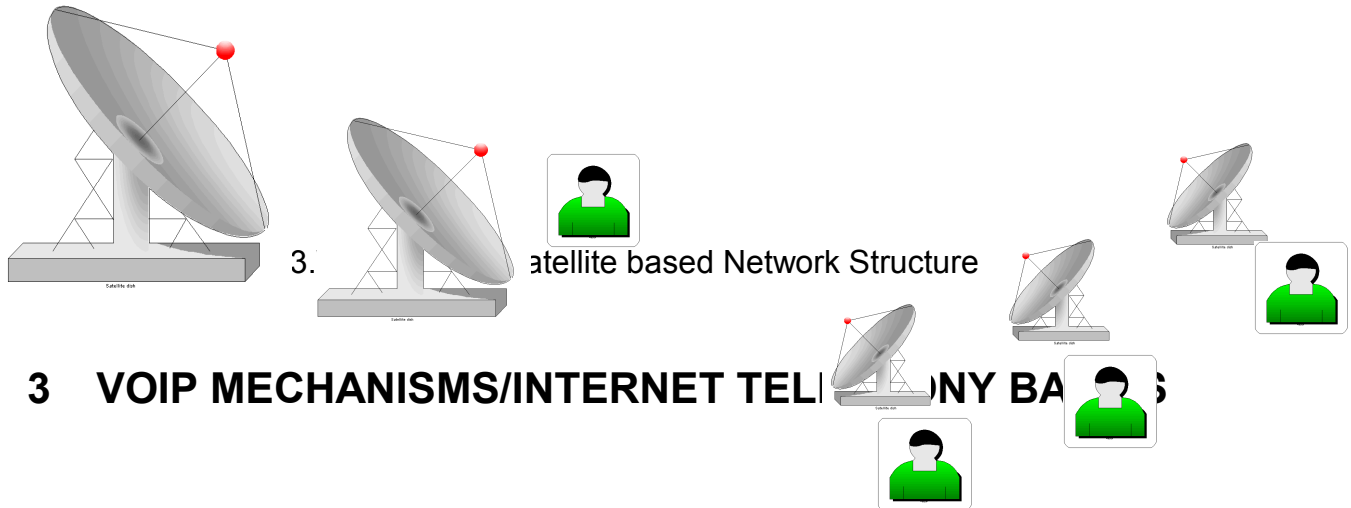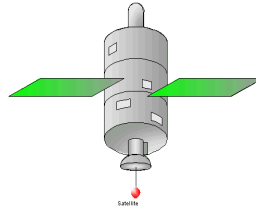
3 VOIP MECHANISMS/INTERNET TELEPHONY BASICS

3.1 Introduction

Simply put, VoIP is a way to have telephone conversations with others using the Internet rather than a traditional telephone line. So the acronym, VoIP, stands for Voice over Internet Protocol— a computer application that is used to send voice data over the Internet.

VOIP is a way of placing a conversation through internet rather than a dedicated telephone line.

In a traditional way, making a telephone call needs our phone to be connected to a jack in the wall that connects to the Public Switched Telephone Network (PSTN).The users picks up the phone, dials a number and the call is routed across telephone lines that traverse the nation. (Ledford, 2006)

VoIP differs by using the Internet to transport the call. So instead of being connected to a phone jack in the wall, the telephone is connected to an adapter that plugs into an

Internet connection. When a VoIP call is made, the user picks up the phone, dials the number and the call is transmitted via the Internet. (Ledford, 2006)

A typical VOIP network is shown in the Figure 5. Two VOIP gateways are connected to the IP network. A VOIP gateway is a device used to compress/decompress voice and fax, packet making, call routing and control signaling. Before the voice is transported into the IP network, the analog signal must be converted into digital format. At the receiving end, the digitized voice must be decoded. Both ends must support a voice codec in order to code and decode the voice.
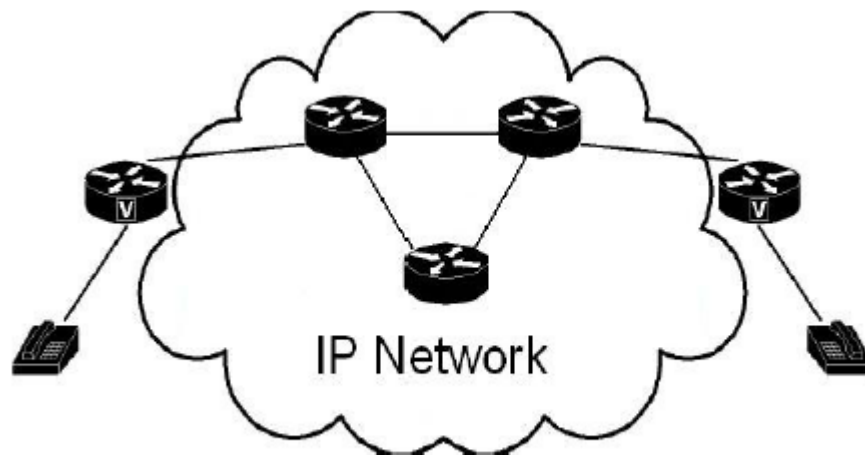

Figure 5. VOIP Mechanisms

3.2   Confusion on VOIP

The services we receive from Skype, Yahoo Messenger, MSN, Viber, Tango and many others are regarded as VOIP. They are simply proprietary systems built for users who own the same software to communicate easily.

However if we want to make a VOIP call to someone who does not have a VOIP, then we need to pay for a *gateway service* which bridge the VOIP and the ISP's phone network (PSTN).

Calling a regular phone will always involve a cost because a carrier has to be involved during the process.

It is known that Ethiopia is one of the countries with the lowest internet penetration rate in the world. The government has to invest to improve ICT infrastructures and liberalize its regulations.

3.3 Circuit- Switching

Circuit- Switching is the basis of the Public Switched Telephone Network(PSTN). This type of connection is known for dedicating end to end connection while making a call.Full bandwidth is consumed until both parties hang up the phone.

Public Switched Telephone Network (PSTN) is a network of the world's public circuit switched telephone networks (Wikipedia). The switching centers interconnect telephone lines, cellular networks and undersea telephone cables, enabling telephones in the whole world to communicate with each other.

PSTN combines analog, digital and electromechanical data links that strive to make sure that every time a user picks up their phone receiver, the user hears a dial-tone. (Wallingford, June 2005)

3.4 Packet-switching

Unlike Circuit-Switching which dedicates a physical copper connection between the caller and receiver, Packet-Switching is a connectionless communication whereby data is routed across the network based on the destination address on the packet.

 While dealing with voice, it is important to know how to represent the speech in a digital form with minimal bit rate to conserve bandwidth.
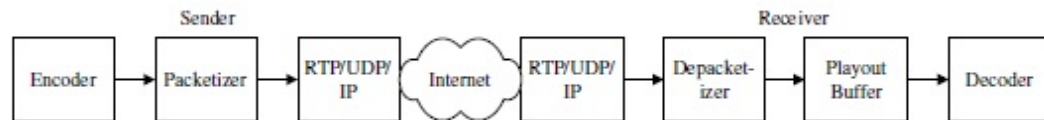

Figure 6. Encoding Decoding Phase

As shown in Fig 6, the voice data has to be encoded and packetized. To use the IP network model, the voice has to be packetized with information about the destination. IP phones are capable of performing the digitization, compression and packetization and transfer of the packet data through an Ethernet connection.

IP gateways /VOIP gateways can be used to interface voice signals coming from IP phones or analog signals to convert them into a VOIP packet stream.

3.5 CODECS

CODECS refers to Coder/Decoder devices in the IP phones or IP gateways which perform the actual digitization, compression and packetizing. Based on the bandwidth availability and acceptable voice quality, it is appropriate to choose a codec that compresses a voice. There are quite many CODECS in use but the most widely used voice and video CODECS are:

- G.711

G.711 produces audio uncompressed to 64Kbps. It uses Pulse-code modulation (PCM), a method used to digitally represent sampled analog signals, coding type and is used within LAN due to having enormous bandwidth and being inexpensive. Most sound cards support and able to record directly in G.711 format.

- G.729

G.729 produces audio compression to 8Kbps. It is used across WAN links because of the bandwidth savings and reliable voice quality (Ellis, 2003).

3.6   The ISO (International Standard Organization) Model

It is very important to know the Internet Protocol stack that make up the voice packet before going through the fundamentals of the voice codec and packetizing process.

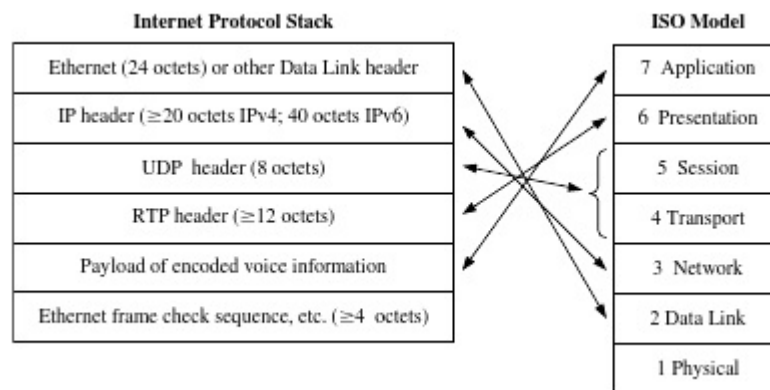| Internet Protocol Stack	ISO Model
Ethernet (24 octets) or other Data Link header	7 Application
IP header ($\geq$20 octets IPv4; 40 octets IPv6)	6 Presentation
UDP header (8 octets)	5 Session
RTP header ($\geq$12 octets)	4 Transport
Payload of encoded voice information	3 Network
Ethernet frame check sequence, etc. ($\geq$4 octets)	2 Data Link
	1 Physical

Figure 7.ISO model and Internet protocol correspondence

The concern of this thesis is on the ISO layer 3 and layer 4. Layer is the position of the Internet Protocol (IP). The main function of IP is to send packets across the internet. IP does not assure the delivery of packets. While dealing with voice, packet delivery assurance is the main issue.

VOIP implements two sets of protocols:

- Protocols that provide signaling and call control (SIP, H.323,MGCP)

- Protocols that carry voice payloads (UDP,RTP,RTCP)

3.7 User Datagram Protocol (UDP)

UDP is suitable for purposes where error checking and correction is either not necessary or performed in the application, avoiding the overhead of such processing at the network interface level. (Wikipedia)

For time sensitive applications like VOIP, it is better to drop the packet instead of waiting for a missing packet. Streaming media, real-time multiplexing games are other applications that use UDP. When there happens to be a need for strong reliability, Transmission Control Protocol (TCP) might be used. UDP provides no assurance about proper delivery for upper layer protocols. This is why UDP is considered as unreliable datagram protocol.

3.8 Real Time Transfer Protocol (RTP)

RTP defines a standardized packet format for delivering audio and video over IP network (Hersent, 2010).

After the voice gets digitized and encoded using the Codec mechanisms, RTP takes the responsibility of streaming the data across the network.

RTP's main service includes timing recovery, loss detection and correction, payload and source identification etc. RTP helps receivers to compensate for the jitter, which the IP network brings. RTP has no power to control the network delay or packet drop. Rather it facilitates a receiver to recover from a network jitter by adopting different mechanisms like buffering and sequencing. By doing so, more information is available on the network to make a corrective measure.

The figure below shows a typical RTP header format.

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|V=2|P|X|  CC   |M|     PT      |       sequence number         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           timestamp                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           synchronization source (SSRC) identifier            |
+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+
|            contributing source (CSRC) identifiers             |
|                      ....       (optional)                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            data...                                            |
|                                                               |
```
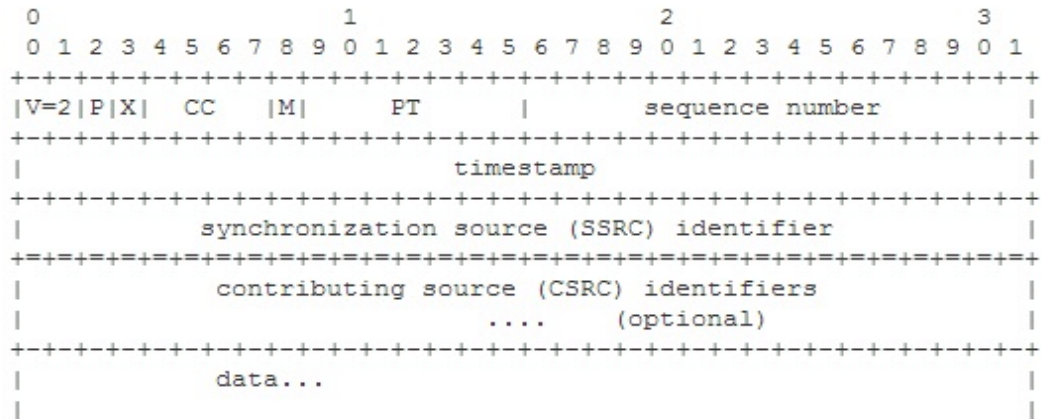
Figure 8. RTP Header

Version(V)

This is RTP version identifier and 2 signifies the version number

Padding(P)

The padding shows if the payload has been padded

Extension(X):

This indicates the presence of one variable-length header extension.

Payload Type (PT):

The payload format indicates how to interpret the payload at the receiver.

Sequence number (SN):

Sequence number increments by one whenever a packet sent. The receiver can use the SN to check lost packets.

Timestamp:

Timestamp helps the receiver to calculate jitter and synchronize in different streams.

SSRC:

The synchronization source identifier is a random number which must be unique within the RTP session. Each source data has a unique number to enable the receiver to keep related packets together when played back.

4 ADVANTAGES AND DISADVANTAGES OF VOIP

There are many reasons to switch to VOIP in today's telecommunication technology. VOIP has a number of drawbacks which have been major targets to tackle in the future.

4.1 Advantages

Low cost - With the help of VOIP providers one can make a free call from PC-to –PC. The cost of PC-to –phone is not even so high compared to the traditional ones.

Easy deployment - VOIP is more suitable to deploy in homes and business.

Simplicity - VOIP requires an IP network. Compared to the old PBX system ,which requires a network of copper wires.

Portability - With the presence of broadband internet, one can make a VOIP call without any problem.

4.2 Disadvantages

It is very important to know the factors which degrade a VOIP call. The traditional telephony system, PSTN, assures quality of service (QoS) by allocating a dedicated bandwidth to overcome latency and congestion issues.

Latency -

 Latency or delay is defined as the amount of time it takes for speech to exit the speaker's mouth and reach the listener's ear. (Bhatia, July 2006)

Jitter -

Jitter is the variation in packet arrival time. Jitter is one issue that exists only in packet-based networks. While in packet environment, the sender is expected to reliably transmit voice packets at a regular interval. (Bhatia, July 2006)

Packet Loss –

Many data protocols use packet loss so that they know the condition of the network and can reduce the number of packets they are sending. It is important to build a network that can handle voice traffic in a reliable and timely manner.

Echo –

Hearing your own voice while talking in a phone is major problem in VOIP. A louder echo can be very annoying.

5 ALTERNATIVE SOLUTIONS

5.1 Variety of ISP

ETA has to make a crucial step forward to liberalize its regulations and allow competition in this area. Private ISPs have to emerge in the market for competition and quality of service.

A lot has been said about ETC's monopoly on this area. The outcome has been clearly reflected in Ethiopia's rate in the internet and telephony penetration indexes. Other African incumbent operators, like Kenya and South Africa are licensing private ISPs. Doing so has benefited citizens to choose providers based on cost and service.
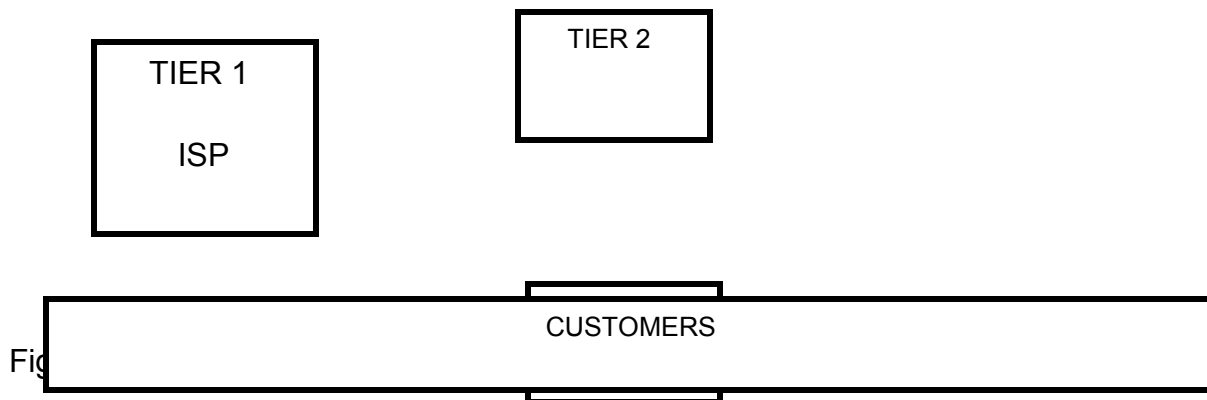
The figure above shows a model of ISP interaction. Unfortunately, in Ethiopia there is only one ISP. All incoming and outgoing packets have to pass through the ETC's routers. Tier 1 ISPs own the broadband infrastructure, routers, and switches. It would have been more beneficial to license more Tier 1 ISPs and share the cost of infrastructure. The author proposes TIER 2 and TIER 3 ISPs to emerge, which is more logical for the situation in Ethiopia.

Tier 2 ISP does operate beneath Tier 1's. They are one router hop away from the core of the internet. Tier 3 ISPs are customers of higher ISP's to provide services for their customers.

5.2   Internet eXchange Point (IXP)

ETC is the sole provider of internet and owner of the ICT infrastructure. In this study, the author found out that licensing private companies to use the Infrastructure is very crucial for VOIP and other telephony and internet services to flourish (Williams, 06/2011). Competition creates better service for the customers.

IXP is a physical network infrastructure that allows networks to interconnect directly, via the exchange, rather than through one or more 3rd party networks. The advantages of the direct interconnection are numerous, but the primary reasons are cost, latency, and bandwidth. Traffic passing through an exchange is typically not billed by any party, whereas traffic to an ISP's upstream provider is (White Africa Blog)

In other words, IXP can be considered as a location where two or more different ISP's meet. Establishing IXPs that can route packets between ISP's can minimize the cost of international transit. Figure 10 below (Tatipamula, 02/2012) shows IXP as an intermediary between ISPs.
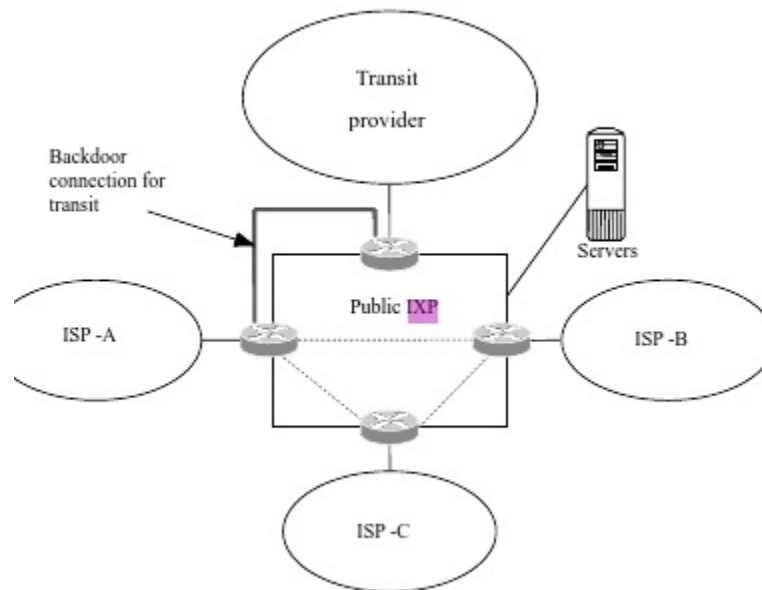
Figure 10.Internet Exchange Point

There are not many IXPs in Africa but none in Ethiopia. It might appear unrealistic to implement IXP when there is only one ISP in the country. Benefits of IXP as mentioned by The International Communication Unit (ICU) ITC policy forum 2013 are:

- Enabling local peering of domestic traffic

- Increasing the number of route options available

- Optimizing use of international internet connectivity

- Reducing transmission costs

- Increasing internet penetration etc.

IXP is a logical point to offer value-added services such as Web hosting, caching, and content distribution. This makes the IXP as important to the function of the internet as the ISP's internal network themselves. (Tatipamula, 02/2012)

VOIP service can be provided too as value-added service. It creates a win -win situation for the incumbents and IXP holders.

As Figure 11 below shows each Autonomous System (ASes) or ISPs share the IXP routers and switches to interconnect to each other. The cost involved with the ASes is only the circuit connection to the IXP. Routing is performed on the premises of the IXP.
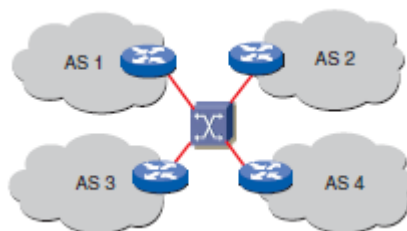

Figure 11.Autonomous Systems. (Kuai XU, 2010 USA)

6 CONCLUSION

There is a number of problems regarding Ethiopian internet service and VOIP as part of a service. The problems were poor ICT infrastructure, invisible broadband backbone, closed competition and so on. The first action that should be taken is to enhance the fiber optic installation. This can alleviate the problem of internet in general. A better internet can make VOIP and other value added services flourish.

The second most important factor is regulation. New ISPs have to emerge in the country. This can create competition in the market. In addition to that the more ISPs come to the market, the better the ICT infrastructure becomes. This is because ISPs

share the cost of infrastructure. Whenever there is a need to reach remote areas, all ISPs can invest on fiber optic installation and in general invest on ICT infrastructure.

Regarding VOIP services, ETC has to make a crucial step to enhance the voice services. This can be achieved by deploying more voice gateways that can process voice data, supplying affordable IP phones and work hard to increase the internet penetration rate. ETC has to work hard to provide good services to customers.

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