Low and Expensive Bandwidth Remains Key Bottleneck for Nigeria's Internet Diffusion: A Proposal for a Solution Model.

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Abstract

Although Internet and telephone density has experienced quantum growth in the last ten years since President Obasanjo's Telecommunications Deregulation policy, a large proportion of the citizens, particularly those living in the remote communities do not still have access to telephone and the Internet. Part of the problem is the continuing collapse of local Internet Service Providers (ISPs) which has been attributed to high cost of bandwidth paid in US Dollars, absence of good energy supply, weak and poor service delivery. These bottlenecks have dwarfed the expectations of the citizens to fully participate in the new world economic order galvanized by e-commerce and world trade. It is estimated that M.I.T in Boston USA has bandwidth allocation that surpasses all the bandwidth allocated to Nigeria put together. Low bandwidth has been found to handicap effective Research and Development efforts by academics and professionals in Nigeria's tertiary institutions. To create a quantum leap for accelerated diffusion of Internet and telephone applications, there is urgent need for private/public sector intervention and collaboration to improve current ICT infrastructure and Local Bandwidth capacity in order to reduce cost of application and improve ***Quality of Service.*** *We have proposed as solution- the launching of additional communications satellites in the orbit, aggressive deployment of broadband wireless technology, construction of fibre optics backbone around the country to link to Africa-1 hub, Free Space Optics, WiMax Technologies to expand density. The National Communications Commission (NCC) which is the Apex body that allocates spectrums should put up effective control mechanisms for radio frequency users to improve infrastructure and Quality of Service. This paper has also attempted to provide mathematical guide for the accurate estimation of bandwidth requirements for organizations to reduce cost of monthly subscription.*

Key Words: ISPs, Quality of Service, Internet Diffusion, energy supply, bottlenecks, Bandwidth tariff.

1.0 Introduction

M'bow, the former UNESCO Scribe, had captured what the introduction to this topic should be last 40 years ago: *"Information Technology has opened up such tremendous vista for modern societies that any failure to master it would mean a life of permanent subordination. For information technology is more than a form of power, it is a power system. The technology which it involves is not just one form of technology among others but an ability to make use of other techniques to give or refuse access to a whole range of scientific data and knowledge and thus to design new models of development* **[10]**

A critical examination of the above statement suggests far-reaching implications for socio-economic and technological development of the third world nations. That is to say a nation that plays lip service to information technology infrastructural development, application and training is likely to lead a wasted generation! This technology is said to have broken traditional walls that divide and shape unique sovereignties. *It is not just a technology; it is a form of power system* [11].

If you have ever visited, lived or worked in the United States of America, and the developed West, you will get the import of M'bow's statement. Nations are today galvanized by IT, its sociology, business and technology and how people live and work. You will also agree with us that although the Federal Government and the Private Sector have made efforts to leapfrog the gap chasm and eliminate the digital divide, the road to the ***Promised Land*** is still far from sight. Academic literature you can download in one week say in the US, Canada or Europe will take you close to six months to download same in Nigeria if you have regular power supply and link to the Internet. It may also be very costly. 8g per month by Glo Network costs N7500! The secret for the developed West is that there is high bandwidth deployment because they have been able to develop ICT infrastructure such as strong terrestrial telephone network, fibre optics backbone and communications satellites. You hardly will see RF and microwave antennas litter the ionosphere and landscape. This infrastructural base has given the developed west solid foundation for IT diffusion. This has also brought down the cost of bandwidth, and improved the speed and quality of service by operators. Most cities are linked by fibre optics rings and these countries rely less on wireless technology. The truth is that we are trying really to leapfrog even with bad legs – no electricity, no strong telephone infrastructure, no fibre optics ring, no strong satellite capability!

In the few short years of existence, the Internet has shown that despite security concerns and slow access, it can deliver on the long sought after goal of electronic commerce and global integration. For its ease of use, low cost and extensive world coverage, it has attained stunning and rapid success which no other system has come close to delivering these fundamentals in our time. The Internet has portrayed itself as a tool for educational development, a tool for technological emancipation. It has introduced many services which has galvanized our world into one virtual electronic village. One of the excellent services provided by the Internet is the email and associated services.

Today the value of e-commerce trade is in the range of 240 billion US Dollars. The internet is hitherto the world's biggest market place and any nation that fails to capitalize on this economic enabler stands to be poor and doomed for life. This explains why this paper is significant. What are the governments and the private sector doing to expand internet density and national bandwidth for delivery of Quality of Service? Low bandwidth in Nigeria and the presence of several bottlenecks which will be discussed later in this paper, has contributed in no small measure to low IT diffusion in Nigeria.

2.0 **Research Background** – NCC and Radio Frequency Allocation in Nigeria, internet diffusion in and current situation

Telecommunication facilities in Nigeria were first established in 1886 by the colonial administration. At independence in 1960, with a population of roughly 40 million people, the country only had about 18,724 phone lines for use. This translated to a teledensity of about 0.5 telephone lines per 1,000 people. The telephone network consisted of 121 exchanges of which 116 were of the manual (magneto) type and only 5 were automatic.

Bandwidth refers to the rate of data transfer that is the capacity of the Internet connection that you use. The greater the capacity, the more speed of uploading and downloading of data [12]. Low bandwidth slows down data transfer which can occur as a result of network overload. As at 2002 bandwidth allocated to some African countries are show in Table 1. Table 2 presents current bandwidth utilization by some African Universities. Compare this with Table 3 which has information on the Bandwidth utilization in the developed West. You can observe how ridiculously low they are. This explains why Local ISPs are packing up – the high cost of bandwidth and inability to obtain adequate bandwidth to meet the needs of users. This explains the poor quality of service and lack of interest in the use of services provided by ISPs [8] [9] [12].

Nigeria does not have a national network backbone. The SAT-3/WASC submarine cable project with a landing point in Bonny has been completed to develop an international fiber link to Lagos, but the lack of national network backbone infrastructure implies that more than 90 per cent of the country is currently left out [13]. However in 2002, Nigeria added 1.3 million new mobile customers and reported the highest annual growth rate – 369 percent – in the world [13]. During this period of telecom deregulation, Nigeria licensed another national carrier – Globacom – to compete with the incumbent national fixed line operator, Nitel, which is now moribund. The National Communications Commission (NCC) which is the Regulatory authority for licensing Telecom firms issued 25 Fixed Wireless Access to operators. Because of the near absence of telephone infrastructure, Internet distribution is highly skewed towards the major cities such as Lagos, Port Harcourt, Ile-Ife, Abuja, Kano, Enugu, Owerri, Oshogbo and Kaduna.

Motivation for Deregulation

The main reasons for deregulating the Nigerian telecom industry, within the context of National Communications Commission Decree No. 75 of 1992, can be summarized thus:

- The inability and unwillingness of government to continue to subsidize the public telecom company, NITEL;
- The need to spread some of the burden of running telecom services to the private sector;
- A growing demand for more efficient and enhanced modern facilities especially by the business community;
- The generally poor service delivery, and a slow growth of the infrastructure, access by rural populations, and Quality of Service (QoS);
- The global trend towards liberalization of telecom services towards a free market economy [14]

Provisions of the Deregulation Act empowered NCC to license four distinct categories of entities in the telecom sector. These include:

- Carriers, defined to include owners of networks and trunks.
- Authorized operators of telecom services to provide public services.
- User operators who operate their own network mainly for their internal communication needs.
- Technical services e.g. equipment/system installation, repair and maintenance, and cabling.

Up till quite recently, Internet link in Nigeria is powered by foreign satellite firms in New York, Italy, Germany and some other advanced countries of the world**.** This deregulation is intended to leapfrog current gap chasm in digital technology and to accelerate the growth of Internet diffusion. This has yielded fruit. The deployment of Nigeria's .ng Domain which makes it possible for internet addresses to be allocated using Nigerian domain name, .ng. Current development efforts are praiseworthy but more needs to be done. Table 1 below presents statistics of growth of the Telecommunications sector in Nigeria from 2000-2004 while Table 1.1 provides evidence of the contribution of the telecom sector to GDP growth.

Table 1: Growth of the Telecommunication Sector in Nigeria from 2000-2004 [19]

	2000	2001	2002	2003	2004
Population	120,000,000	120,000,000	120,000,000	120,000,000	120,000,000
Households	12,800,524	13,173,020	13,545,516	13,893,868	14,254,520
Fixed	553,374	600,321	702,000	888,534	1,027,519
Mobile	35,000	266,461	1,569,050	3,149,472	9,174,209
Total	588,374	866,782	2,271,050	1,038,006	10,201,728
Internet Users	107,194	153,350	420,000	1,613,258	1,769,661
Internet Penetration (%)	0.1	0.1	0.3	1.3	1.5
Net New Additions (Fixed)	80,058	46,947	101,679	186,534	138,985
Net New Additions (Mobile)		231,461	1,302,589	1,580,422	6,024,737
Net New Additions (Total)	80,058	278,408	1,404,268	1,766,956	6,163,722
Teledensity (%)	0.49	0.72	1.89	3.36	8.5
Fixed Growth (%)	16.9	8.5	16.9	26.6	15.6
Mobile Growth (%)	0.0	661.3	488.8	100.7	191.3
Total Growth (%)	15.7	47.3	162.0	77.8	152.6
Growth in Internet Users (%)		43.06	173.88	284.11	9.69
Teledensity Growth (%)	16.7	46.9	162.5	77.8	153.0

Source: Nigeria Communications Commission (NCC) (2005).

Table 1.1 Telecom's Contribution to the GDP 2000 2004

	2000	2004
Sectoral Growth of the Telecommunication Component of the GDP	8.0	30.0
Sectoral Contribution to GDP (%) by the Communication Sector[2]	0.11	1.14
Total Telecommunication Revenue (% of GDP)	0.8	3.5
Total Telecommunication Investment (% of Revenue)	37.2	18.1

Sources: CBN Annual Report and Statement of Accounts (Various Years) and NCC (2005).

The Current situation

Table 2 lists current market growth and operator share of the market as at 2010 [15]
Table 2 presents Installed Capacity, active lines and connected lines as at August 2010. Table 3: provides information on Mobile Operator share of the market.

Table 2 : installed capacity, active lines and connected lines as at August 2010

Lines	Connected Lines	Active Lines	Installed Capacity
GSM	95,718,928	74,074,793	134,025,308
CDMA	11,706,269	6,616,457	75,415,597
Fixed Wired/ Wireless	2,722,322	1,239,973	9,315,277
Total	**110,147,519**	**81,931,223**	**218,756,182**

Source: NCC, 2010

Table 2 indicates that Nigeria has had a quantum leap.

From a mere 18,724 Lines in 1960 [19], connected lines has jumped to 110,147,519, active stood at 81,931,223 providing total installed capacity of 218,756,182. Studies have also shown that there is a positive relationship between telecommunication infrastructure development and economic growth [19]. This explains why Nigeria remains the fastest growing market for telecom operators in the world. However, these figures do not suggest that Nigeria has reached her optimum. There are still many remote communities who are yet to smell neither telephone nor the Internet. In most cases, these group of citizens have to come to the cities to write and send their mails. This means a lot of work remains to be done in the areas of infrastructure and diffusion.

Table 3: Mobile Operator share of the market

Technology	% share
GSM	87.24
CDMA	10.65
Fixed	2.12
TOTAL	100

Source: NCC, 2010

Table 3 gives GSM 87.24% share of the total telecom market, followed by CDMA (10.65) and Fixed lines 2.12%. This implies that broad band technology represented by GSM is now the Lord of the Nigerian telecom market. This estimate has been crossed in 2013.

3.0 Need for adequate bandwidth for Internet applications

Router's instability affects badly the speed of processing in a network. However, stability of the router increases the speed of processing and reduces delay which affects browsing speed. It is therefore recommended that for better routing stability and efficiency, you ought to increase your bandwidth to avoid very slow internet access. This factor explains why most internet cafes in Nigeria are not able to deliver quality service, low bandwidth but expensive bandwidth regime [19] [20].

How is bandwidth measured?

Since bandwidth generally refers to a capacity of a communication line i.e. the amount of information that can be transferred from one point to another, its measurement units are the same as those of disk space and monthly traffic - bits, bytes, kilobytes (Kbps), megabytes (Mbps) and gigabytes (Gbps). The standard bandwidth period is considered to be second, so when we refer to a bandwidth quota we say such and such kilobytes per second.

Bandwidth and ISPs

As a medium between the global network and your computer, the ISP is connected to the Internet at a much higher speed than the speed you get as an Internet subscriber. Its main function is to rent portions of the expensive high-speed connection to you and thus ensure the Internet access that you need at an affordable price. The various Internet access technologies currently offered have different bandwidth standards. For instance, the dial-up Internet provides a very narrow bandwidth limit of about 50 Kbps per second, while the broadband connection ensured by the DSL or the LAN Internet allows data transfer at a much higher speed, ranging from 128 Kbps to 2,000 Kbps. So this means you can browse through the web and download stuff much faster if you have broadband Internet connection at home or in the office than if you use dial-up.

Bandwidth and web hosting

The bandwidth is also a factor you should consider when selecting your web hosting provider. If you intend to run your own website, you will need to search for a host that provides the best combination of resources for keeping your site online. While most of the features included in a hosting offer represent server resources, the bandwidth refers to the Internet connection between the servers in the data center where your site is hosted and the data center's ISP.

Difference between bandwidth and traffic

In the field of web hosting, the term 'bandwidth' is often incorrectly considered as a synonym of 'data transfer'. Web hosting providers often use it to designate the maximum amount of data transferred between a website and a user's computer over a certain period of time, most often a month. However, from a technical point of view, considering the fact that the bandwidth refers to the speed at which data is transferred, not the data amount itself, this use is not appropriate and the correct term to apply should be data transfer (or monthly traffic).

Application Areas demanding High Bandwidth

Bandwidth is a scarce resource. There are a number of areas where extremely high-bandwidth networking is required to support scientific research community: These include graphical visualization of supercomputer results through the movement of high rate sensor data from space to the ground-based scientific investigator. Others are military command and control where there is need to quickly access and act on data obtained from real-time sensors. Other areas include battle management, war gaming or process control applications where extremely short response times are critical to accomplish as many as hundreds of interactions in real time. So there is need to develop and achieve raw bandwidth in Gigabit and Terabits per second given current and emerging Information Technology applications. Absence of adequate bandwidth has terribly dwarfed application of Information Technology (IT) in scientific research and development in Nigeria and Africa. This has to be urgently addressed. So how will Nigeria develop indigenous capacity to provide raw bandwidth on the order of several Mbits/s to a large number of users in a cost-effective manner through the aggregation of communications traffic?

4.0 Current bottlenecks

There are many bottlenecks. These include:

- **Poor energy supply**. This implies that most of the time, generating sets are used to power IT systems. This increases the cost of application as much as twice the cost of public electricity supply. This is one of the factors responsible for the collapse of most ISPs and Internet Cafes.
- **Poor Service Delivery:** Most internet access facilities are very slow. Downloads are very difficult and takes much time. More time implies additional cost of application. This performance de-motivates users who need information for research but are not able to have them when they need them.
- **High tariffs of between 20K and 50k per second**

There is currently a price war amongst telecom operators. Only Airtel offer 20k per seconds. Average tariff in Nigeria is 35k per second which is the highest in the world! Because of the destruction of telecom infrastructure in the northern part of Nigeria, operators whose masts were destroyed are proposing dynamic price regime such that troubled states will pay more than peaceful states.[19]

In a recent research conducted by Hassan, Afees Olumide of the Department of Political Science and Public Administration, Fountain University, Oshogbo [15], it was discovered that current bottlenecks include network failure, network congestions, charging for undelivered SMS, call drops, over billing, inability to connect other networks, poor connections, inability to recharge, inability to check balance and disappearance of credit. Table 4 catalogues the complaints and per cent of users who participated in the survey and rating of complaints in (%).

Table 4: Telecom User complaints

S/N	Complaints	% of users	Rating of Complaints (%)
Telephone			
1	Network failure	60.8	15.71
2	Network congestions	50.4	13.01
3	Charging for undelivered SMS	43.6	11.26
4	Call drops	42.7	11.03
5	Over billing	42.7	11.03
6	Inability to connect other networks	35.0	9.04
7	Poor connections	34.2	8.84
8	Inability to recharge	33.3	8.60
9	Inability to check balance	28.2	7.28
10	Disappearance of credit	16.2	4.18
	TOTAL		**100.00**
Internet			
1	Slow downloads	71.8	42.81
2.	Connection failure/drops	54.7	32.62
3	Inability to connect	41.2	24.57
	TOTAL		**100.00**

Source: Field Survey, 2010

These findings were reinforced by the works of Ekwonwune [16] and Nwakamma et.al. [17]. Nwakamma had found out that high tariff by telecom operators have been the key factor militating against internet growth and diffusion in Nigeria. Ekwonwune attributed the collapse of the local ISPs to poor irregular electricity generation and high bandwidth costs from satellite providers.

5.0 Estimating your bandwidth Requirements using bandwidth metrics

Bandwidth Capacity Requirement Metrics:

A layer-2 link can normally transfer data at a constant bit rate called transmission rate of the segment. For example this rate is 10Mbps on a 10BaseT Ethernet segment, and 1.544Mbps on a T1 segment. The transmission rate of a segment is limited by both the physical bandwidth of the underlying propagation medium as well as its electronic or optical transmitter and receiver hardware. Thus, at the IP layer a hop delivers a lower rate than its nominal transmission rate due to the overhead of layer-2 encapsulation and framing. Suppose that the nominal capacity of segment is C_{L2}, then the transmission time for an IP packet of size LL3 bytes can be calculated thus:

$$\Delta_{L3} = \frac{L_{L3} + H_{L2}}{C_{L2}} \quad (1)$$

where H_{L2} is the total layer-q overhead (in bytes needed to encapsulate the IP packet. Therefore the capacity CL3 of that segment at the IP layer can be calculated thus:

$$C_{L3} = \frac{L_{L3}}{\Delta_{L3}} = \frac{L_{L3}}{\frac{L_{L3}+H_{L2}}{C_{L2}}} = C_{L2}\frac{1}{1 + \frac{H_{L2}}{L_{L3}}} \quad (2)$$

IP networks do not provide explicit feedback to end hosts regarding the load or capacity of the network. Instead hosts use active end-to-end measurements in an attempt to estimate the bandwidth characteristics of paths they use. Thus, at any specific instance in time, a link is either transmitting a packet at the full link capacity or it is idle, so the instantaneous utilization of a link can only be either or. Accordingly, any meaningful definition of available bandwidth requires time averaging of the instantaneous utilization over the time interval of interest [18]. The average utilization

- $\bar{u}(t-\tau,t)$ for a time period $(t-\tau,t)$ is :

$$\bar{u}(t-\tau,t) = \frac{1}{\tau}\int_{t-\tau}^{t} u(x)\,dx \quad (3)$$

where u(x) is the instantaneous available bandwidth of the link at time x . We refer to the time length as the averaging timescale of the available bandwidth.

After a packet pair goes through each link along an otherwise empty path, the dispersion that the receiver will measure is:

$$\Delta_R = \max_{i=0,\dots,H}\left(\frac{L}{C_i}\right) = \frac{L}{\min_{i=0,\dots,H}(C_i)} = \frac{L}{C} \quad (4)$$

where C is the end-to-end capacity of the path. Thus the receiver can estimate the path capacity from $C = L/\Delta_R$.

Thus, the minimum link capacity in the path determines the end-to-end capacity C, i.e.

$$C = \min_{i=1,\ldots,H} C_i \qquad (5)$$

Where C_i is the capacity of the *i*-th hop, and H is the number of hops in the path. The hop with the minimum capacity is the narrow link on the path

.

$$\Delta_{L3} = \frac{L_{L3} + H_{L2}}{C_{L2}} \qquad (6)$$

Where HL2 is the total layer-2 overhead (in bytes needed to encapsulate the IP packet. Therefore the capacity CL3 of that segment at the IP layer can be calculated thus:

$$C_{L3} = \frac{L_{L3}}{\Delta_{L3}} = \frac{L_{L3}}{\frac{L_{L3}+H_{L2}}{C_{L2}}} = C_{L2}\frac{1}{1+\frac{H_{L2}}{L_{L3}}} \qquad (7)$$

After a packet pair goes through each link along an otherwise empty path, the dispersion d_R that the receiver will measure can be calculated thus:

:

$$\Delta_R = \max_{i=0,\ldots,H}\left(\frac{L}{C_i}\right) = \frac{L}{\min_{i=0,\ldots,H}(C_i)} = \frac{L}{C} \qquad (8)$$

where C is the end-to-end capacity of the path. Thus the receiver can estimate the path capacity from $C = L/\Delta_R$.

Taxonomy of Bandwidth Estimation Tools

Only few bandwidth capacity calculations are presented above. However, full discussion on the above taxonomies is a subject of another journal paper. Table 5 provides Taxonomy of bandwidth estimation tools as presented by R.S. Prasad et.al [18]. Table 5 gives the names of these tools together with the target bandwidth metric they try to estimate and the basic methodology used.

Table 5 Taxonomy of Bandwidth Estimation Tools

Tool	Author	Measurement metric	Methodology
pathchar	Jacobson	Per-hop Capacity	Variable Packet Size
clink	Downey	Per-hop Capacity	Variable Packet Size
pchar	Mah	Per-hop Capacity	Variable Packet Size
bprobe	Carter	End-to-End Capacity	Packet Pairs
nettimer	Lai	End-to-End Capacity	Packet Pairs
pathrate	Dovrolis-Prasad	End-to-End Capacity	Packet Pairs & Trains
sprobe	Saroiu	End-to-End Capacity	Packet Pairs
cprobe	Carter	End-to-End Available-bw	Packet Trains
pathload	Jain-Dovrolis	End-to-End Available-bw	Self-Loading Periodic Streams
IGI	Hu	End-to-End Available-bw	Self-Loading Periodic Streams
pathChirp	Ribeiro	End-to-End Available-bw	Self-Loading Packet Chirps
treno	Mathis	Bulk Transfer Capacity	Emulated TCP throughput
cap	Allman	Bulk Transfer Capacity	Standardized TCP throughput
ttcp	Muuss	Achievable TCP throughput	TCP connection
Iperf	NLANR	Achievable TCP throughput	Parallel TCP connections
Netperf	NLANR	Achievable TCP throughput	Parallel TCP connections

Source [18]

How National Bandwidth capacity may be enhanced.

National Bandwidth capacity can be increased via expansion of broadband access such as WiMix and Free Space Optics Technology (FSO), deployment of Fibre optics ring backbone, launch of additional communications satellites in the orbit and expansion of submarine cables. The following paragraphs present other technical options for increasing national bandwidth capacity.

Suggested Strategies to increase raw bandwidth:

Some of the strategies here suggested include:

- ***Efficient utilization of shared-access satellite channels for communications between geographically diverse sites***. The effective implementation of this option will depend on the successful launching and sustenance of Nigeria's communications satellite in 2014.

- ***Packet radio networks for mobile tactical Environments.***

Packet radio is a form of packet switching technology used to transmit digital data via radio or wireless communications links. It uses the same concepts of data transmission via Datagram that are fundamental to communications via the Internet, as opposed to the older techniques used by dedicated or switched circuits[4][21]

Packet radio can be further defined as a form of digital data transmission used in amateur radio to construct wireless computer networks. Its name is a reference to the use of packet switching between network nodes, which allows multiple virtual circuits to coexist on a single radio channel. [5][22]. A basic packet radio station consists of a computer, a modem, and a transceiver with an antenna. Traditionally, the computer and modem are combined in one unit, the terminal node controller (TNC), with a dumb terminal (or terminal emulator) used to input and display data. Increasingly, however, personal computers are taking over the functions of the TNC, with the modem either a standalone unit or implemented entirely in software. The computer is responsible for managing network connections, formatting data as AX.25 packets, and controlling the radio channel. Frequently, it provides other functionality as well, such as a simple bulletin board system to accept messages while the operator is away.

Layers

Following the OSI model, packet radio networks can be described in terms of the physical, data link, and network layer protocols on which they rely.

Physical layer: modem and radio channel

Modems used for packet radio vary in throughput and modulation technique, and are normally selected to match the capabilities of the radio equipment in use. The first amateur packet radio stations were constructed using surplus Bell 202 1,200 bit/s modems, and despite its low data rate, Bell 202 modulation has remained the standard for VHF operation in most areas. More recently, 9,600 bit/s has become a popular alternative. At HF frequencies, Bell 103 modulation is used, at a rate of 300 bit/s. Custom modems have been developed which allow throughput rates of 19.2 kbit/s, 56 kbit/s, and even 1.2 Mbit/s over amateur radio links. However, special radio equipment is needed to carry data at these speeds, and their adoption has been limited.

Data link layer: AX.25

Packet radio networks rely on the AX.25 data link layer protocol, derived from the X.25 protocol suite and intended specifically for amateur radio use. Despite its name, AX.25 defines both the physical and data link layers of the OSI model. (It also defines a network layer protocol, though this is seldom used.)

Network layer

Packet radio has most often been used for direct, keyboard-to-keyboard connections between stations, either between two live operators or between an operator and a bulletin board system. No network services above the data link layer are required for these applications. To provide automated routing of data between stations (important for the delivery of electronic mail), several network layer protocols have been developed for use with AX.25. Most prominent among these are NET/ROM, ROSE, and TexNet. In principle, any network layer protocol may be used, including the ubiquitous Internet protocol.

Examples of Packet radio include:

- MDI (1979)
- DCS (1984)
- DRN (1986)
- Mobitex (1986)
- ARDIS (1990)
- CDPD allowed packet data to be carried over AMPS analog cellular telephone networks
- GPRS is the packet data facility provided by the GSM cellular telephone network

Development of a Gigabit Backbone network (GB)

The rapid growth in demand for high-bandwidth data, such as on-line video, is driving many network administrators to convert their existing network backbones to gigabit speeds and higher. The problem faced by industrial network administrators is how to build a redundant network backbone that is sufficiently reliable in harsh industrial environments. Below Moxa [6] illustrates with a case study how Redundant Gigabit Backbone network (GB) can be constructed:

Case study Scenario

A 300 km highway was being constructed in a desert and required both traffic and environmental monitoring. Video cameras, vehicle detectors, and weather stations were to be installed along the length of the highway. Data from these devices needed to be transmitted to a control center for immediate recording and analysis. It was essential that the Ethernet infrastructure be extremely rugged and reliable.

Requirements

1. Field switches require tough construction to stand up to the harsh desert conditions. We can assume a temperature range of -40°C to 75°C.
2. Due to the bandwidth that is required for multiple video streams and other data, gigabit Ethernet speeds are required for the network backbone. Network and system redundancy are required to ensure the utmost reliability.
3. Fiber optics is the media of choice for the network backbone, due to the long transmission distances involved.

Solution proffered:

1. ***Network Structure***: Since the control center is located about halfway down the length of the highway, two separate redundant gigabit rings with redundancy were used, one for each half.
2. ***Core Switch***: Since the core switch is located in the control center, exceptional ruggedness was not required. A general 26-port gigabit Ethernet switch was used.
3. ***Field Switch***: Two gigabit Ethernet ports were required on each switch to support the redundant ring topology. An industrial Ethernet switch with sixteen 10/100M ports and two 1000M ports was used for most field switches. Certain field switches required an additional gigabit port for connecting to the core switch. For those switches, an industrial Ethernet switch with seven 10/100M ports and three 1000M ports was used. Both types of switch met the requirements for reliability and ruggedness in harsh environments.

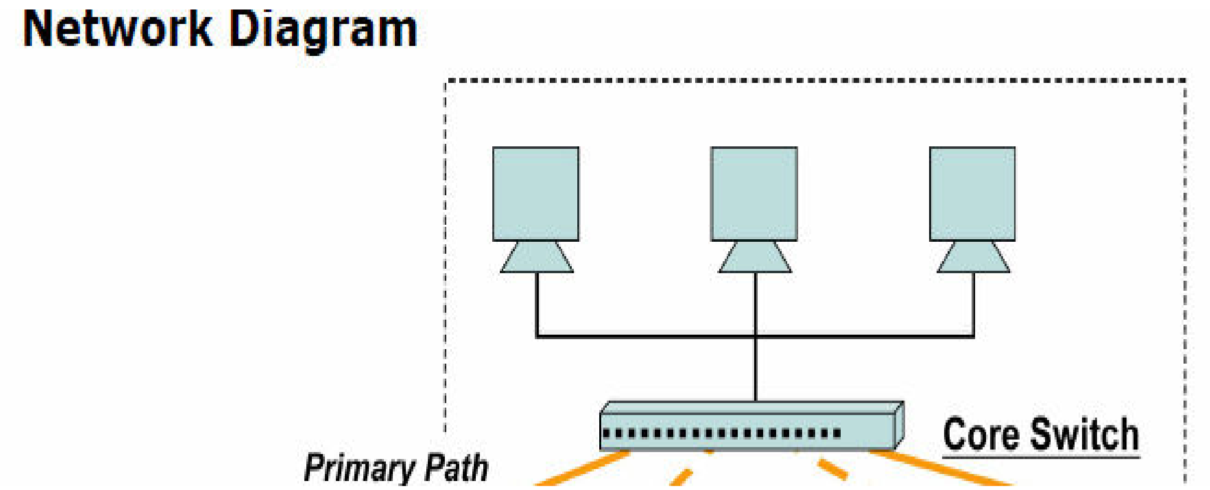

Fig. 1: A switched Network

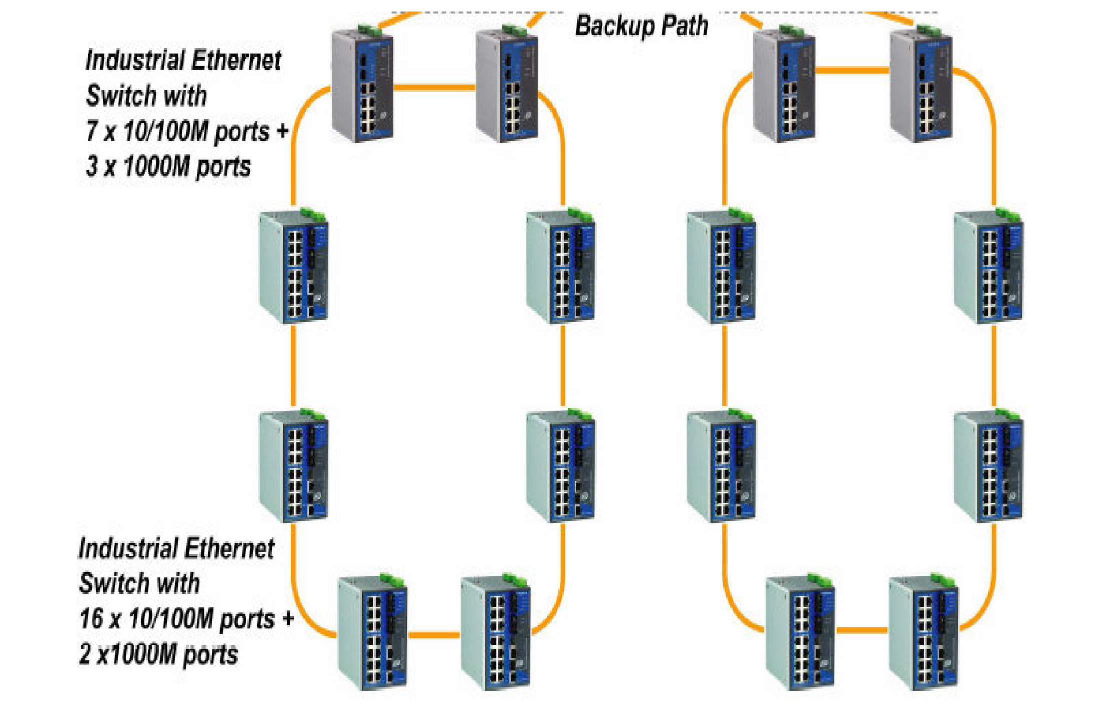

Fig. **1b Network Diagram of the proposed Redundant Gigabit Backbone for the case study**
source: [6] [20]

Explanatory notes:

Core Switch: In the system control center, several servers or processing computers handle monitoring and control of devices in the field. The core switch establishes the communication channel for data transmission between the control center and the field site. The required bandwidth depends on how much data these system servers or computers need to receive. Ethernet ports that are connected with the uplink ports of Field Switch A should support gigabit transmission speeds to prevent network bottlenecks. Usually, the core switch is located in a staffed room or other temperature-controlled facility, making rugged industrial-grade construction unnecessary. However, using industrial-grade switches is still preferable in harsh environments or for applications where reliability cannot be compromised

Field Switch A: Field switches may be exposed to harsh environments full of dust, Electromagnetic fields, moisture, or extreme temperatures. A field switch must be of rugged design in order to perform reliably under such conditions. In the gigabit backbone of an industrial network, at least two gigabit Ethernet ports are required to build a redundant ring. Since Field Switch A is connected with the core switch, at least one more gigabit Ethernet port is required for uplink.

Field Switch B

Field Switch B is connected to the end devices. Ethernet port requirements depend on how many devices are connected and how much data each device needs to transmit. In general, 100Mbps is enough for each device. It may not be convenient to connect every device in one large redundant ring, especially when some devices are at remote sites. Instead, devices can be grouped into smaller redundant rings that are connected using a “ring coupling” function.

Other issues that will need be addressed in design and construction of Gigabit Backbone include:

- Power redundancy – the need to provide backup in the event of primary power supply failure.
- Media redundancy; This involves forming backup for network access
- Node Redundancy: Make provision for dual configuration of nodes as backup.
- Network and system redundancy: This may involve provision of backup network in the event of emergency.
- EMI and surge protection**:** Most industrial environments are subject to more severe electricity and magnetic fields than other environments. Strong EMI and surge protection are essential to protect network devices for industrial applications

Enclosure: devices must be protected from damage from external factors.

- development of an interconnected set of networks with gigabit throughput and appropriate management techniques;
- Development of fibre optics Ring connected to Africa1.
- Development of the required overall architecture that allows users to gain access to such high bandwidth.
- We shall also need general communications architecture, high-bandwidth switching, high-bandwidth host interfaces, network management algorithms and network services to address this problem.

Deployment of the 4G broadband Technology.

4G refers to the fourth generation of cellular wireless standards. It is a successor to 3G and 2G standards, with the aim to provide a wide range of data rates up to ultra-broadband (gigabit-speed) Internet access to mobile as well as stationary users. Another way of describing **4G** (short for **Fourth Generation wireless Technology)** is basically the extension in the **3G technology** with more bandwidth and services offers in the 3G. Hitherto, nobody exactly knows the true **4G definition**.

Some people say that **4G wireless technology** is the future technologies that are mostly in their maturity period. The expectation for the 4G technology is basically the high quality audio/video streaming over end to end Internet Protocol. If the Internet Protocol (IP) multimedia sub-system movement achieves what it going to do, nothing of this possibly will matter. **WiMAX** or mobile structural design will become progressively more translucent, and therefore the acceptance of several architectures by a particular network operator ever more common. 4G delivers true mobile broadband for the masses with a superior user experience. 4G mobile broadband provides improved performance, lower total cost of ownership and enables a new era of personalized services. 4G networks are IP-based and flatter with fewer nodes to manage. The benefits are significant and can make 4G mobile broadband a truly disruptive technology providing service providers a cost-effective way to deploy next generation technology and services and redefining the end-user experience.

Sample Components of the 4G technology include:

- **WiMAX** is a unique technology that delivers high-speed, broadband fixed and mobile services wirelessly to large areas with much less infrastructure than is needed today. It supports and enables applications that allow your network to move from one access network to another seamlessly.
- **IP Multimedia Subsystem (IMS)** by Nortel turns the Intelligent Network into an Intuitive Network that is device, application and access aware. With IMS, delivers empowered multimedia services that provide new levels of personalization, security and mobility.
- **Long Term Evolution (LTE)** by Nortel combining OFDM and MIMO, will provide on average up to 5 times greater spectral efficiency than the most advanced 3G networks, reducing the cost per bit and allowing better economics for operators and end users.

New Terabyte Bandwidth Initiatives

The Rambus Terabyte Bandwidth Initiative pioneers new memory signaling technologies useful for the development of a future memory architecture capable of delivering a terabyte per second of memory bandwidth (1 terabyte = 1,024 gigabytes) to a single System-on-Chip (SoC). This unparalleled memory bandwidth will enable future memory systems to benefit from an order of magnitude improvement in memory performance.

To achieve 1 TByte/s memory bandwidth, Ram bus has developed fundamental innovations that include:

- 32X Data Rate - A new memory signaling technology which transmits 32 data bits per input clock cycle;
- Fully Differential Memory Architecture (FDMA) - Providing the benefits of differential signaling on both the DQ (data) and C/A (command/address) channels;
- FlexLink™ C/A - The industry's first full speed, scalable, point-to-point command/address link.

With these innovations and others developed through the Terabyte Bandwidth Initiative, Rambus will provide the foundation for a future memory architecture that offers increased performance, higher and scalable data bandwidth, area optimization, and enhanced signal integrity for gaming, graphics and multi-core computing applications of the next decade.

Background

Faster, multi-core processor-based systems require greatly increased memory performance over systems built around single-core processors. Without adequate bandwidth, memory systems will be the limiting factor in delivering the required performance desired in next-generation consumer and computing systems. As an example, graphics processors currently require as much as 128GBytes/s of memory bandwidth and are targeting 500 GBytes/s in the near future. The current generation of gaming systems uses 25-50 GBytes/s of memory bandwidth. Over the next 4-5 years, graphics and game consoles will push memory bandwidth needs towards 1 TByte/s.

Innovations

Rambus' innovative 32X Data Rate technology transmits 32 bits of data per clock cycle on each I/O. Conventional double data rate memory systems transfer two bits of data, per I/O, every clock cycle. While double data rate memory architectures can achieve a one gigabit per second transfer rate with a 500 MHz clock, 32X Data Rate enables an amazing 16Gbps signaling rate using the same 500 MHz clock.

Huawei announced on September 21, 2010, a **breakthrough in DSL technology** with the **world's first 700Mbps prototype**. This will enable worldwide operators to build high-bandwidth access networks with SuperMIMO technology. Considering the current industry standard is a mere 100Mbp, this is considered a huge leap forward in the world of Internet connectivity. It is expected that this new technology will greatly improve the capabilities of operators supporting ultra high broadband services.

This method increases DSL (Digital Subscriber Line) bandwidth by 75 percent from 100Mbps to 175Mbps per twisted pair. SuperMIMO technology utilizes four twisted pairs, which means the downstream rate is equal to four times that of a single twisted pair. Four times 175 equals 700Mbps. Many worldwide carriers use Huawei's FTTx poducts, just some of these are France Telecom, Vodafone and Telecom Italia. You Yiyong, President of Huawei's Access Network Product Line, said, "DSL technologies for broadband access are showing great market potential. As a leader in the development of DSL technologies, Huawei newest DSL prototype demonstrates the company's commitment to providing customer-centric and groundbreaking solutions and services for operators to enhance their competitiveness and profitability.

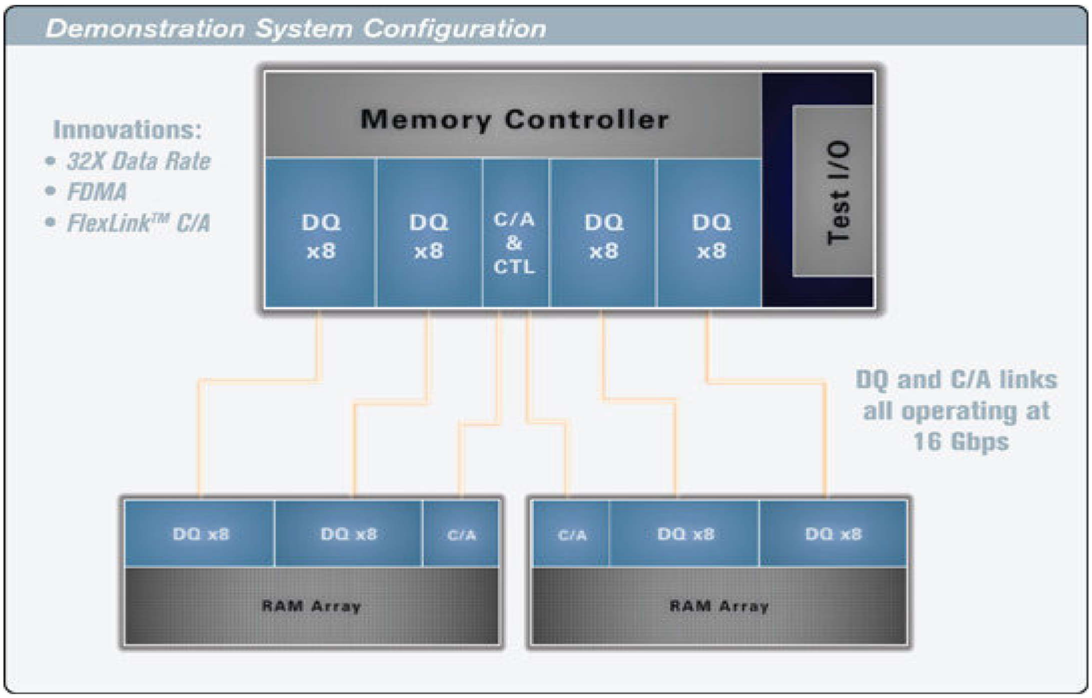

Fig. 2: The Rambus Terabyte Bandwidth Initiative

The Rambus Terabyte Bandwidth Initiative also showcases the industry's first fully differential memory architecture (FDMA). In FDMA, both the data path and command/address channel employ differential signaling for robust communications between the memory controller and the DRAM. Rambus pioneered high speed differential memory signaling by transitioning the data signals from a single ended architecture to a differential scheme and used the signaling technique in its XDR™ DRAM design. Differential signaling inherently reduces interference noise, such as simultaneous switching output (SSO), crosstalk, and electromagnetic interference (EMI). Rambus has expanded the use of differential signaling in the Terabyte Bandwidth Initiative to include not only the data signals, but also the command/address signals, resulting in improved signal integrity and enhanced performance.

The third featured innovation of the Terabyte Bandwidth Initiative is FlexLink C/A. FlexLink C/A implements the industry's first full-speed, scalable, point-to-point command/address link. Operating at 16Gbps, FlexLink C/A reduces the required number of signal pins on both the DRAM and the memory controller. In contrast with a 1Gbit DDR2 device which requires 28 wires to connect the command/address link between the memory controller and the DRAM, FlexLink C/A implements a full 16Gbps command/address link with only two connections. This serial, scalable link also provides fine access and scalable capacity through a single command/address link per DRAM. FlexLink C/A's serial connectivity also delivers reduced area, power and pin count and lowers overall system costs.

Benefits

Through 32X, FDMA, FlexLink C/A and other innovations to be developed through the Terabyte Bandwidth Initiative, Rambus provides the foundation technologies for a terabyte memory architecture. A future SoC connected to 16 DRAM devices, each operating at 16Gbps with a 4-Byte wide interface, will achieve an impressive 1 terabyte per second of memory bandwidth. Through the Terabyte Bandwidth Initiative and the products that follow, Rambus enables its customers to develop a new generation of consumer and computing products that enrich the lives of consumers worldwide.

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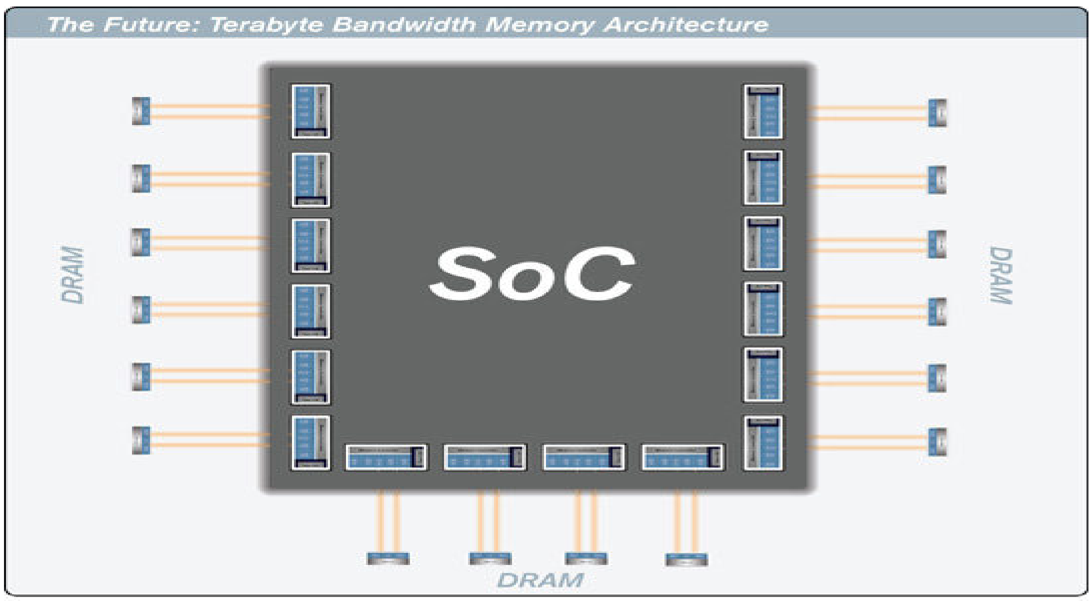

Fig. 3: concept of double-tuned waveguide coupled slots as a feasible approach for increasing bandwidth

A theoretical model that shows that the concept of double-tuned waveguide coupled slots is a feasible approach for increasing bandwidth is developed. A full-wave integral equation technique has been developed which allows the analysis of not only thick slots. but also slots which are coupled through a section of waveguide. The latter case also provides a mechanism for improved performance. By adjusting the slots on the ends of the waveguide section to different lengths. One can essentially 'stagger tune' each slot to a different frequency, increasing the overall bandwidth. Within the limited range of parameter variation used, apparent bandwidth increases in the order of at least 50% have been seen. To illustrate the behaviour of the structure, a 0.60 in×0.60 in cavity fed by a strip line with a ground spacing of .125 in at 9.7 GHz is studied

6.0 Way forward for Internet Diffusion in Nigeria

The most probable safe route to leapfrog this gap chasm is to develop the political will to make Nigeria central hub of ICT for the African content by expanding ICT infrastructure not only in the big cities but also in the rural communities of Nigeria. Only about 30% of Nigerian population live in cities. The remaining 70% live in remote communities without power, water, telephone and internet access. To empower this class of citizens, aggressive deployment of functional Internet and Telephone infrastructure by governments with collaboration with Telecom operators has become very critical. The Federal Government of Nigeria is vigorously working to improve electricity supply. When regular and quality power supply becomes a reality, Nigeria's quest for IT diffusion will receive a quantum leap**.** The real solutions are summed in the concluding summary and recommendations in section 8.0 below**.**

7.0 Summary, conclusion and Recommendations

No country can develop in modern civilization without Internet powered communications. The basis for enjoying the new world economic order and enhancing the wellbeing of citizens is participation in world trade via e-commerce. E-commerce implementation is hinged on the availability of Internet connection to the super highway.

Apart from the existing Information Technology Infrastructural hiccups, the most debilitating factor against Internet diffusion in Nigeria is low speed and expensive bandwidth. This has dwarfed the expectations of the ICT industry. The absence of indigenous satellite capability calls for political will on the part of governments in Africa to put efforts together to design and launch functional communications satellites, work on local breed raw bandwidth via broadband revolution and the deployment of terrestrial and broadband Internet infrastructure to create adequate opportunity for her citizens to join the new world information society and economic order. No nation can effectively develop nor compete in the global market place without seriously embracing information technology as an economic enabler.

Governments need to budget fund for realistic research in the new technologies outlined above, lay the right information technology infrastructure such as the construction of fibre optics ring to be linked to Africa 1, provision of good and regular electricity power, launching of a sustainable communications satellite, sponsor mass I.T. education from the school system to the civil society as well as provision for the retraining of lecturers in the new I.T. paradigm, development of infrastructure and superstructure for increment of local content of locally assembled PCs and work towards component fabrication, foundries for micro-lithography/Very Large Scale Integration.

Thus, Nigeria's internet diffusion will get a quantum leap if computers are cheap, tariff for telephone and internet access low, emergence of functional and sustainable energy supply, continuing investment via public-private participation for provision of additional ICT infrastructure nation wide. Other tactical strategies include collaboration with African Universities for proper coordination of ICT budgets; establishment of a detailed plan, costing for setting up a hub in Europe or North America to provide bandwidth at low tariff to tertiary institutions in Africa. That is the way forward for Nigeria and the black race

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