MODELING A LOW LATENCY IP NETWORK IN NIGERIA.

D. E. Bassey[1].,J. C. Ogbulezie[2]., B. E. Okon[3].

***Abstract*— Investigations have shown that interior places of the nation lacked capacity for high speed Internet usage; except the cosmopolitan sections. This article, therefore, conceptualizes a robust Broadband roadmap that can effectively deliver IP-wholesale and IP-retail services, through traffic convergence. The interconnect platforms are designed to ensure automatic re-routing of broadband traffic during link or node failure. The IP-wholesale services can be delivered to all main cities in Nigeria through different wholesale hobs connected to the optic fibre backbone of converged carriers. Through these measures, IP-backbone with core-routers shall be created. From this traffic level, regional IP-network operators can feed into the IP-backbone; with the main tasks of creating resilience in the network. All IP-traffic going to the Internet will be divided over 3 physical separate landing stations to either SAT-3, GLO-1 or MAIN-1 sea cables. This system shall have the advantage whereby any sea-cable cut on one of the operators (owner) shall not cause complete traffic failure to and from Internet. Further to this, the Internet Gateway facility shall be sited in high density metropolitan cities with high consumption capacity. Metropolitan cities such as Lagos, Port-Harcourt, Kano and Abuja shall be selected for data traffic interconnection point. All the Gateways shall function as Tele-house facility. Through these mechanisms apart from securing the highly redundant IP network, valuable data can be stored at these locations. The main advantage of this model is that they share the use of the access network. Through this venture, the ISPs shall focus their efforts to their main task: providing Internet related services like IP WEB-hosting, E-mail services, value added services; without worrying about transmission and distribution of traffic generated.**

Key Words: Broadband, Internet gateway, IP-retail, IP-wholesale, traffic convergence.

1. INTRODUCTION

Going by the role communications technology is playing on the on-going globalizations of the world, communication between nations is continuously intensified. Traditional and natural barriers are no longer a set-back. The overture of the worldwide Internet has further globalized the world.

Telecommunications infrastructural developers and service providers in developing nations can underline the significance of this communications conduit to advance the infrastructure that promotes broad penetration of the Internet. Through this, the realization of the learned society can be extended to the disadvantaged areas.

In this regard, Nigeria cannot be left aside from networking her rural and sub-urban areas. Earlier studies carried out have confirmed that the growth rate ofbroadband penetration in Nigeria is very slow, and limited to selected urban areas [8,10]. Inadequate last mile infrastructures, compounded by total collapse of fixed-line network have slowed Internet penetration in Nigeria. This has evidently led to poor quality of service. This poor state of service-delivery can be improved if Broadband access is implemented. This article, therefore, intends to conceptualize a robust Broadband roadmap that can effectively deliver IP-wholesale service, through traffic convergence. The interconnect platform is designed to ensure automatic re-routing of all traffic during link or node failure. Remodeling the present phase of telecommunications network, in collaboration with the existing structure is very essential. The project is therefore anchored on a combination of a robust fixed-line network as the major carrier, while wireless networks supplement the terminal traffic.

2. REVIEW OF NETWORK MODELLING PARAMETERS.

To develop this new model, a review of the basics of queuing theory, the assumption of Poisson arrival processes and exponential distribution of service time were briefly carried out. These assumptions usually hold in classical circuit-switched networks, but shall be extended from the scenario of one traffic type (as currently operated in Nigeria) to multiple traffic types; which are common for integrated services networks and packet networks. The emphasis is a multi-dimensional network, basically made up of fixed wire-line and mobile/wireless cellular networks.

In mobile networks, different channels may be occupied and released several times during one call. This phenomenon is due to the cellular topology of mobile and wireless networks, where each cell is a service zone with limited capacity [12]. Here, handover or a handoff is defined as a process of carrying an ongoing connection from one cell to one of its adjacent cells. This means allocation of resources in the new target cell by some algorithm and release of the resources in the earlier cell. If an idle channel is available in the target cell, the hand-over call is resumed nearly transparently to the user. Other- wise, the handover call is dropped [2, 5-6]. So, a channel in cellular wireless networks may be occupied by an arrival of a new call, or a handover call. Also, a channel may be released either by ending the call or by handing the call over to one of the neighboring cells [1]. However, the study restricts the analysis to wireless cellular networks with one traffic type. In cellular networks, traffic parameters are related with mobility parameters, such as velocity of users and characterization of their movement within a cell. In wire-line networks, consideration is given on performance parameters: call arrival process, call departure process, and blocking [16-19]. For analysis of cellular network,

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additional wireless-specific parameters due to handover phenomenon are introduced. These are average channel holding time, new call and handover call intensities, new call blocking probability, and handover call blocking probability [13,17]. The last two parameters define the QoS levels in the network.

First, consider the following simple traffic transaction: subscribers in a particular cell, 1, initiate fresh calls as a Poisson process at the rate:

$\lambda_1 = \lambda_n$ *(1)*

and receives no handovers. The distribution function for arrival of new traffic becomes:

$p_n(t) = \lambda_n e^{\square\lambda_n t}$. (2)

However, the calls are allowed to perform handover to the neighboring cells. The number of subscribers in the cell is assumed as:

$N >> c$,

wherec is the number of channels in the cell. So the transactions from different subscribers may be considered as independent; and a simple resource allocation scheme (one channel per subscriber) is applied. Also, assume that each mobile subscriber in the originating cell may complete the transaction in the cell, or at a certain period, may handoff to one of the neighboring cells. The time of transaction is assumed to be exponentially distributed, and the mean values are:

$1/\mu_c$and $1/\mu_h$,

respectively. Thus, an ongoing transaction (new or handoff) completes service at rate, μ_c. Also, a mobile engaged in a transaction departs the cell at rate, μ_h.

Finally, the total termination rate for the transaction in the cell is obtained as:

$U_T = U_c + U_h$ (3)

Considering the case of new transactions in the observed cell and applying Little's result [1], the traffic intensity becomes:

$A_1 = \lambda_1/\mu_T$. (4)

Also, considering the queuing system, *M/M/c/c, under a scenario where the policy of the* channel configured blocked transactions to be cleared (when all channels are busy, an incoming call is lost), the blocking probability for new calls can be calculated by using the Erlang-B formula [1]:

X1 = $$P_{Bn} = \frac{A_1^c / C!}{\sum_{i=0}^{c} \left(\frac{A_1^i}{i!} \right)}$$

While carried traffic in the cell may be calculated by:

X2 = $$Y_1 = \frac{\lambda_1}{\mu_T}\left(1 - P_{Bn}\right)$$

However, if consideration is given on incoming handoff transactions in a cellular environment, it becomes unnecessary to apply Erlang-B formula directly [22,23]. Since the property of the exponential distribution is memory-less, the handoff process can be assumed to be a Poisson process with mean intensity, $\lambda x h$. The total intensity of transaction arrival process becomes:

X3 = $$\lambda_T = \lambda_n + \lambda_b$$

Considering a generalized case, the effective offered traffic is:

X4 = $$A_e = \frac{\lambda_T}{\mu_T} = \frac{\lambda_n + \lambda_b}{\mu_c + \mu_b}$$

Since the handoff transactions depend on new arrival of transaction processes, they are assumed independent. Denoting P_B *as* the total blocking probability in a cell for new transaction and handoff, then, traffic carried in the cell is:

X5 = $$Y = \frac{\lambda_T}{\mu_T}\left(1 - P_B\right)$$

Considering the position of equilibrium in a cell, handover intensity from the observed cell to its neighboring cell is equal to incoming handover intensity to that cell from other cells [7]. This may be written as:

X6 = $$\lambda_h = \lambda_n = \left(1 - P_B\right) - \frac{\mu_h}{\mu_c + \mu_h} * P_B$$

Using the last two equations, after some simple algebra, we obtain the effective offered traffic to a cell:

X7 = $$A_e = \frac{\lambda_n}{\mu_c + \mu_h P_B}$$

If the handoff rate from a cell is similar to or lower than transaction completion rate, and the blocking probability is small, then the effective offered traffic can be calculated as approximately equal to the effective traffic offered by the cell. **Equation 4**becomes applicable. Thus:

$Ae \cong \lambda n/\mu c$.

Assume further that no channel was reserved during the handoff process, the new call blocking probability, P_B, *shall be assumed* equal to the blocking probability of the handoff and can therefore be calculated using Erlang-B formula. From this assumption, the effective offered traffic becomes:

X8 = $$P_B = P_{Bn} = P_{Bh} = \frac{A_e^c / C!}{\sum_{i=0}^{c} \left(\frac{A_e^i}{i!} \right)}$$

wherec is the number of channels in the cell.

2.1 Principles of Dimensioning

The basic principle in telecommunications networks is balance of *quality of service* (QoS) requirements against economic costs. There are several measures to characterize the services. The most important is QoS, which includes different aspects of a connection such as delay, loss, and

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reliability [8,9]. The subset of these measures, which refers to the traffic performances, is called *grade of service* (GoS). GoS is considered as blocking probability in the network. To have a well-functioning system, network blocking should be at lower values (e.g., GoS≤ 1%). . To observe the constraints on the GoS, it is convenient to apply the Erlang-B formula to systems with different numbers of channels and different traffic loads [4],

Analyzing the theory of Erlang-B Table, two different trends can be observed:

1. Large groups (e.g., n = 100 channels) have higher utilization of the resources (channels), compared to smaller groups (e.g., n = 10channels).
2. The blocking probability due to overload increases faster for large groups compared to small ones.

2.2 Characterization and Classification of IPTraffic

IP traffic is fundamentally different from classical voice telephony traffic. Therefore, in order to design a mobile IP network, there is need to characterize and classify IP traffic using existing measurements of IP traffic from wired networks [22,23]. The first step towards analysis and design of wireless IP networks is to clearly specify the description of the network traffic and the performances requirements of the applications. The approach taken in this study, however, assumes that applications possess certain generic inherent properties that result from human behavior and interaction, which are therefore independent of the network infrastructure and are not likely to change in the future. Furthermore, on the Internet, exist heterogeneous services with different traffic and QoS demands. Some services demand real-time communication; others do not have such requirements. Also, there is heterogeneity in the bandwidth needed by traffic flows generated from different applications. Therefore, we need to determine the nature of IP traffic and to consider its characteristics. Traditional techniques in telecommunications for QoS support are based on voice traffic, where resource allocation is deterministic (allocation and switching of channels). Compared to the traditional networks, IP traffic has two main differences:

*Resource allocation is dynamic, and resources are allocated on a per packet basis.

*There is no explicit support for the allocation of a specific quantity of network resources. On the other hand, this simplicity of IP networks provides transparent transmission of different traffic types: voice, video, audio, data, and multimedia, over the same network. There is no need to build parallel network infrastructure for each traffic type. These characteristics of IP networks, together with the development of different services offered to the end users, have introduced IP as the main new concept for the telecommunication networks [1, 2]. Internet traffic, based on IP, includes many multimedia services that have different characteristics considering their traffic parameters: bit rate, burstiness, connection duration time, as well as their demands upon performance metrics (i.e., packet delay, loss, and throughput) [3,14]. The major interest in network aspects is the analysis of IP traffic. Therefore, there is need to capture the behavior of individual streams as well as the behavior of aggregate Internet traffic. That is, to analyze the aggregate Internet traffic by using traces from real traffic measurements. Furthermore, to filtrate different components from the aggregate traffic depending on the applications that generate that traffic.

2.3 QoS Classification of IP Traffic

The analysis of IP traffic shows the heterogeneity of the network considering different types of services and applications. The result is a wide range of services with various characteristics and different demands to the network. To provide network design, especially when focusing on wireless access to the Internet, we need to classify the traffic that exists today as well as the traffic expected to occur on the integrated network in the future. Classification of IP traffic upon QoS demands from different services should be reviewed. Table 1 shows services that exist on the Internet as well as services that can be offered by the integrated network.

Table 1: Comparative review between 2G and 3G Mobile Network hard-ware

Network	2G	2GT	3G
CORE Network	MSC/VLR, EMSC, HLR AUC, ETR	MSC/VLR GMSC SGSN, GGSN, HLR, AUC, EIR	3G-MSC/VLR 3G-GMSC 3G-SGSN 3G-GGSN,HLR AUC, ETR
RADIO ACCESS NETWORK	BSC, BTS, MS	BSC, BTS, MS	RNC, access node, mobile station
SERVICES	Voice, sms, /SDN	Voice, sms, email /NAP service	Voice, internet, multi-media service video telephone
DATA RATES	Up to 9600 6ps (for up to 14,400 6ps)	Up to 57.6k 6ps for HSCSD. UP TO 115K 6Ps for GPRS, up to 384k 6ps for EDGE	Up to 2 M6ps
Mobile terminals	Voice-only terminals	User-friendly terminals enhanced service capabilities	Voice, data, and video terminals multiple modem.

Consideration should also be given to services with different QoS demands and different types, what seems to be enough to perform classification of the traffic. Today's most common applications on the Internet do not have requirements for real-time service, neither strict QoS support. Examples include www and e-mail. These applications use best-effort service, which is the basic service of the current Internet. Most of the applications given in Table 1 are multimedia applications, containing audio, video, and data/images. From the user perspective, one may classify applications in three main groups:

*Interactive applications (e.g., IP telephony);

*Distributive services (e.g., audio or video streaming and Web TV);

*Services on demand (e.g., e-mail, video or audio on demand, and data transfers).We classify service's requirements based on packet loss, packet delay and delay variation (jitter), and throughput.

3. NETWORK CONVERGENCE.

Apart from the robust carrier network, interconnected from the major operators' carriers (fixed access networks and mobile access networks), network convergence can be formed with the existing standards in 2G (CDMA, GSM, TDMA), 3G and 3G+. This brings in the

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advantage of standardizing the networks in line with the higher data rates in the air interface of modern wideband technology. It shall also introduce packet-based services to the end-user. The operation of the converged network should be transparent and open to new services created by the content providers. In order to design a cost-effective wireless IP network, there shall be need to create many small network domains that are interconnected, as well as connected to the commercial carrier networks.

Furthermore, telecommunications' networks can be classified based on traffic homogeneity into homogeneous and heterogeneous networks. The homogeneous type is used to describe classical telecommunications service initially dependent on voice transmission and switching functions. The proposed heterogeneous type includes integrated traffic streams from different sources (voice, audio, video, and data) into a single network. Using these classifications, four types of telecommunications networks are reviewed:

*Circuit-switched networks with homogeneous traffic;
*Circuit-switched networks with heterogeneous traffic;
*Packet networks with homogeneous traffic;
*Packet networks with heterogeneous traffic.

3.1 IP wholesale

IP-Wholesale is an Internet connectivity service for Internet Service Providers, Application Service Providers, Carriers and large-capacity bandwidth corporations. To offer this service, the Federal Ministry of Communications, through the Nigerian Communications Commission has to create an agency that can be vested with the license and assets of the moribund NITEL in other to revamp the existing facility of NITEL; if the privatization process continues to be a failure. The Atlantic sea cables (SAT-3, Glo-1 and MAIN—1) can jointly provide more than the needed bandwidth capacity for the West African region. The SAT-3 sea cable runs from South-Africa to Portugal and is owned by a consortium of operators of various countries. NITEL owns a part of SAT-3 and therefore, part of the capacity of SAT-3.

These cables have connection to the Internet at the London Internet Exchange (LINX). The advantages of this service are the low latency (less than 80 milli-seconds round trip time to London) and the unlimited bandwidth when compared to the alternative Satellite option [11,12].

The IP wholesale Internet capacity can be obtained from either of these operators (SAT-3, GLO-1 or MAIN-1) using leased capacity that ranges from *1 to 155Mbit/s full duplex.* This leased or purchased bandwidth capacity shall be delivered as exclusive bandwidth all the way to and from the London Internet Exchange [15]. SAT-3, GLO-1 or MAIN-1, are fiber based transmission media. The quality (in terms of Bit Error Rate) and available bandwidth are unmatched.

The IP-wholesale service can be delivered to all main cities in Nigeria that are connected to the fibre backbone of the agency managing SAT-3, GLO or the subsidiary of MAIN-1. The IP capacity is transported using the subsidiaries' SDH networks. These networks, each with a separate fibre optic carrier-ring route is to ensure automatic re-routing of all traffic during a link or node failure.

3.2 Internet Exchange

Given the opportunity of ISP's to offer their services all over Nigeria, with the IP wholesale service, it is unavoidable that IP traffic between the customers of the various ISPs will occur. Therefore, the networks of ISPs need to be inter-connected and linked to the carriers. This leads to seamless exchange of traffic. This kind of traffic exchange points are referred as Internet exchanges are normally created on a point in the country where many ISPs and carriers are present and where there is good (fibre) connectivity from the rest of the country as well as to the Internet.

The major carriers should identify high traffic locations within the different zones of the country to install their Internet exchange. The Internet Exchange can be the initiative of NCC to all major operators, or owners of the Atlantic undersea cables. It can also be managed by an independent organization appointed by stakeholders. If the Internet Exchange is an independent body, the centralized facility should be sited whereby various accredited ISPs and long distance carriers' operator can rent equipment room, under an enabling operating environment where these ISPs or carrier-operators can conveniently terminate its network for peering or Internet Access (IP Wholesale).

3.3 Connectivity to End Customers (backbone and last mile)

Through the implementation of the above, good connections to the Internet and an efficient way to exchange traffic among each other have been achieved. But what remains is the high cost to reach our customers. Up to this moment, most ISPs create their own access network and backbone network to reach their customers. These networks are based on fiber, copper, radio or even Satellite.

A major drawback from this model is the immense cost that is incurred for the creation of a physical access network. For some reason, everyone seems to understand that it doesn't make sense to build several highways to reach the same destination. Somehow in Telecommunications, the way of thinking is different because all ISP's are building their own networks.

In order to reduce the operating cost of these ISPs, which invariably shall reduce the end users' cost, the major carriers should open its network for ISP to reach its customers using the carrier's IP backbone and access network. Example: if a Lagos based ISP wants to extend its network to Abuja, then the only thing that needs to be done is opening a sales office in Abuja. Once the ISP succeeded in selling to a customer in Abuja, then, the carrier's operator will connect the customer through dial-in or ADSL, to its IP backbone and thereafter

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transport the customer's traffic to the interconnection point with the involved ISP.

The main advantage of this model is that they share the use of the access network. Through this venture, the ISP will focus their efforts to their main task: providing Internet related services like IP WEB-hosting, E-mail services, value added services; without worrying about transmission and distribution of traffic generated. The struggle for investment in network, maintenance of the network, housing, etc., is no longer their concern.

3.4 VPN and VOIP Services

After the implementation of the IP network, thereby establishing access to the end-customers, and Internet access secured, the next stage is to add intelligence to the IP-network.

The carrier operators shall create an IP-backbone with core-routers. From this traffic level, regional IP-network operators can feed into the IP-backbone. The main tasks of the IP backbone are specified below:

•Creation of resilience in the network: All IP-traffic going to the Internet will be divided over 3 physical separate landing stations to either SAT-3, GLO-1 or MAIN-1 sea cables. This system shall have the advantage whereby any sea-cable cut on one of the operators (owner) shall not cause complete traffic failure to and from Internet. Further to this, the Internet Gateway facility shall be sited in high density metropolitan cities with high consumption capacity. Metropolitan cities such as Lagos, Port-Harcourt, Kano and Abuja shall be selected for data traffic interconnection points. All the Gateways shall function as Tele-house facility. Through these mechanisms, apart from securing the highly redundant IP network, valuable data can be stored at these locations.

•New market opportunities shall be opened such as Virtual Private Networks (VPNs) over the IP network.

•Discrimination between traffic flows shall be eliminated in view of the capacity of the IP network; thereby ensuring real-time qualitative voice, data and video services using the IP network. This convergence of signal shall promote new services like teleconferencing, e-learning, near video-on-demand, voice, etc., at reduced cost.

• Content Distribution Services

Another landmark is to ensure that the network is used efficiently with minimum duplication of data for non-real-time services. However, the local storage of video, data and SW-packages or other ASP service data may be inevitable. The ADSL network shall be dimensioned to convey high bandwidth services, while the backbone network shall concentrate on distributing the traffic contents to the Cyber locations.

4. CONCLUSION.

As enumerated in the proposed model, implementation of IP-wholesale and ISP's connections can be achieved all over Nigeria. This shall put every part of the country into the path of enjoying unlimited bandwidth under the lowest latency.

The roll-out of ADSL services should be encouraged, and ISPs should face the challenge to connect their customers using IP backbone and access network of their carrier operators. These carrier operators can collaborate with ISP's, to implement the much needed networked society in Nigeria. This convergence of signal shall promote new services like teleconferencing, e-learning, near Video-on- Demand, Voice, etc., at reduced cost.

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