TELECOM NETWORKS CONVERGENT ARCHITECTURE AND MIGRATION STRATEGIES FOR OPERATORS

By

Augustine Chiedu Odinma
Telecom & Internet technologies Consultant
34 Charford Road, London E16 1QQ

ABSTRACT

Advances in packet, digital and optical technologies are catalyst for converged network architecture that is scalable, robust, flexible and reliable. Converged networks should support voice, data and video traffic. This network must also be packet based. Packet based networks usually have IP and or ATM interfaces. The resultant effect is that knowledgeable telecom operators can leverage their networks to provide IP or ATM services to corporate or Service providers. Unless an operator can exploit the corporate and service providers business, it may be out of business before this decade runs out. Moreover, operators can also leverage the migrated networks to become an ISP by converting some or all their networks to Internet points of Presence (PoP). Operators would have no alternative but to migrate their networks. AT&T and BT, telecom giants in the USA and UK respectively are telephone operators, service providers and ISP. No doubt, some Nigerian operators can follow this lead. This paper discusses converged Telecom Networks architecture and suggests the migration strategies that operators need to adopt or follow in order to prepare their networks for the business of today and tomorrow.

1.0 INTRODUCTION

Voice, Data and Video sources are systematically been carried in the same network, resulting in a robust, scalable, cost effective and affordable information systems. Until the late 80s it was inconceivable that voice and data could technologically co-exist in the same information system. This is so because of the differences in the characteristics of the various traffic sources and the non availability of the technologies that was able to cope with the demands of the different characteristics. Notable differences are not far-fetched. First, voice is very time sensitive and must be carried in real time for the information to be intelligible. Secondly, Data is not time sensitive and could accommodate reasonable delays. Video, on the other hand can be both in the real time or non real time depending on video services at stake (i.e. video conferencing, streaming, etc), but one distinguishing factor is that video is very resource intensive. These characteristics dictated that voice is circuit switched, meaning that a connection is first established between parties wishing to communicate and the connection is reserved for the duration of the communication. Data on the other hand is not real time traffic and so it seeks efficient use of the communication systems. There is no specific connection reserved on a per call basis for data; a message is divided into little chunks known as packets and each packet can traverse different routes to get to the distant end. At the distant end the packets are re-assembled in order to retrieve the original message. Until few years ago the bandwidth required by video was a hindrance for reliably packetising and carrying video over the network.

In the 80s the ITU started to look for ways to deal with the different characteristics, so that economies of scale can be reaped from using a single system to carry the different traffic sources. Broadband ISDN was suggested, with ATM as the unifying technology (1). ATM did not fully meet the vision of ITU because it was too expensive a technology to own end to end. Fibre optics, Optical communications and advances in DWDM did not help the ATM vision, as operators focus turned to IP technology to be the unifying technology. IMT-2000 (2), an initiative of ITU to bring about 3G mobile technologies has also given roadmaps in their release 99, 4 and release 5. These roadmaps seek to evolve the different traffic sources and ultimately converge them into an IP packet core. Traffic patterns destined for transport in a packet network has been an active research area particularly in the 90s. Video has been duly modeled by (3,4,7,8), Voice by (9,10) and Data has been considered by (11).

So, the trend is to have a single network that is capable of carrying all traffic types. Operators desirous to stay in business in the near future have no alternative but to migrate to single network architecture. This is a hard nut to crack for operators, but one, which is inevitable. Operators are concerned of the cost of the migration and often times do not know how to go about it. This paper also suggests a phased approach for migration to a single packet network core. We shall begin by defining the target converged network architecture in section 2. Next, a background discussion to packet networks is given in section 3. Section 4, discusses the convergent migration strategies. Finally, conclusions are given.

2.0 TARGET NETWORK ARCHITECTURE

Telecom infrastructure has evolved dramatically. Until a decade ago information systems and telecom infrastructure were predominantly defined to meet the demands and characteristics of voice traffic. In fact, voice telephony was synonymous with telecommunications. Advances in digital and packet technologies have systematically altered this perception. Moreover the availability of bandwidth to support high skewed and sporadic traffic patterns for data and video has called for more efficient means of transporting these services. Voice is circuit oriented and ubiquitous; it leaves little room for timely service differentiation, development and deployment. Thus, operators concerned about future business turned to packet technology. The adoption of the Internet, the world over, has also made packet transport a strong contender to be the underlying technology behind all future communication systems. As a matter of fact, the ITU has released three UMTS 3GPP (2) standards evangelising packet technology as the backbone technology for the next generation networks (NGN). Release 99, which came out in 1999 supports an ATM core technology. Release 4, which came out in 2000 supports a multi-service core and release 5 standards was published in 2001. The release 5 took the packatisation notion beyond the core to "all IP" across the board.

Obviously, to get to an all-packet end to end technology, although many vendors are already working on it, may take over a decade to achieve. Moreover, the issue of investment protection is also paramount in the minds of many operators; most 2G operator's infrastructures are only few years old and they wish to protect that investment. This means that although the benefits of migrating from the conventional circuit based to packet are numerous, most vendors are opting for a phased approach.

The goals and aspiration of ITU is to have a single network that would converge all networks and all media. The network is also expected to support communication any-where and any-time. That is communication without encumbrances. It was for this reason that Next Generation Network (NGN) is more associated with mobile communications.

Up until recently, there are separate networks for different information services; Wireline Networks, Wireless Networks, ISP Networks and the voice signalling (SS7) Networks in most operators network. The targeted network with the packet core technology is shown in Figure 1. The strategies that operators can adopt to packetise their networks are discussed in section 4 and the benefits for carrying out the migration is given elsewhere (14,15).

3.0 PACKET NETWORKS

There are four packet technologies that are worth mentioning, some of which currently form the packet core switching elements. The packet technologies are X.25, Frame Relay (FR), Asynchronous Transfer Mode (ATM) and multiservice switches.

As pointed out earlier the packet technology is robust, scalable, and flexible. It offers much more revenue opportunities than the circuit-based approach. However, this comes at a cost. Traditional packet technology was optimised for data only and not for voice. In order to carry voice there is quality of service issues to be addressed. The first packet data network is X.25, which was published in 1976 by ITU. Until the 90s, it was said to be the widely used protocol (6). X.25 is layer 3 protocol of the OSI module. The protocol was developed at a time when there were poor transmission facilities and technology to support high speed was a bottleneck. It was therefore designed with enormous control features to make the best use of what was available and as such it was a very slow technology. The slow speed made vendors to begin studies of the protocol now known as Frame Relay (FR) to reduce the effect of the control features in X.25 by actually removing them. This was successful and in 1992 the enormous benefit of FR was published (12) FR was originally designed for speed of 2Mbps (ITU-T I.233) and later for a maximum of E3/T3 Traffic.

Data rates of E1/T1 and E3/T3 were considered very high speed then, but as technology advanced and demand for high bandwidth broadband services increased, it became obvious that another faster technology was needed. In the late 80s, a vision of a switching technology that would support high-speed and broadband services was being conceived. Asynchronous Transfer Mode (ATM) was chosen to support the BISDN networks. ITU published the ATM standards in 1996. ATM is a technology designed for the high-speed transfer of voice, video, and data through public and private networks using cell relay technology. ATM is a very flexible and scalable technology and it was originally designed to operate at a low access speed and network-to-network speed of 155 Mbps and 622 Mbps. Today, it can switch data traffic in Giga Bits per second (Gbps). If we take a sample page as this one you are reading, a Gbps is equivalent to sending over 37,000 pages per second. I know of ATM switches operating at 25 Gig and more. ATM supports both connection and connectionless services, but the technology comes at a high cost too. The ATM header also consumes between 10 – 20% transmission resources and it could not be commercially used for end to end switching because it was too expensive to have as access device.

Internet traffic is switched between networks by routers. When ATM was been planned, routers could only support a maximum of 45 Mbps. This rate was certainly too small for the IP core backbone or switching and ATM was touted as the ultimate switching technology to carry IP data. But because ATM was too expensive for an end to end switching, other elements are then used. The implication is that multiple switching technologies have to be used in a particular network, but this means that there will also be needs for different element management. Moreover, advances in Optical DWDM meant that the transmission links could now support rates that are in Exabit per seconds (2^{60} bps) – that is more than 10^{16} bps. The resultant effect was that attention turned to switches that would exploit the advances in technology to support IP. There are now commercial Gbps routers and Multiservice switches that would support IP, but ATM still remain the dominant core switch and would remain so for some time to come because of its quality of service capabilities. However, IETF, the Internet Engineering Task Force has recommended RFC 2475 and 2205 - 9 to support QoS. The two approaches are referred to as DiffServ and RSVP protocol.

In order to fully appreciate the discussions in subsequent sections the reader is expected to have a reasonable understanding of the mobile networks and TDM switching elements. Unfortunately, we are not able to provide this additional information here due to space constraints, but the interested reader can get the background information elsewhere (7,13,16).

4.0 NETWORK MIGRATION STRATEGIES

Convergence of the various network architectures into a common packet core is the way forward. The benefit of moving to the packet core can never be over emphasised and only few of the benefits have been given elsewhere (14,15). It is not a matter of whether the operators will move to a packet core technology, but when and how they will get there. The move to packet core is propelled by the desire for a high-speed data communication and the ability of packet technology to be modular, thus supporting varied applications development and 3rd party applications deployment within a short time. These numerous benefits have made the ITU, other international professional bodies and the telecom companies to be touting a next generation network (NGN) model, which uses a packet core technology.

Although the ultimate NGN model evangelises an entirely packet-based voice network with all legacy voice functions replaced, but because of the investment in the legacy elements (i.e. MSC, GMSC, Class 4 and 5 TDM switches), there is a case to be made for phased migration. First, for some, the entire packet voice vision will be too radical. There is also the fact that there is little justification to replace existing voice switches and other TDM hardware that have not yet reached end of life or been fully depreciated. *Doing nothing is not necessarily the cheapest option as it could cost an operator its business in the future. A phased approach business case for the convergence to packet core would be much easier to justify than a single step complete packet voice migration approach.* It is to be said that the 3GPP release 5 advocates a complete "all IP" NGN. Though many mobile operators are already working to evolving to the all IP architecture, it would be very challenging for the financially starved operators and may take a decade or so to accomplish. However, dividing the migration up into phases may indeed be the best commercial solution as each part can proceed under its own economic constraints and timeframe. Though, if widespread switch replacement is not planned, there are some immediate benefits that can be achieved with modernizing the control of existing voice switches and their signalling networks. Therefore, most industry experts advocate a step-by-step approach to moving towards a NGN convergent model. The approach adopted by each operator would obviously differ because of the architectural differences and design of their networks. New entrants have nothing to migrate, but without proper planning they can dabble into a traditional TDM network design that would call for migration to packet at a later date and that is why we shall discuss them as well.

4.1 New Entrant Voice Operators

There is enormous benefit for new operators to consider a packetised voice rather than conventional TDM Voice switches and hardware. New entrants really need differentiating services to offer consumers in order to penetrate the market, but the traditional voice is ubiquitous in nature and very mature; it offers no room for service differentiation. Moreover, Voice switches are optimised to handle tens of thousands of users and typically have a high entry price point, thereby making a high entry barrier for new operators. Furthermore, the functionality of the voice switches is typically very similar and there is often little scope for innovation in voice services. Development of new features and regression testing phases for switch software take long to accomplish with the conventional voice. A method of using "distributed servers" is what a new entrant should follow. The distributed server has the advantage of being data oriented and as such can easily evolve into the NGN. But, more importantly the "distributed servers" approach is significantly cheaper and faster to implement. Taking a traditional 2G MSC for instance, a port would cost at least $500, where as the same port in the distributed server architecture would cost less than $40. I believe that sufficient business justification has been made against traditional voice switches for new entrants.

4.2 Existing Mobile and Fixed Network Migrations

In the previous section we brought in the concept of distributed server approach to migrating to packet domain. The "distributed servers" approach is also referred in the literature to the "Softswitch" approach. The "distributed server" consists of Call Agents (CA), Media Gateways (MGW), and Signalling Gateways (SG). In most cases the media gateway function is placed in another box, while the signalling and control functions reside in the server or Softswitch (SS). Therefore, the server migrations approach advocates a two pronged network elements to replace the functionality of the traditional class 4 or 5 switches. The functionality of the distributed servers can then be scaled to achieve different functions in addition to the voice packetisation. Heretofore we shall refer to the "distributed servers" as a Media Gateway (MGW) and Softswitch (SS). The MGW performs the conversion of the TDM voice to packet and also the relaying function that would otherwise be done by a class 4 or 5 switches. The SS would assume the call controlling function and other signalling functions that may be required in the future.

We shall now look at four main migration strategies that those existing mobile or fixed lines operators can adopt. The strategies are as follows:

A. Toll - Tandem Packet trunking,
B. The Class 4 Switch functionality Migration,
C. Gateway Signalling migration and
D. NGN Wireless Gateway Migration.

4.2.1 The Toll-Tandem Packet Trunking

This migration approach is heralded as the most appropriate starting point in the process of packet voice migration. The class 4 switches remain in the network, but MGW is placed in the network to aggregate all the TDM traffic and also convert same to packet. The voice traffic converted to packets is then forwarded by the MGW through a packet core. The SS provides the call control functions. This approach eliminates the use of several lease lines.

In Figure 2, we show a sample mobile architecture with a media gateway aggregating the MSC TDM voice traffic and forwarding it as packet through a packet core. The diagram further shows that all the MSC that otherwise would have been meshed with several lease lines are only connected to MGW that provides trunking savings as already shown elsewhere (14,15).

4.2.2 The Class 4 Switch functionality Migration

This approach advocates the replacements of the class 4 switch. Class 4 represents a smaller investment for the service operators and with less functionality than a Class 5 switch. A packet-based Class 4 switch replacement can still communicate with the existing Class 5 switches using Inter Machine Trunk (IMT) as well as supporting ATM/IP interfaces. This dual mode capability enables conversion of voice trunks at the Class 5 switch from TDM to ATM/IP packet. In this approach the class 4 switches are replaced with a MGW, which provides the TDM to packet conversion and also forwards the traffic through a packet core. The SS provides the H.248 control of the MGW. In the mobile domain this approach is known as GMSC replacement.

4.2.3 Gateway Signalling Migration

The traditional SS7 or C7 are predominantly lease line networks and as such there is a justifiable business case to move away from a dedicated SS7 network. The higher layer functionality, which involve the database querying and forwarding functionality should remain. But the lower layer functionality should be removed by moving the querying functionality of the class 4 and 5 switches to the SS. It has been argued in the industry that the cost justification for the start of a packet migration has come from migrating some of the lower layer signalling functionality to the SS.

If we re-examine Figure 2, ordinarily all the MSC would be connected to the SS7 network resulting in several lease lines cost. Further savings can be achieved by moving some of the SS7 lower level functions into the SS.

4.2.4 NGN Wireless Gateway Migration

This is the ultimate migration strategy. It is a migration strategy that puts an operator in a position to evolve fully to NGN architecture. A GSM mobile operator only needs to add UTRAN to the GSM network in order to be fully 3G compliant. In this approach all the class 5 or MSCs are replaced with a gateway that has also a wireless gateway functions in addition to the media gateway functionality. As a matter of fact this is the strategy suggested in 3GPP (2) Release 99, 4 and 5, an IMT-2000 initiative of the ITU. In the Figure 3, the media gateway replaces the class 4/5 switches (GMSC/MSC) and the Softswitch (MSC server) provides the call controlling of the MGW through H.248 or IP. In the diagram we can observe that the UMTS Terrestrial Radio Access Network (UTRAN) is added to provide 3G services. Furthermore, the Base station subsystem (BSS) is also shown in the diagram because the 3G would support also a migrated packetised GSM. Radio Network Controller (RNC) aggregates and controls all the call requests coming from a node B. There are usually several RNC in a UTRAN.

CONCLUSIONS

The vision of ITU is to have all the different operators to converge their individual networks into a single packet core network. This would lead to infrastructure that is robust, scalable and cost effective in the future. A network that would support numerous value added services necessary for business growth. More importantly, any packet technology is easier to evolve into the Internet technology and also the next generation networks. The more operators that would upgrade their infrastructure to the packet technology, the more there would be operators that would help bring affordable Internet services closer to service providers and hence the society. This paper has discussed the need and the strategies to migrate operators' network to a packet technology and hitherto, NGN.

The need to migrate operators' network in a developing economy cannot be over-emphasised. The more the operators embrace the packet technology; the most likely emphases would be placed on the technology. Consequently, the more the associated services can be brought closer and affordable to the service providers, the more services can be offered to the general public and hence the faster the digital divide can be bridged.

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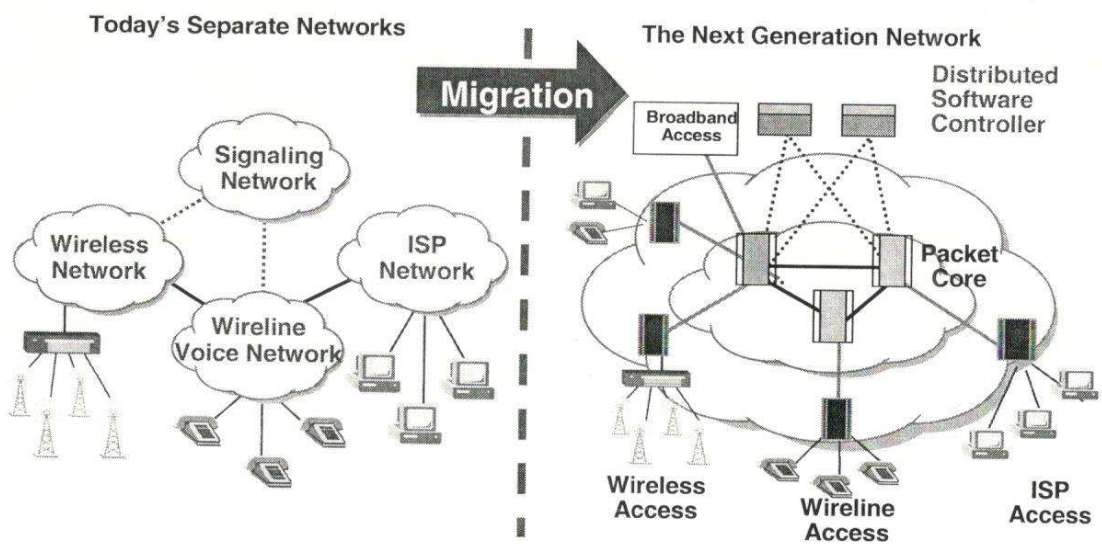

Figure 1: Migration Target Architecture

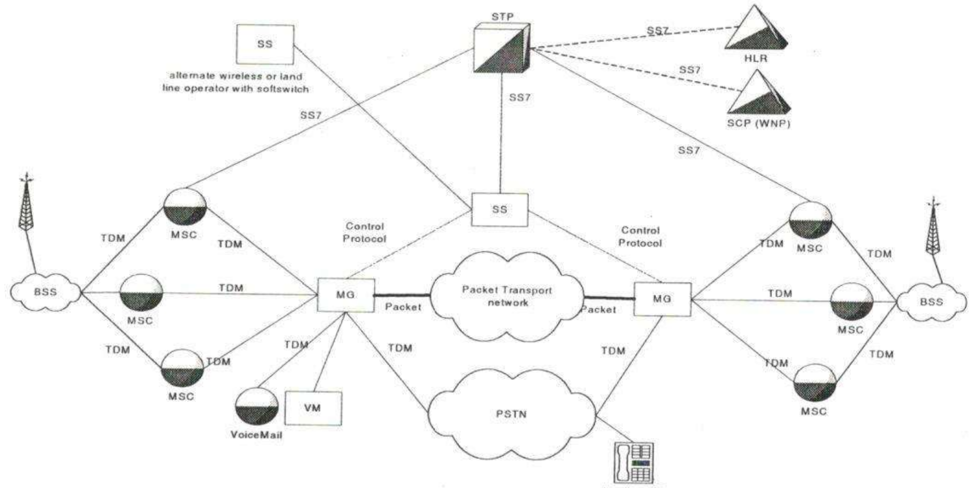

Figure 2: Toll-Tandem Packet Trunking

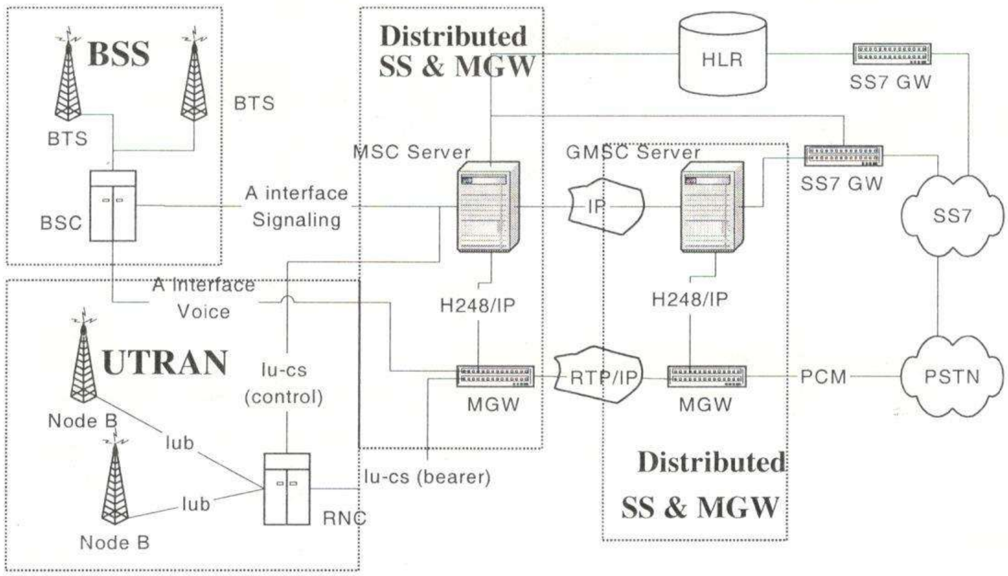

Figure 3: Adaptation of 3GPP Release 4