The Pathway of GSM to 3G Systems in Nigeria.

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ABSTRACT

GSM is playing a vital role in bringing great changes in the telecommunication sector in Nigeria and the world at large. The GSM has brought communication to the doorstep of every Nigerians. The clarity nature of the voice communication, which is the major application on the GSM, has made it more acceptable than the landline. Recently, the interest of Nigerians in accessing their e-mails and browsing of the Internet while on the move has increased due to the introduction of GPRS to the network. This GPRS is limited in the number of data that can be accessed at a time. Many Nigerian GSM operators are now Jostling to improve or upgrade their Network to 3G, which promise better quality of service and customer's satisfaction.

In this paper, the GSM technology is reviewed. The major upgrade to the GSM technology that has made the deployment of higher technology like GPRS, EDGE possible is analyzed. The deployment of GSM and its upgrade through the GPRS to EDGE and UMTS, which is the major 3G technology that is compatible with the GSM, is presented here. The evolution scenarios that can minimize cost and bring users satisfaction are also stated.

(Keywords: GSM, GPRS, EDGE, 3G, UMTS, WCDMA, communications technology)

INTRODUCTION

The introduction of digital systems gave rise to the second generation (2G) of cellular telephones and it was at this point that Global System for Mobile Communications (GSM) was released. GSM is more advanced and handles more subscribers than analog systems. It offers high quality voice communication and low bandwidth (96 kb/sec) data connections for fax and short message service (SMS). Data connection services like browsing, videos, multimedia, and e-mail demands on mobile telephone have increased tremendously; thereby necessitate the need for a reliable and always available infrastructure to support these services (Hartel et al., 1999). In the quest to meet this demand, 2.5G GSM was introduced through GPRS, HSCSD to give support for these demands.

3G Mobile Technology was created to support Internet connectivity and packet-switched services as well as circuit switched services such as phoning on the cellular radio. The data rates on the 3G ranges from 144Kbps for fast moving mobiles to 2Mps for slow moving mobile users. The future 4G is considered to be the integration of the existing cellular networks and wireless LANs with added personalized mobile networks and broadband radio access networks to provide end-to-end IP connectivity.

The aforementioned introduction now opens our eyes to the relationship and connectivity that exist between the GSM technology and other higher technologies. All other technologies are based on the GSM technology; in other words, GSM technology stands as a backbone for other cellular technology. The ITU always put the backward compatibility to the GSM as one of the criteria for rolling out new technology.

CELLULAR SYSTEMS CONCEPTS

A cellular network is a mobile network in which radio resources are managed in cells. A cellular network is regarded as a regular grid of hexagonal cells. An n x m cellular network has n rows and m columns of cells. Figure 1 shows a 7 x 7 cellular network. Cell coverage is determined by the coverage of a transceiver's signal. Cell radii vary from tens of meters to hundreds of meters or more.

The cellular equipment can communicate with the mobiles as long as they are within range. The low-power level transceiver is called channels, which are located at the Base Transceiver Station (BTS). Since radio energy dissipates over distance, the mobiles must be within the operating range of the base station for communication (Scourias, 1997).

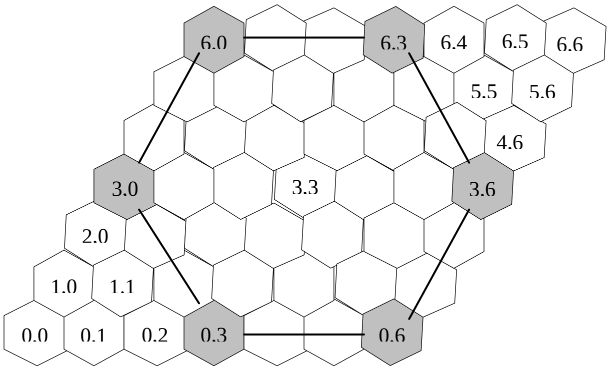

Figure 1: 7 x 7 Cellular Networks.

GLOBAL SYSTEM FOR MOBILE COMMUNICATIONS (GSM)

The Global System for Mobile communications is a digital cellular communication system. GSM was developed in order to create a common European mobile telephone standard but it has been rapidly accepted worldwide.

From 1982 to 1985 discussions were held to decide between building an analog or digital system. After multiple field tests, a digital system was adopted for GSM. The next task was to decide between a narrow or broadband solution. In May 1987, the narrowband time division multiple access and frequency division multiple access (TDMA/FDMA) solution was chosen (Scourias, 1999).

GSM is a major digital cellular radio network in Europe since 1980s, where it is used in the 900MHz radio band. The radio band is also known as frequency of the network (Harte et al., 1999). GSM has been standardized to 900MHz, 1800MHz, and 1900 MHz. The 900MHz and 1800 MHz used the same base band signals, but they operate on different carrier frequencies. The radio frequency separation between matching the uplink and downlink carrier for 900MHz is 45MHz while that of 1800MHz is 90 MHz as indicated in Figure 2. The 1900MHz is used mainly in North America. The frequency separation between matching the Uplink and downlink frequencies is 80MHz.

Other GSM specifications are:

- Channel separation—the separation between adjacent carrier frequencies in GSM is 200 kHz.
- Modulation—Modulation is the process of sending a signal by changing the characteristics of a carrier frequency. This is done in GSM via Gaussian minimum shift keying (GMSK).
- Transmission rate—GSM is a digital system with an over-the-air bit rate of 270 kbps.

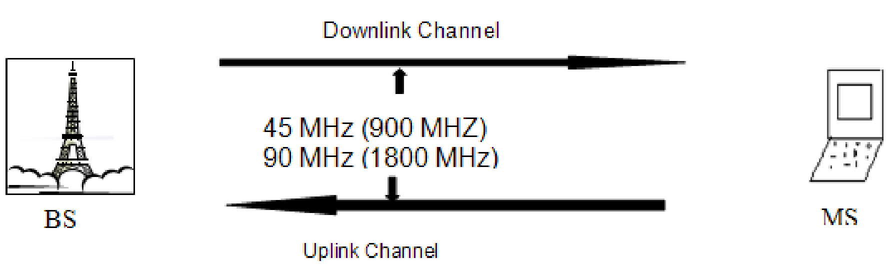

Figure 2: GSM Duplex Radio (Source: Mehrotra, 1997).

GSM PUBLIC LAND MOBILE NETWORK (PLMN)

GSM Public Land Mobile Network (PLMN) defines and summarizes description of the elements comprised in the network, and their functions and the associated performance objectives within the digital cellular telecommunications system (Scourias, 1999).

A GSM PLMN in cooperation with other networks provides a set of network capabilities, which are defined by standardized protocols and functions and enable telecommunication services to be offered to customers. The general objectives of a GSM PLMN network are to provide:

- Voice & non-voice services, which are compatible with fixed networks like PSTN, ISDN.
- Exclusive services to mobile stations.
- Facilities for automatic roaming, Locating and updating mobile Subscribers.
- Service to a wide range of mobile stations, including vehicle mounted stations, portable stations and handheld stations.

THE GSM NETWORK ENTITIES

The GSM network is divided into three major systems: the base station Subsystem (BSS), the switching Subsystem (SS), and the operation and support system (OSS). The basic GSM network elements are shown in Figure 3, details of all these subsystems are described in subsequent sections.

GSM NETWORK INTERFACES

The GSM network is made up of geographic areas. As shown in ***Figure 4***, these areas include Cells, Location Areas (LAs), MSC/VLR service areas, and Public Land Mobile Network (PLMN) areas. The Cell is the area given radio coverage by one base transceiver station.

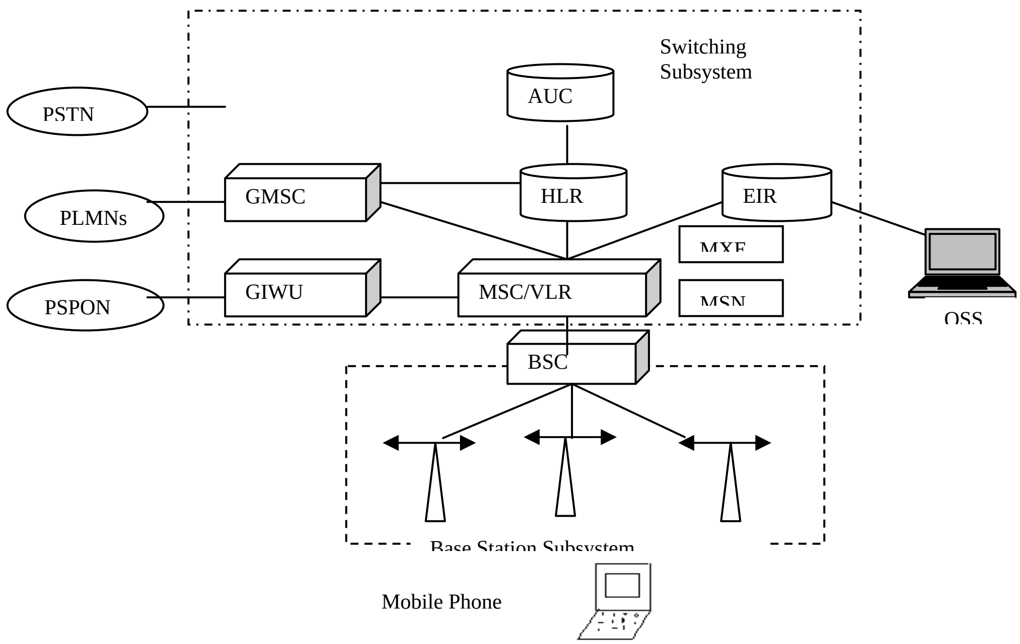

Figure 3: GSM Network Elements *(www.iec.org/online/tutorials/gsm).*

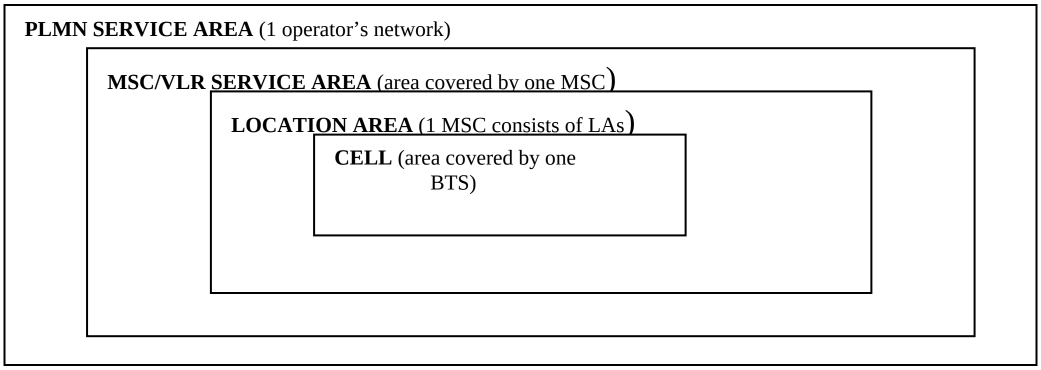

Figure 4: PLMN Service Area *(Courtesy: www.iec.org online /tutorials/gsm).*

The GSM network identifies each cell via the Cell Global Identity (CGI) number assigned to each cell. The Location Area (LA) is a group of cells where subscribers are paged in the area. One or more base station controllers serve each LA, but with a single MSC. Each LA is assigned a Location Area Identity (LAI) number. An MSC/VLR service area represents the part of the GSM network that is covered by one MSC and which is reachable, as it is registered in the VLR of the MSC. The PLMN Network area is an area served by one network operator

MOBILE STATION

The Mobile station consists of Mobile equipment (mobile phone) and Subscriber identity module (SIM). SIM provides personal mobility so that the user can have access to subscribed services irrespective of a specific terminal (Scourias, 1999). SIM has a microprocessor and a memory that can hold information that will remain in the chip even if the SIM card is deactivated (Harte et al, 1999).

THE BASE STATION SYSTEM (BSS)

A GSM network is comprised of many base station subsystems (BSSs), and it consists of base station controllers (BSCs) and the base transceiver stations (BTSs). The BSS performs the necessary functions for monitoring radio connections to the Mobile Station (MS), coding and decoding voice, and rate adaptation to and from the wireless network. The covered area of a cellular network is divided into smaller areas called cells. Each cell is connected to a base station system, which communicates simultaneously with all mobiles within the cell, and passes traffic to the Mobile Switching Center. The Base Station System is connected to the mobile phone via a radio interface (Perianan and Fahham, 1996).

BASE TRANSCEIVER STATIONS (BTS)

The BTS handles the radio interface to the mobile station. The BTS includes all the radio equipment (i.e., antennas, signal processing devices, and amplifiers) necessary for radio transmission within a geographical area called a cell. Transceiver consists of a transmitter and a receiver, which has a duplicated "front end" to match up with the two receiving antennas used in the base antenna assembly (Mehrotra, 1997). A BTS is usually placed in the center of a cell and its transmitting power defines the size. A group of BTSs are controlled by a BSC.

BASE STATION CONTROLLERS (BSC)

The BSC provides all the control functions and physical links between the BTS and MSC. BSC is used for data communication with MSC and data signaling with the mobile station on the radio path. BSC comprises a central processor, data communication facilities, and multiplexing and de-multiplexing equipment (Harte, et al., 1999). A number of BSCs are served by an MSC. The Base Station Controller manages the radio resources for one or more BTSs (Scourias, 1999).

THE SWITCHING SYSTEM

The central component of the Network switching subsystem (SS) is the Mobile services Switching center (MSC). MSC is the link between the Base station subsystem and network switching subsystem of the GSM Network. Also it acts as the link between the cellular system and the PSTN. MSC is responsible for performing call routing to a roaming subscriber, registration, authentication, location updating, handovers and subscriber-related functions (Scourias, 1999).

These services are provided in conjunction with several functional database entities, which together form the Network switching system. The databases are HLR, VLR, AUC, EIR, GCR, MXE, MSN, and SMSC. Signaling between functional units in the MSC uses Signaling System Number 7 (SS7). SS7 is widely used for trunk signaling in the ISDN and in public networks. Signaling allows different functional units to interwork successfully and provide a data communication path between network nodes (Erricsson, 2002).

Some MSC are called gateway MSC (GMSC). A gateway is a node used to interconnect two networks. The GMSC is the interface between mobile network and other mobile network or any other network. All incoming calls to the PLMN from another PLMNs, fixed wireless or landlines must pass through the gateway (Mehrotra, 1997).

Gateway MSC works as an incoming transit exchange for the GSM/PLMN. Gateway MSC contains interconnecting functions to make interconnections btw two PLMNs, PSTN, or fixed wireless. They also route incoming calls to the proper MSC within the Network.

GENERAL PACKET RADIO SYSTEM (GPRS)

The general packet radio system (GPRS) provides packet radio access for mobile Global System for Mobile Communications (GSM). GPRS is built on GSM network to provide effective data service like Internet applications as shown in Figure 5. It allows data to be sent and received across the mobile circuit switched network. Since it introduces a packet-switching service to a circuit-switching network, some hardware and software are added to provide upgrades to this form (Pentikousis, 2003). GPRS is the first step toward an end-to-end wireless infrastructure. The main importance of GPRS is to allow circuit-switched GSM subscribers have access to data services since the transmission speed increased up to 172kbps, which is not achievable under GSM/SMS.

Packet switching means that GPRS radio resources are used only when users are actually sending and receiving data. Rather than dedicating a channel to a mobile data user for a fixed period, the available radio channel can be shared between several users (Pentikousis, 2003). In addition, a mobile host can be allocated more than one of the 8 available slots in the TDMA Frame. GPRS improves the peak time capacity of GSM supporting virtual connectivity and migrating traffic that was previously sent using Circuit Switched Data to GPRS and reduces SMS center and signaling channel loading.

Two extensions were made to GSM Switching system to accommodate the GPRS packet switching, they are; Gateway GPRS support node (GGSN) and Serving GPRS support node (SGSN). GGSN performs functions equivalent to gateway MSC and SGSN performs functions comparable to Visited MSC (VMSC/VLR) (www.iec.org). The BSC includes the packet control unit (PCU), which supports all relevant GPRS protocols for communication over the air interface.

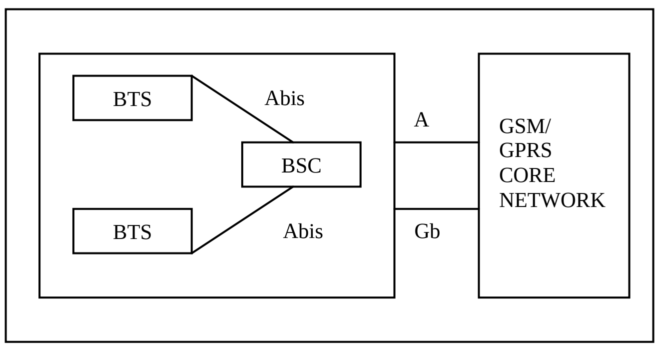

Figure 5: GSM/GPRS EVOLUTION (Source: www.kate-kom.com).

GPRS defines four channels coding schemes namely CS1, CS2, CS3 and CS4 with radio data rates 8.8 kbps, 13.3 kbps, 15.6 kbps, and 21.4 kbps per slots in the 8-TDMA frames, respectively. In practice, CS3 is commonly used for providing 124.8 kbps per frequency channel in TDMA frame. The real life experience is around 40kb/s, which is acceptable for Internet access and web browsing. GPRS facilitates instant connections whereby information can be sent or received immediately as the need arises without any modem dial-up connection. Subscribers with mobile phone that is GPRS enabled and subscribe to GSM network that has been GPRS upgraded can only enjoy GPRS.

LIMITATIONS OF GPRS

1. Limited Cell Capacity: GPRS depends on the GSM timeslots to operate. This, thus limit the capacity expansion of GPRS.

2. Speeds lower in reality: Achieving the theoretical maximum GPRS data transmission speed of 172.2 kbps would require a single user taking up the 8 timeslots without any error protection. It is unlikely that a network operator will allow all timeslots to use by a single user.

3. No store and forward: The store and forward engine present in the short message center of GSM service is absent in the GPRS standard.

4. Transit delays: GPRS packets are sent on all different direction to reach the same destination. As a result there is possibility of some of the packets to lost or corrupted on the way. Though GPRS standard recognize this and then incorporates data integrity and retransmission strategies, however, the result is that potential transit delays can occur.

ENHANCED DATA RATES FOR GLOBAL EVOLUTION (EDGE)

Enhanced Data Rates for GSM Evolution (EDGE) is a standardized set of improvements to the GSM/GPRS network radio interface and brings higher data rates. EDGE allows consumers to connect to the Internet and send/receive data, at up to three times faster than possible with an ordinary GSM/GPRS network. EDGE builds on the GSM infrastructure uses the same channel structure, frequency planning, protocols and coverage. EDGE is another step in GSM/GPRS evolution towards 3G (Figure 6).

The EDGE network offers average data speeds of up to 384kbps and it is faster than any other wireless data network including CDMA and GPRS (Cingular, 2005). GPRS and GSM are based on a modulation technique known as Gaussian minimum-shift keying (GMSK) but EDGE is based on a new modulation scheme that allows a much higher bit rate across the air interface- this is called eight-phase-shift keying (8-PSK) modulation (PentiKousis, 2003).

This technique uses the same GSM carrier bandwidth and timeslot structure and shares the GPRS network elements. Enabling this application requires some hardware charges as well as adaptations in the signaling structure on the BSS side (www.kate-kom.com). Nine modulation and coding schemes are defined for edge; MC-1 to MC-9. Charges on EDGE networks are done as per amount of data transfer at a given time, so, subscribers pay for data sent and received and not on the number of minutes spent when connected to the Internet.

It is very essential that the subscriber be equipped with the right mobile equipment for them to enjoy the service. Some new mobile phone handsets and Personal Digital Assistants (PDAs) come with EDGE-capability and thereby allow instant connection to Internet. Another alternative is to connect an EDGE-enabled handset to a Personal Computer, laptops through edge-capable PC cards (Cingular, 2005).

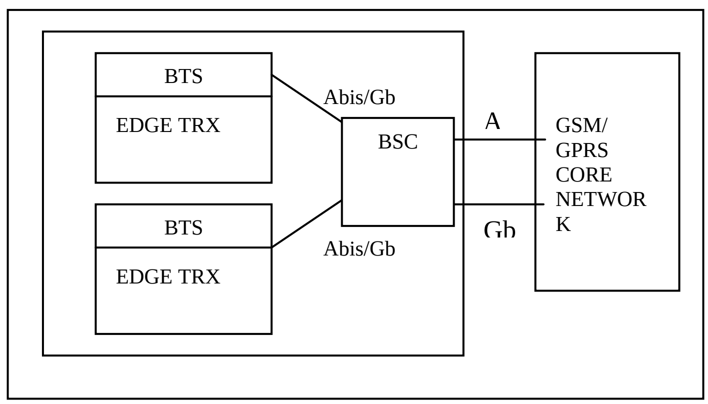

Figure 6: EDGE Enhancement for GSM/GPRS Network (Source: www.kate-kom.com).

THIRD GENERATION (3G) WIRELESS SYSTEMS

International mobile telecommunication (IMT)-2000 is the standard choosing for 3G communications system development. IMT-2000 is a set of requirements defined by International telecommunication union in the year 2000, thus, the name IMT-2000. IMT-2000 aims to realize 144 Kbps, 384 Kbps, and 2 Mbps under high mobility, low mobility, and stationary environments, respectively. 3G communications system have the ability to provide high data transmission capability for processing multimedia applications, internet personal services, the convergence of digitization, mobility based on the global standard (Prasad and Muñoz, 2003).

The international bodies responsible for the standardization of 3G wireless systems are the 3GPP and 3GPP2. The 3GPP based its evolution to all-IP core network on GSM/GPRS while 3GPP2 is based on CDMA1xRTT. Mobility management of 3GPP is based on GSM/UMTS Packet Switched network and 3GPP2 is based on the Mobile IP. 3GPP was established to harmonize standards that will evolve GSM/GPRS to WCDMA (3G) and 3GPP2 for CDMA fixed wireless to CDMA2000 (3G) (www.iec.org).

WIDEBAND CODE DIVISION MULTIPLE ACCESS (WCDMA)

Universal Mobile Telecommunication System (UMTS) is the standard for 3G mobile technologies and W-CDMA is the radio technology chosen for UMTS. WCDMA is a new, highly efficient technology for both packet- and circuit-switched traffic. It provides more capacity and higher data rates to enhance the User's experience of existing voice and data services as well as new advanced Mobile Internet services.

UMTS is designed to provide access to the existing Internet services as well as UMTS specific services. It augments the existing capabilities of 2G mobile networks and GPRS, and will be extended to provide either higher rates at stationery situations, or support higher mobility at the same rates (http://seacorn.ptinovacao.pt)

Code Division Multiple Access (CDMA) is a multiple access technology where users are separated by unique codes, which means that all users can use the same frequency and transmit at the same time. The use of unique codes means that the frequency is repeated in all cells, which are commonly referred to as frequency re-use of 1 (Erricson, 2001). This is the principle used in WCDMA. The International Telecommunication Union (ITU) allocated a specific spectrum – 2GHZ frequency bandwidth for WCDMA system (Erricson, 2001)

The carrier spacing can vary from 4.2 to 5.4 MHz. Different carrier spacing is used to obtain suitable adjacent protections depending on the interference scenario (Ojanpera and Prasad, 1998). WCDMA supports a higher bit rate up to 2 Mbps, higher spectrum efficiency and higher quality of service. It establishes a global roaming standard

WCDMA ARCHITECTURE

The WCDMA network consists of three subnetworks as shown in Figure 7:

- UMTS Terrestrial Radio Access Network (UTRAN)
- Circuit-Switched (CS) domain
- Packet-Switched (PS) domain

The UTRAN composed of a set of radio network subsystems (RNSs) connected to the core network (CN) through the Iu interface. The RNS consists of radio network controller including some IP routers and Node B that can be compared to the BSC and BTS of GSM Network respectively. UMTS core network uses the same network with the GSM/GPRS core network with some extensions to accommodate the UMTS requirements.

The core network consists of the MSC/VLR, serving GPRS support (SGSN), Gateway SGSN (GGSN) HLR and some other components for signaling. CN is composed of the circuit (CS) – and packet (PS) – domains. RNS is connected to circuit switched domain through Iu interface (Iu-CS) and packet switched domain through another Iu interface (Iu-PS). These interfaces are logical interfaces, which may be provided via any suitable transport network (Prasad and Muñoz, 2003).

SGSN is responsible for delivery of data packets form and to the UEs within the service area while GGSN allows interconnection with external packets switched networks (kaaranem et al, 2001). RNC handles protocol exchange between Iu, Iur and Iub interfaces. RNC uses Iur to handle 100% of Radio Resource Management thereby eliminating the burden from CN (www.iec.org). The control RNC (CRNC) is used for the control of resources allocated within node Bs connected to the RNC. Serving RNC (SRNC) handles admission control, RRC connection to the UE, congestion and handover.

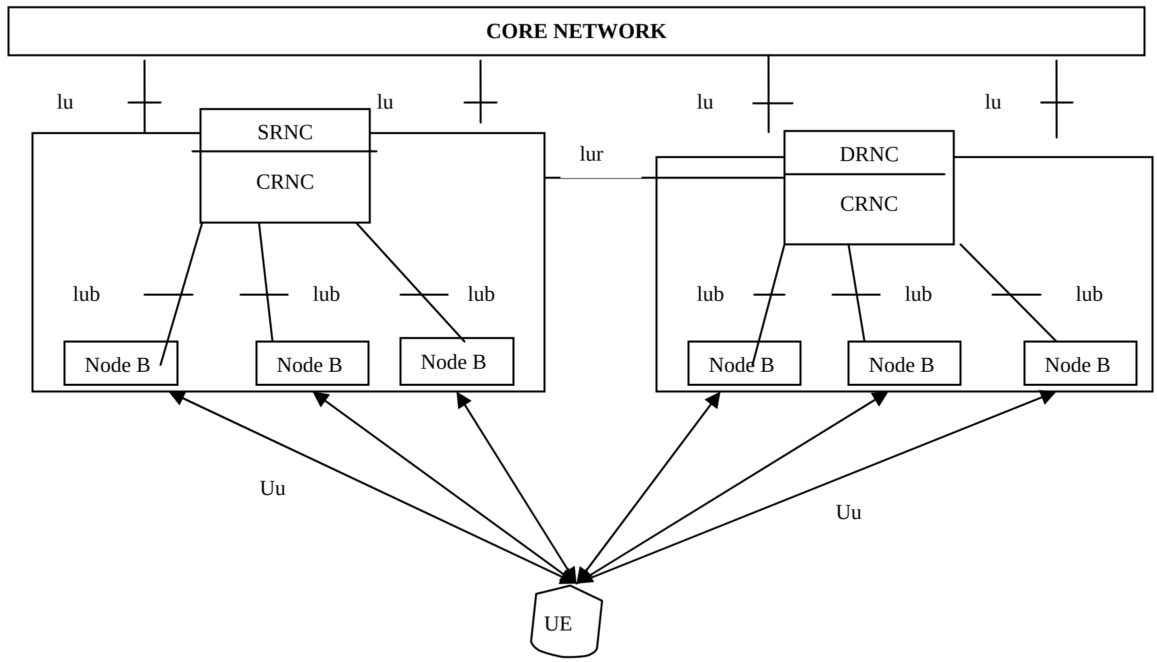

Figure 7: GSM/WCDMA Architecture.

There must be one SRNC for every connection between UE and ultran. Drift RNC (DRNC) support the SRNC by providing radio resources within radio cells. Any RNC can take on the role of SRNC or DRNC on a per-connection basis for a UE (Prasad and Muñoz, 2003).

Node B is the support for user equipment based on Frequency Division Duplex (FDD), Time Division Duplex (TDD) (Dual mode). It is the physical unit for radio transmission and reception with cells (www.iec.org). A Node B can serve one or more cells. It can be located with the GSM-BTS to reduce implementation cost. Node B is connected with the user equipment (Ue) through Uu and connected to RNC by lub. UE is based on the same principle as GSM mobile station and is used for connection to the radio cells for onward transmission to Network.

In addition to UTRAN, GSM/EDGE evolution incorporated in UMTS form GSM/EDGE Radio Access Network (GERAN) to provide the same circuit and packet switched services as UTRAN. For that purpose, GERAN architecture offer backward compatibility to GSM/GPRS using A and Gb interfaces (Figure 8).
Most of today's GSM networks will evolve to converge GSM and UMTS in view of this architecture.

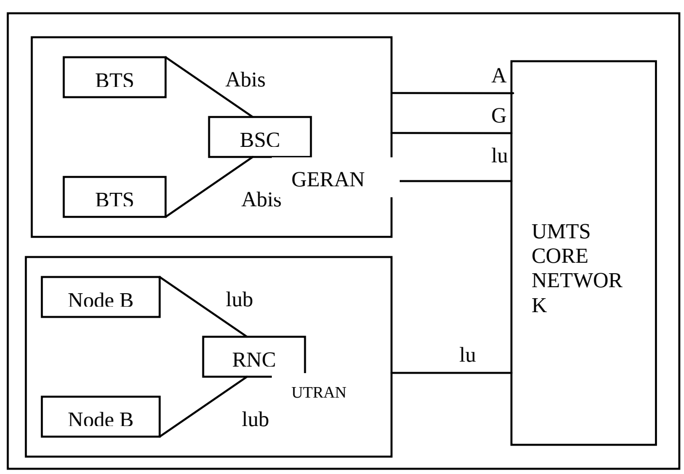

Figure 8: GERAN and UTRAN Architecture.

THE PATHWAY OF MOVING FROM GSM TO 3G SYSTEMS

Movements of GSM Network to 3G have different paths. The methods below are suggested for easy deployments. They are:

a. Some GSM Network operators can adopt moving through the 2.5G to 3G, that is, moving through GPRS (171 Kbps) to 3G as the core network of GSM/GPRS can be extended to support the 3G. The most modifications have to be done at the base station subsystem and at the mobile station to be able to suit the new application.

b. Some can plan for Edge (384 Kbps) as a step towards the 3G especially the new entrants like the Etisalat and GLO. Wideband CDMA (WCDMA, 2Mbps) is a standard for GSM evolution to 3G. Migrating to the WCDMA will just be a matter of incorporating the Edge network with the new 3G network.

c. Some operators can deploy an independent 3G-Core Network (3G-CN) from the 2G core Network (2G-CN), but Inter-Operability Tests (IOTs) will be needed depending on the architecture because it is likely possible that there is going to be multi-vendor scenario of the equipments to be used (Prasad and Muñoz, 2003).

This deployment of new 3G Core Network will be running in parallel with the 2G-Network.

CONCLUSION

The 2G wireless communications was driven by the high demand of voice communication and that was successful, but there is limitation to data it can transmit. Now, there is a paradigm shift to high demand for high-speed data transmission, which forms the basis for 2.5G and beyond. There is always a backward compatibility with the 2G systems for voice communications in all 2.5G and above. Therefore, the movement will not be too much burdensome to the operators since it will only involve incremental upgrade.

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