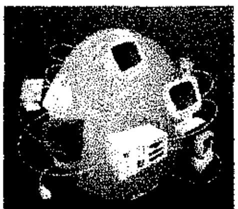

SEMESTER 1, 2001

Analysis of GPRS Limitations

By

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Submitted for CSE5702 Master Project

Supervisor: Chintha Tellambura

Master of Information Technology
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School of Computer Science & Software Engineering
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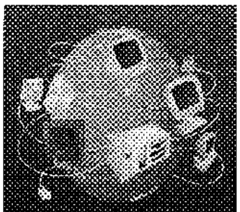

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this thesis has been examined and award a high distinction (HD).

C. Tellambura
CSE/Monash University
01/08/01

Master of Information Technology
Faculty of Information Technology
School of Computer Science & Software Engineering
Monash University

ABSTRACT

The General Packet Radio Service (GPRS) is a new standard for mobile data communications, which is implemented under the existing infrastructure of Global System for Mobile Communications (GSM). The promise capability of handling Internet Protocol traffic enables instant and constant connection to global network regardless of location and time. With its packet-based nature, the new technology facilitates new applications in wireless communications that have not been available previously. Nonetheless, there are numbers of limitations that have to be taken into consideration before this technology can be implemented commercially. Despite all arguments and challenges, the GPRS system is here to stay and evolving towards the third generation mobile communications. This report covers the background of the GPRS and discusses the issues involved in implementing this current technology besides considering the deployment of third generation networks beyond GPRS.

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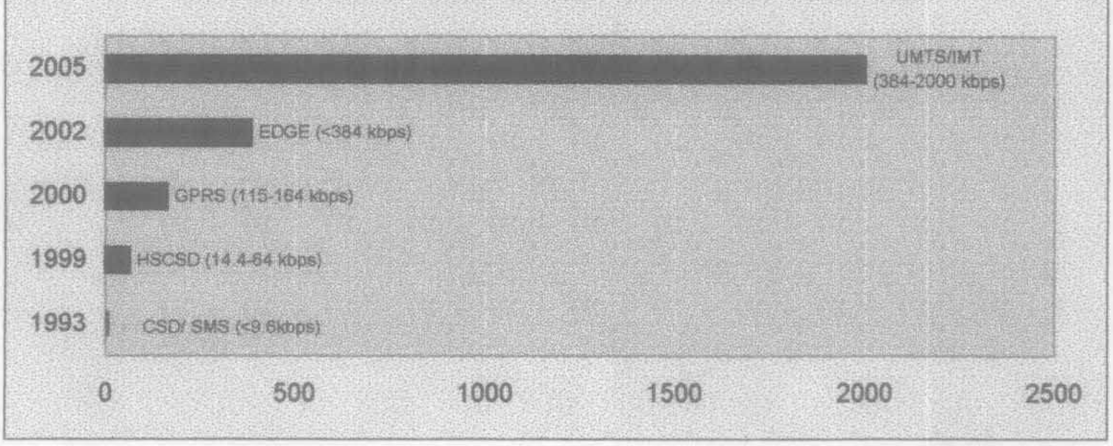
Chapter 1

INTRODUCTION

Mobile and personal communications have undergone a rapid growth during the last decade. People are beginning to treat mobile communications as a necessity, not just means of wealth. In some leading countries in the world, for example Finland [18], subscription for mobile network is in fact higher than the fixed line subscription. Mainly, the key force to this exponential expansion is the desire to access corporate information or global network via mobile communication means such as mobile phone regardless of location and time. For this reason, network operators and providers are improving their network infrastructures and services offered from time to time to ensure that the demands are fulfilled besides taking advantages of the enhance network availability in providing high quality data services at low prices. Figure 1 shows the evolution in data communication and its predicted growth timeline. The GPRS network in this case is expected to be deployed under GSM infrastructure with an initial data rate of approximately 100 kbps, which is 10 times more than the current circuit-switched employed in the GSM.

FIGURE 1: Mobile Services Evolution And Predicted Data Rate [9]



In order to enhance mobile capabilities, there are several important aspects that need to be addressed since the shifting technology will require numerous channels to be implemented to increase the network capacity. Considerations should be given on the issues such as distribution of co-channel interference, mobility of users, characteristics of the surrounding environment and modulation techniques to be used in adapting such technology [2]. Taking into account all these complexity, at the beginning of 1999, GPRS was introduced which was based on a concept of packet data transmission over voice cellular network, the approach known as Dynamic Channel Stealing (DCS) [19]. Another application that uses this concept is the Cellular Digital Packet Data (CDPD) over Advanced Mobile Phone System (AMPS), which is widely used in the Northern American region.

The GPRS design is seen as an intermediate stage allowing the GSM network to accommodate a wide range of global networks including the Internet services before a full scale of 3G wireless communications can be fully deployed. The 3G networks are predicted to be utilized in a few years coming and these includes EDGE and UMTS. Known as the 2G+ network, GPRS is intended to work parallel with the existing 2G wireless technologies such as the GSM. The technology that is contemplated to support wireless Internet usage besides giving the GSM countries an opportunity to catch up with Japan and its I-mode. For this reason, GPRS is aimed for both the GSM and the AMPS infrastructure, with a standard packet switched that able to provide faster packet data access since users would bound 40 to 60 seconds setup delay over the traditional circuit switched modem connections [18]. Based on its packet nature, GPRS will be able to open up direct connectivity to the Internet with all its inherent user value. The first built GPRS system is now available to users from European carriers, the Sonofon in Denmark and the Europolitan in Sweden [23].

Overall, this project is written to present an overview of the technical background of the GPRS network and cover the aspects involved in this newly available technology. Besides reviewing GPRS concept in general, this report will also discuss the GPRS development phases, the architectural and protocol aspects, the implementation and real time issues that rise and its consequences to the GPRS network structure and the development from Second Generation (2G) to the Third Generation (3G) network.

Chapter 2

GPRS OVERVIEW

The emergence of mobile technology has reached a stage where mobile networks have to facilitate new applications that have not been available previously due to limitations in data circuit networks. The GPRS technology is one of the development experimentation to accommodate both voice and data traffic before the 3G network phases can be deployed completely. Due to the needs of an advance version of existing GSM, the GPRS is proposed to enable subscribers to set up faster network session with high data transmission speed besides staying permanently connected. The one advantage of this progress is that, regardless of the connection duration, customers will be charged depending on the bit transferred, unlike the current billing where customers are charged in accordance to the time connected. On the other hand, it also benefits the GSM operators as they can use the excess capacity in voice networks to send packet data and differentiate themselves by offering unique services for the customers.

The GPRS over GSM is based on shared physical channels between the proposed technology and the existing GSM infrastructure known as Packet Data Channels (PDCHs). The shared-environment aggregates data packets to and from different mobile stations on one PDCH and each mobile station is allowed to utilize many PDCHs simultaneously to transmit or receive data packets. Basically, the main purpose, as mentioned earlier, is to allow volume-based billing, which tend to eliminate connection time oriented billing thus provide cheaper and constant network connection. It is presumed that no interference on voice traffic because once voice is detected, packets will be transferred to other free channel instantly. Therefore, it guarantees instant and constant connectivity to the subscribers.

In order to ensure the GPRS system work, there are two major considerations that have to be taken care of by the network providers. First is the cost that may incurred for upgrading the existing GSM infrastructure and the next is anticipated acceptance by the subscribers. Undoubtedly, at least some minor modifications are expected to upgrade the existing GSM infrastructure with a couple of additional new infrastructure nodes and software upgrade, which in turn is a cost consumption processes [4]. The investment is presumed to be profitable for duration of 3 to 4 years coming.

2.1 GPRS CHARACTERISTICS

The most substantial aspect in GPRS deployment is to ensure that the technology is capable of providing better and improved mobile network applications to the users. Therefore, it is necessary for the operators to guarantee mobility, which is the ability of the technology to maintain a constant connection while users are on the move. Users should be able to reach the network whenever they go even during unstable conditions. The next characteristic that should be determined is immediacy where users can obtain a desired connection whenever is needed, regardless of their location and duration. This is extremely important for time critical applications such as remote credit card application as it will be unacceptable to keep customer waiting for even an extra of thirty seconds for payment authorization [4]. Moreover, the operators have to ensure that these types of application is accompanied by high level of security in order to prevent any network attacks and one way to deal with it is by ensuring immediacy. It is also essential for the technology to support localization where users will be able to acquire information that is relevant to their current location such as the weather forecast or maps on a particular location.

2.2 APPLICATIONS

Currently, limited data applications are supported by the current GSM system. An example would be the Short Messaging Services (SMS) application, which allows limited characters transmission over the network. These types of applications also face certain level of delay and arrival uncertainty where the data has to be queued while the priority is given to the voice transmission. Therefore, the GPRS is expected to improve this condition and is enhanced to be able to endure numerous data applications. The sections below describe the type of applications that should be supported by the GPRS.

2.2.1 Horizontal Applications

To this date, horizontal applications which include mobile Internet services, such as Wireless Application Protocol (WAP), e-mail, and web browsing, are most likely to be a dominant in the GPRS deployment. The WAP is an open application development that supports Internet applications locally or globally, which allow Internet contents to be delivered to the mobile terminal despite mobile type and brand. Another enhanced GPRS application is the improvement in Personal Messaging Services, which include an extended length of SMS, a home automation and email services, that are supported by the Mobile Media Mode (MMM) existed in the WAP terminal. The WWW:MMM protocol is used allowing network operators to launch WAP services as the protocol is conceived to comply with the WAP, terminal, WAP partner, gateway and infrastructure [4]. Added to these global services, the network is aimed at accessing corporate data through company Intranet communications for provisioning product and service information.

2.2.2 Vertical Applications

For specific business segments and user groups, the next consideration is placed under vertical applications. It applies to GPRS in term of the capability of the network to carry out specific chores within company value chain [17]. Some of the applications that will be supported by the GPRS network are the telemetry activities (e.g. road traffic measurement), dispatch services (e.g. taxis) and machine-to-machine management (e.g. vending machines), which might be existed today in private radio network but without global coverage.

2.2.3 Value Added Services

Just to name a few, value added services includes E-Commerce, Banking, Financial Trading, Telematics, and Advertising. These applications are expected to be available in the GPRS terminal in a near future for user convenience, as operators will be competitively attempting to differentiate their services. Two types of value added services that are anticipated for GPRS is the *push application* and *pull application* [17]. *Push* refers to the transmission of data at a predetermined time, or under predetermined conditions such as stock market exchange. On the other hand, *pull* refers to the user's demand of real time data such as daily stock updates. However, realizing that there are numbers of limitations in the current GPRS infrastructure it may be difficult for the network operators to come out with the solution that capable of providing all these current updates. Therefore support for these applications may possibly be held until the 3G network implementations take place in a couple of years.

2.3 KEY USER FEATURES

It is important to note that in order to provide these enhanced services, the mobile phone providers should realized the needs of furnishing an appropriate user interface with the knowledge on how to send and receive data from the phone. Consideration should be focused on the horizontal applications heeding it will be used the most. Added to this a menu screen that intuitive and easy to navigate is a definite requirement to support an extra length of the Internet applications as they are normally long. The devices also have to be consistent with types of terminals that are available to ensure that it will be able to provide a compensated performance users especially when dealing with different approaches of corporate activities. Taking into account the current limitations of phone memory, size and capabilities, some of the applications which are expected by the users, especially the vertical and value added, might not be applicable now.

Chapter
3

DEVELOPMENT PHASES

DATE	STAGES
1999	Trial and commercial contracts for GPRS infrastructure
2000	GPRS infrastructure incorporated into GSM networks
Mid-2000	**Phase 1** - First GPRS trial became available. Typical single user throughput is likely to be 28 Kbps
Jan-2001	- Basic GPRS terminals began to be available in commercial quantities - Only support Point-To-Point GPRS
Feb-2001	- Typical single user throughput is likely to be 56 Kbps - Improved GPRS applications, higher bit rates, greater network capacity, and more capable terminals became available
2001	- Operators launch GPRS services commercially and improve the capacity from time to time - Vertical market and early users begin using GPRS regularly for non voice mobile services
2002	**Phase 2** - Typical single user throughput is likely to be 112 Kbps - Point-To-Multipoint support added - GPRS Phase 2/ EDGE begin to emerge in practice - GPRS routinely incorporate with GSM mobile phones and reach critical mass in terms of usage
Mar-2002	- UMTS arrive commercially

Table 1: Development phases for GPRS [4].

There are number of phases that have to be fulfilled and satisfied before a comprehensive GPRS technology can be fully implemented as in other network standards. The GPRS service development consists of standardization, infrastructure development, network trials, contract-placements network rollout, availability of terminals, application development and customer take-up [4]. The predicted time scales for progress on GRPS development is described in Table 1.

As in other earlier technologies like GSM, GPRS will be introduced in stages and its first phase is expected to be available for commercial use in Mid-2000 to 2001, which supports basic Point-To-Point (PTP) GPRS services. For instance, a GPRS trial had been placed by T-Mobil, one of the GPRS providers, at the Hanover Expo 2000 [4]. Accordingly, the technology is expected to become available and enhanced from time to time as explained in Table 1. However, it is important to notice that this is only estimation on the respective stages of GPRS deployment. The growth may somehow being postponed or delayed due to limitation in resources and unrealistic expectation from providers and operators.

Nonetheless, as regard to the GPRS capacity limitations, the target for vertical market will not serviceable, at least not until the beginning of year 2002. This is because most operators and providers have proven to be quite optimistic with some of their previous promises. Delay is a definite expectation as there are major requirements that have to be completed and limitations that have to be compromised in introducing a new wireless services to the community. It may takes a few more years for the GPRS to be fully functional as it is intended for.

3.1 STANDARDIZATION PHASES

The standardization of GPRS is carried out by the Special Mobile Group (SMG), a special technical body of the European Telecommunications Standards Institute (ETSI). The work is divided into two phases:

Phase 1 of GPRS:

- Point-to-Point (PTP) carrier services
- Radio aspects for Point-to-Multipoint (PTM) carrier services
- Interfaces in the GPRS core network
- Support for TCP/IP
- Security aspects

Phase 2 of GPRS:

- Point-to-Multipoint (PTM) services
- EDGE
- Mobile-IP Internetworking
- Enhanced Quality of Service (QoS) support
- Access to Internet Service Providers (ISPs) and Intranets
- Advanced charging and billing
- Fraud Information Gathering System (FIGS)

The first GPRS standard was released in 1997, which set up a base for an initial GPRS system. Phase 2 was improved to standardize the GPRS with an initial implementation of 3G network, which will also require major changes to the radio and network areas. Hence, there are great challenges for the operators to provide comprehensive and stable services as referred to the phases. However, due to the fact that the upgrading process is not as easy as it seemed, there will be a considerable delay on the release of respective network commercially.

Chapter 4

SYSTEM ARCHITECTURE

As mentioned earlier, GPRS network utilizes a method of sharing same radio resources among all mobile stations in one cell, providing effective use of the scarce resources while improving the network capacity [17]. The design conceive an overlaying packet based air interface on the existing circuit switched GSM network with a couple of infrastructure nodes added and software upgrade to some existing elements.

The communication is carried out by Mobile Data Base Station (MDBS) that detects any free channels and uses its bandwidth to transmit the packet data. The station then sets up an air link for data transmission, which composed of either an uplink or a downlink channel, and each link is shared by multiple Mobile Stations (MS). The MDBS collects the incoming packets in queue and schedules the transmission to the appropriate channel. Data on the downlink channel is based on contention-less broadcast while data on the uplink channel is based on contention multiple access scheme, the Digital Sense Multiple Access with Collision Detection (DSMA/CD) similar to CSMA/CD in Ethernet. Particularly, one condition has to be met because whenever voice data arrives, the free channel that is used to transfer the packet will be taken back thus caused an interruption to its transmission. Hence, it is necessary for the packet to be directed immediately to another idle channel or redirect back to the queue for retransmission.

In order to enable the GPRS, the operators merely need to upgrade the GSM infrastructure by introducing three new GPRS elements while updating a few existing GSM nodes. The most required element is the GPRS Support Nodes (GSN) and its elements the Serving GSN (SGSN) and the Gateway GSN (GGSN). The upgrade also includes a new Border Gateway (BG) that adjoins the network with other GPRS providers through a firewall. Software upgrades are also necessary for several GSM nodes that include the Mobile Switching Center (MSC), the Visitor Location Register (VLR), the Home Locator Register (HLR) and the Base Transceiver Station (BTS). Finally, both hardware and software upgrades are needed for the Base Station Controller (BSC). Roles of the elements mentioned above will be described in the following sections. All information that is used in describing the elements is obtained from the ETSI specification [12][13][14][15]. Figure 2 below illustrates the elements in GPRS architecture.

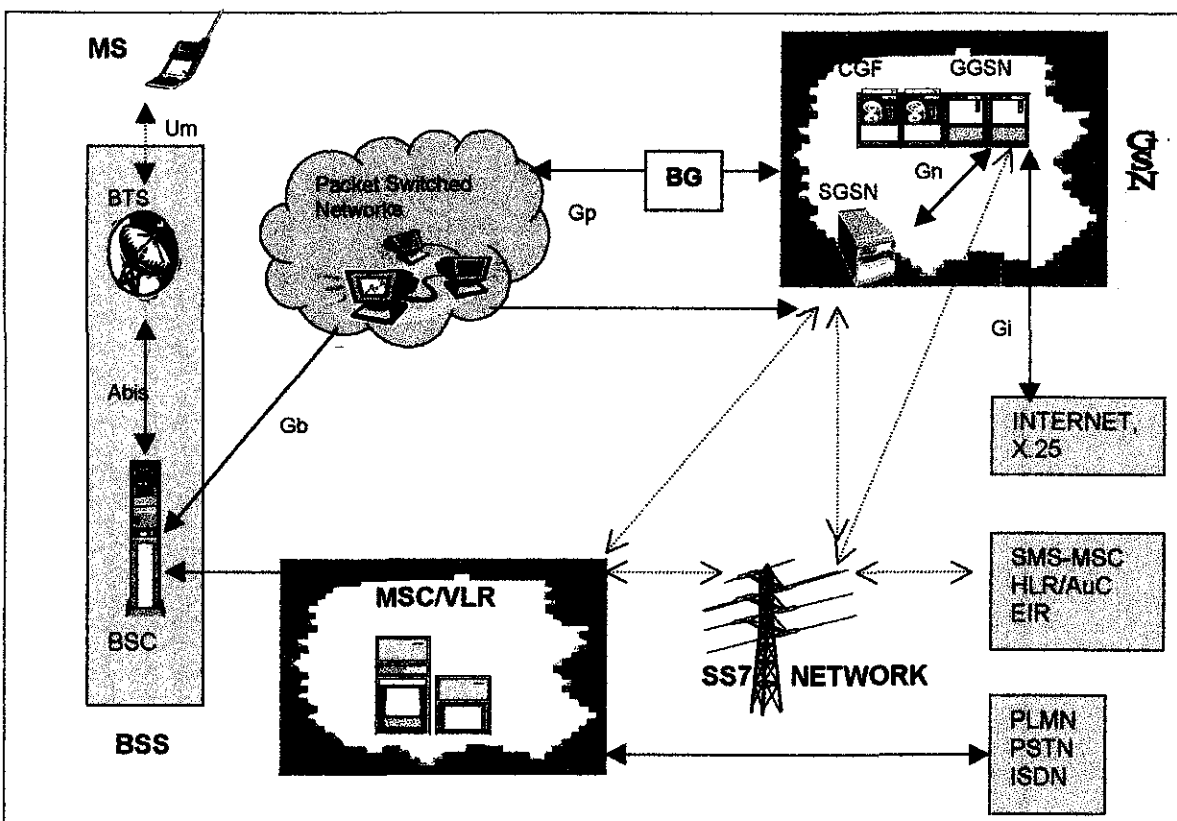


FIGURE 2: GPRS ARCHITECTURE

4.1 MOBILE STATION (MS)

The MS consists of Mobile Terminal (MT) and Terminal Equipment (TE). Both the MT and the TE could be in one equipment piece (e.g. smartphone, communicator) or in separate devices (e.g. GPRS-phone connected to a laptop).

4.1.1 Mobile Terminal (MT)

The MT is associated with a unique subscriber in GSM through the Subscriber Identity Module (SIM) Card that stores user personal data. It acts as a modem for TE to connect to the Internet/Intranet services within GPRS system. The terminal communicates with TE through wireless or cable technologies like Infrared Technology, IrDA, or Bluetooth, and communicates with the BTS via an air link

4.1.2 Terminal Equipment (TE)

The TE is a computer terminal that sends and receives end-user packet data. The devices include smart phone, communicator, handheld computer and laptop.

4.1.3 MS Terminal Classes

The MS is differentiated to specific Multislot classes with distinct capabilities for a reason of fulfilling different market needs. Added to this, there is also a requirement for mobile handset that able to support the applications. Table 2 describes the terminal classes and its functionality.

MS-Classes	Description	Transmission
Class A	- Make and receive calls on two services simultaneously - A minimum of one time slot must be available to both services when needed - Complex, unfavorable - High power consumption	GSM/GPRS - Voice/Packet time, t1
Class B	- Monitor, attach and activate GSM/GPRS simultaneously but only one at a time - Priority on GSM voice - May cause interruption on data transfer	GSM - Voice time, t1 GPRS - Packet
Class C	- Support only non-simultaneous attach - Make and receive calls from only default services - Type of service is selected manually - Specifically for vertical applications	GSM –Voice time, t1 GPRS – Packet time, t2

TABLE 2: MS-Classes

4.2 BASE STATION SYSTEM (BSS)

The BSS is an intermediate station that transmits and receives all radio signals, allowing the Circuit Switched (CS)-GSM and Packet Switched (PS)-GPRS to share available resources. There are basically three elements in the BSS, which will be described next. The BSS upgrade is mainly to allow the existing GSM structure to handle packet data, GPRS information broadcast and resource administration while providing new interfacing to the SGSN-node.

4.2.1 Based Transceiver Station (BTS)

The BTS as part of the BSS is serving a purpose of receiving and transmitting facilities (e.g. antenna) and signals that are related to radio interface. On receiving a signal, the BTS separates GSM circuit switched voice from GPRS packet data and forwards both categories to the BSC (Based Station Controller) using standard GSM protocols for compatibility.

4.2.2 Based Station Controller (BSC)

The BSC is equipped with new hardware and software elements for the GPRS. In term of hardware, it requires a Packet Control Unit (PCU) that responsible for packet transferred from MS to SGSN and is used in the Radio Link Control (RLC) and the Medium Access Control (MAC) protocol layers over an air link. Basically, the BSC consist of a high capacity switch that sets up, supervises and disconnects CS-GSM and PS-GPRS connections from either the BTS on radio side or the MSC and SGSN on core network side. It also acts as a circuit connector that connects several BTS together. For this matter, capacity of BSC in the existing GSM is upgraded up to 1000 Transceiver Units (TRXs) to support high data transmission in the GPRS network [10].

4.2.3 ABIS Interface

Main function of the Abis-interface is to connect the BTS and the BSC. This link is proportioned with respect to the maximum amount of timeslots radio interface that can be transferred from the BTS to the BSC. However it has raised an important issue related to the capacity implementation, which will be discussed later.

4.3 GPRS SUPPORT NODES (GSN)

Two core support nodes in GSN are the SGSN and the GGSN. Both are interconnected with the GPRS core network, often referred to as the Public Land Mobile Network (PLMN), or may be interconnected to different PLMN of other operators. In the latter case, PLMNs will be connected via BG for security and interoperability purposes and uses the GPRS Tunnel Protocol (GTP).

4.3.1 Serving GSN (SGSN)

Basically SGSN forwards the incoming and outgoing IP packet address to and from the MS. It serves all GPRS users that are located within its geographical area, by which mean, it handles the capacity of all connected BSCs in its service area. Thus, it supports same amount of subscribers as the MSC [7]. Another role is to collect charging information for MS according to the internal network usage. Data traffic is routed from the SGSN to the BSC and to the MS via BTS. Therefore, it requires signaling from BSS to other nodes (e.g. HLR, MSC, BSC, GGSN and SMS). These signals are for the purposes of handling the signaling connection functions such as session management, mobility management, logical link management towards mobile station, and ciphering and authentication which is provided through the A5 Algorithm [18][26].

4.3.2 Gateway GSN (GGSN)

The GGSN provides an interface towards the external IP packet networks (e.g. global Internet) as it acts as a router for the subscriber IP-addresses served by GPRS, in which it gathers information on external data network usage and exchanges routing information. It also handles the capacity of all connected SGSNs besides dealing with session management for external networks as SGSN. For scheduling and admission control function, the GGSN uses delay class and mean throughputs

4.4 EXISTING GSM ARCHITECTURE

4.4.1 Mobile Switching Center (MSC)

Basically, the MSC provides a telephony switching functions for CS-GSM. It controls the calls to and from other telephony and circuit switched data systems including the PLMN, the Public Switched Telephone Network (PSTN), the ISDN (Integrated Services Digital Network), and the Public Data Network (PDN) like Internet. Normally, the node is denoted MSC/VLR since both MSC and VLR usually resides in the same physical nodes.

4.4.2 Virtual Location Register (VLR)

The VLR is mainly a database that contains information on MS that is currently located in the MSC location area. Added to this, it also stores temporary subscriber information needed by the MSC or the SGSN to provide services for visiting subscribers. For example, when one MS roams into a new MSC location or SGSN routing area, the local VLR will request the information about that particular MS from its HLR. If the roaming MS makes a connection at some other time, the VLR will already has the information on that MS that is stored for setting up a connection.

4.4.3 Home Location Register (HLR)

The HLR is a database of subscribers' information for both the CS-GSM and the PS GPRS. This includes the International Mobile Subscriber Identity (IMSI) as a reference key in ensuring the GPRS packet is accepted for a particular connection. If the subscription exists, HLR will later include the GPRS information on type of Packet Data Protocol (PDP) to be either IP or X.25, Access Point Name (APN) to the external IP network, authentication parameters and QoS profile. The HLR will assign default QoS if there is no request for specific QoS from users. The role also includes updating the latest SGSN address of the current MS location.

4.4.4 SMS-GMSC and SMS-IWMSC

The existing Short Message Services Gateway MSC (SMS-GMSC) and the SMS Internetworking MSC (SMS-IWMSC) will be changed to support GPRS but with a new interface to the SGSN to enable the MS to send and to receive SMS over GPRS radio channels. Since SMS remains a store-and-forward service, both elements are directly connected to the SMS center for storage which later will either be dropped or routed.

4.4.5 Authentication Center (AuC)

For security reason, the AuC acts as an extension of the HLR in the same physical node that contains all information to authenticate connection requests. Once connection is established, authentication keys are given to users to prevent any transmission threats since radio interface is inherently open for unauthorized access. It also stores authentication algorithms and encryption codes.

4.4.6 Equipment Identity Register (EIR)

The EIR is a central database with subscriber and equipment numbers such as the International Mobile Equipment Identity (IMEI), which will be checked upon each connection. The database includes a white list of valid mobile equipment, a gray list of malfunctioning equipment or not in service, and a black list of stolen or suspended equipment.

4.5 GPRS NETWORKS

There are two types of network in GPRS, the internal and the external. The external networks include Internet and Intranet while the internal is described as below. Normally, the internal network capacity is ranged with respect to signaling and data amount that is being served from the core network.

4.5.1 GPRS backbone network

As illustrated in Figure 3 below, there are two types of backbone networks, the Intra-PLMN backbone and the Inter-PLMN backbone network. The Intra-PLMN backbone network is a private IP network interconnecting GSNs within one PLMN for GPRS data and signaling. The Inter-PLMN backbone is the IP network that interconnects the GSNs that belong to the same operator but in different countries or interconnects Intra-PLMN backbone of other operators. Different Intra-PLMN backbones are connected together via Gp interfaces using the BG and over the Inter-PLMN backbone, which is selected by a roaming agreement which also includes the BG security functionality.

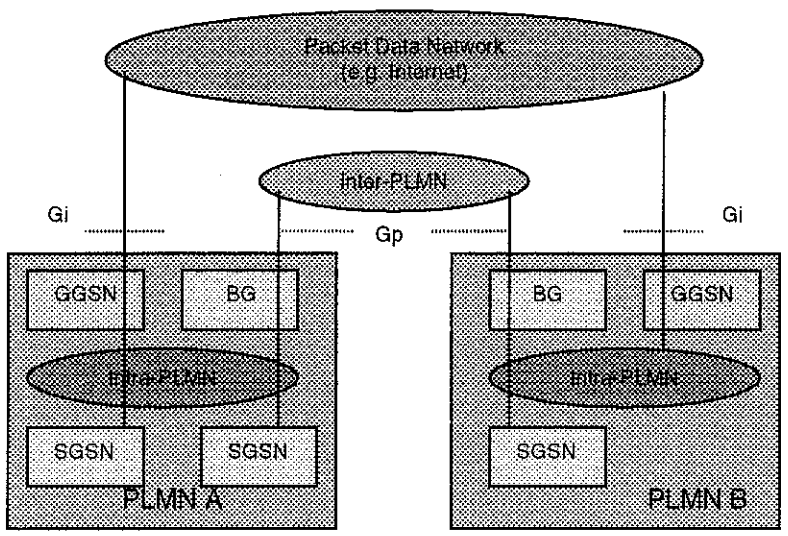


Figure 3: Intra and Inter- PLMN Backbone Networks [16]

4.5.2 SS7 Network

The SS7 network uses Signaling System #7 protocols, which is basically a signaling transport within the Network and Switching Sub-system (NSS) that includes EIR, HLR/AuC, MSC/VLR, SMS-MCS, SGSN and GGSN. The network also enables internetworking between the NSS-entities and other GSM networks. The capacity is measured slightly over dimensioned to minimize congestion.

Chapter 5

GPRS PROTOCOLS

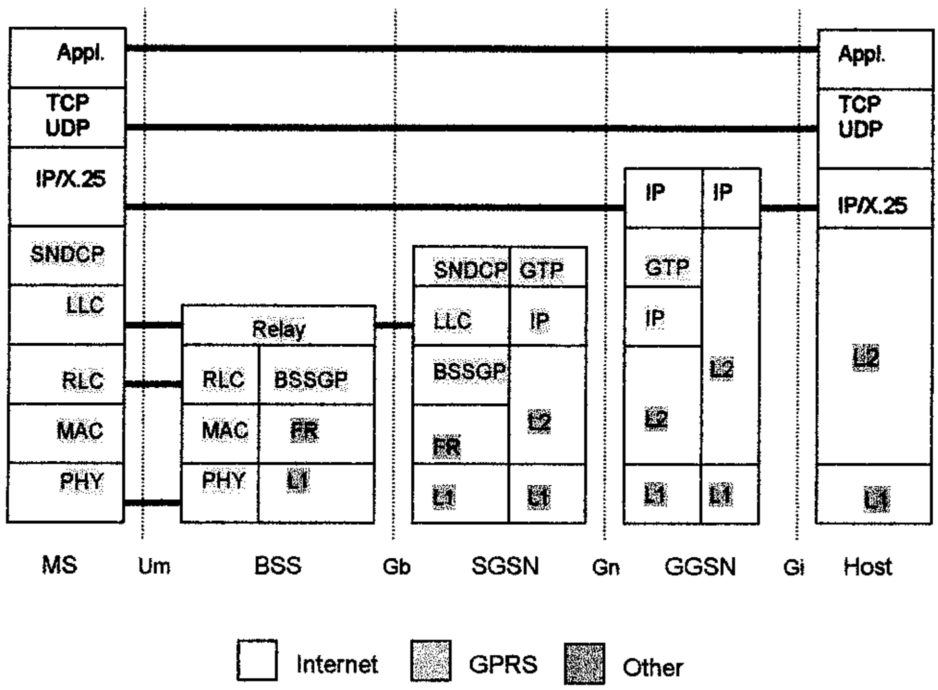


FIGURE 4: Protocol Stacks (source from ETSI)

The GPRS architecture is based on the GSM physical radio layer, which supports the Open System Interconnection (OSI) communication protocol system. The GPRS is distinguished between two protocol planes [14]:

- *Signaling plane* consists of protocols for control and support of user data transmission. The functions cover control and support for network access connection and its attributes, routing and mobility management, and network resources.
- *Transmission plane* covers the protocols for transmission of user information and the associated control procedures like error handling and flow control. As illustrated in Figure 4, it deals with data traffic in the GPRS network. The functions of the related protocol layers will be described in the next section.

5.1 THE INTERNET LAYERS

5.1.1 Application Layer

As in other Internet applications, this layer is primarily specified for software with no connection to the GPRS architecture. It contains logic of different protocols that is needed for managing application sessions and data presentation.

5.1.2 Transport Layer

This layer comprises of mechanisms that exchange user data on the end-to-end connection. This function is supported by two different protocols, the Transmission Control Protocol (TCP) and the User Datagram Protocol (UDP). The TCP is expected to be the most used protocol since it provides reliable data flows between two hosts by retransmitting unacknowledged packets and buffering data at sender and receiver ends. An adaptive time out mechanism called the Automatic Repeat Request (ARQ) is used to ensure that the receiving end has accepted the packets. The UDP inversely is simply used to send datagrams from one host to another without guaranteeing the arrival and no retransmission is supported in case of error detection. The UDP is normally suitable for real time streaming media such as audio and video.

5.1.3 Network Layer

Either IP or X.25 carries out the tasks in this layer. However, it is predicted that the IP will be the dominant protocol as it is widely used in global network. The GPRS network will initially be based on the IPv4 at which the IP user addresses are either allocated by the GGSN or supplied by an external network (e.g. ISP, LAN). Moreover, each external network has its own unique access point in the GGSN with functionality to handle network access and IP address assignment. This is done through the Remote Access Dial in User Service (RADIUS) or the Dynamic Host Configuration Protocol (DHCP).

There are two types of IP addresses. The *Public Address* that is globally unique and make up the Internet address space from the regional Internet Assigned Numbers Authority (IANA), and the *Private Address* that is a specific range of addresses reserved within the public address space from the Network Address Translation (NAT). The GGSN supports both dynamic and static IP addressing. Dynamic addressing allows operators to use and reuse addresses from their address poll while static addressing allocates the same IP address for a particular subscriber.

5.2 THE GPRS LAYERS

5.2.1 Base Station System GPRS Protocol (BSSGP)

The BSSGP carries the QoS and routing information between the SGSN and the BSS. It is standardized using the Frame Relay Q.922 core protocol as a transport mechanism to enable high data rate as it stripped out most of the overhead in data frames that deals with error control.

5.2.2 Sub-Network Dependent Convergence Protocol

The SNDCP maps the network layer characteristics (e.g. IP) onto specific characteristics of the underlying network. It performs packet segmentation to match the LLC frame size of up to 1600 bytes besides multiplexing data packets from other protocols. The V.42 bis data compression technique is used for efficient utilization of radio resources. The protocol also handles the TCP/IP header and provides data encryption using the A5 Algorithm.

5.2.3 Logical Link Control (LLC)

The LLC acts as a Data Link Layer protocol for the GPRS to support PTM transmissions and defines mode of operations to be either acknowledged or unacknowledged. Most importantly, it establishes a secure and reliable logical pipe between SGSN and MS for data transfer across the network, which is identified by the Temporary Logical Link Identifier (TLLI). Optionally, a reliable connection can be established in the LLC layer by enabling an error checksum method.

5.2.4 RLC/MAC

The RLC and MAC are considered to be part of same sub-layer. The RLC deals with the LLC segmentation and reassembly while providing link level acknowledgment procedure, ARQ to the LLC for data frames transfer between the SGSN and the MS. The ARQ over the channels tends to reduce number of control blocks used and transmission delay [2]. On the other hand, the MAC provides access signaling, resolves contention between multiple terminals for simultaneous channel access, allocates radio channels on request, and arbitrates multiple service requests from different data terminals besides providing detection and recovery procedure. It also enables multiple MSs to share a common transmission medium, which may consists of several PDCHs with priority handling [2].

5.2.5 GPRS Tunnel Protocol (GTP)

Mainly, GTP acts as a tunnel for the protocol data units through the IP backbone by adding routing information to the packets. Besides, it also acts as the GSN interconnection, which operates on top of the TCP/UDP over the IP.

5.3 FRAME RELAY

The relay facilitates seamless internetworking with external data network (e.g. TCP/IP, X.25). In the BSS, the frame relays the LLC PDUs between Um and Gb interfaces and in the SGSN, it relays Packet Data Protocol (PDP) PDUs between Gb and Gn interfaces.

5.4 NETWORK SERVICES (L1, L2)

The role is to manage the convergence sub-layer that operates between the BSSGP and the Frame Relay Q.922 Core by mapping the BSSGP service requested to the appropriate Frame Relay services.

Chapter 6

GPRS REQUIREMENTS

In addition to the protocols and architectural requirements, there are several other technical requirements that are necessarily to be accomplished to enable the GPRS network. Furthermore, the operators and providers have to consider all these requirements in order to guarantee the promised connection to the subscribers.

6.1 CARRIER SERVICES

In the GPRS term, carrier services refer to how packets are transmitted across the network. The key requirement is to enable network roaming as to ensure the global mobile Internet services is possible [23]. There are two types of carrier services in this term, the Point-to-Point (PTP) and the Point-to-Multipoint (PTM).

The PTP connection provides a transmission of one or more packets between two users, sender and receiver. As to this date, the most feasibly used PTP is predicted to be the Connectionless Network Service (CLNS) that utilizes IP at which packets are independent and takes different path through the network. The PTM on the other hand allows connection between one sender and multiple receivers. There are three types of PTM-services. 1) *Multicast* where the packet is sent to a group of receivers within one area and no acknowledgements of packets are made. 2) *Group Call* where data is sent to receivers in a limited geographical area and the acknowledgements are optional. 3) *IP-Multicast* where packet is sent to a disperse location which requires packets to be duplicated in the routers along the paths to receivers.

6.2 FREQUENCY AND BANDWIDTH

The GPRS radio resources are occupied only when users are actually sending or receiving data. Thus, several users can share the available channels and bandwidth. Unlike the GSM method where radio channel is dedicated to one user for a fixed time period. As listed in Table 3, there are 498 carriers for the current GSM-900 and GSM-1800 systems. Considering a fixed carrier spacing of 200 kHz, the frequency border spacing adds up to 25 MHz and 75 MHz respectively and this is the total frequency bandwidth available in both uplink and downlink, which have to be shared and divided accordingly by all operators in one country.

CHARACTERISTICS	GSM-900	GSM-1800
Frequency Band	890-915 MHz 935-960 MHz	1710-1785 MHz 1805-1880 MHz
Border Spacing	25 MHz	75 MHz
Duplex Spacing	45 MHz	95 MHz
Carrier Spacing	200 kHz	200 kHz
Carriers	124	374
Timeslots per Carrier	8	8
Cell Range	0.8 & 8 W	0.25 & 1 W

TABLE 3: CHARACTERISTICS OF GSM STANDARD [9]

For more than a decade mobile networks have been dominated by voice traffic, which limit the growth in data transmissions and require major upgrades to the existing infrastructure to expand the network capability. Added to this, there are limited terminals to handle excessive graphics and long text messages in packet networks. The challenge is, therefore, to ensure that the infrastructure will be able to handle the loads. Two methods to overcome this issue are to adapt resource management technique that applies to data traffic and to fully utilize the available cell.

6.3 CHANNEL CODING SCHEME

Coding Scheme	Encoder Rate	Payload	Max LLC Throughput (kbps)
CS-1	1 / 2	182	9.05
CS-2	2 / 3	268	13.4
CS-3	3 / 4	314	15.7
CS-4	1	428	21.4

TABLE 4: Coding Scheme for GPRS over GSM

The Coding Scheme (CS) is the channels that are standardized for the RLC/MAC radio blocks. There are four channels that are used for data transfer or error checking, CS-1, CS-2, CS-3 and CS-4. In a good traffic condition CS-4 will yield the highest throughput. However, due to system imperfections, unexpected degradation in throughput will always occur, especially for CS-4 that resides in physical layer and does not employ any error correcting coding [18]. In this case, the CS-1 with highest amount of error protection will achieve the highest throughput, as it will not be used for block controls when the access bursts [2]. As referred to Table 4, the bit rates increase as the error protection overhead decreases from CS-1 to CS-4 for a non-error environment and the condition is vice versa during error occurrences.

6.4 QoS PROFILES

The Quality of Service (QoS) profiles can be considered as a single parameter value that is defined by a unique combination of attributes, as in QoS parameters. There are numerous QoS profiles available but for GPRS network, only certain profiles are selected to support only a limited subset. The ETSI body has specified four QoS classes that are important to support the transmission in the GPRS network [3][24]. The classes are listed as below:

6.4.1 Traffic Precedence Class

The Precedence class indicates the relative priority of maintaining the service under abnormal environment. Under this condition, this class will identify packets that have to be discarded. The scheduling mechanism in QoS architecture will apply different priorities to different type of data flows, based on the subscribed precedence. For instance, in a high traffic condition the SGSN may drop packets from data flows with low priority in order to transmit higher priority packets. The SGSN may even initiate a renegotiation of low precedence profile data if it does not meet a desired level of the QoS. The three levels that are defined consist of HIGH, NORMAL or LOW priority.

6.4.2 Delay Class

Delay is the maximum values for mean delay and the 95-percentil delay to be incurred by data transfer through the GPRS. It defines the possible transfer delay during the transmissions of user information within the network. There are 4 classes determined for the GPRS including the best effort.

6.4.3 Reliability

Reliability is the transmission characteristics that requested by the application. The characteristics on three types of applications are set.

1) Error sensitive applications with no error correction and limited error tolerance
2) Error sensitive applications with limited error correction and good error tolerance
3) Non error sensitive applications with full error correction and good error tolerance

6.4.4 Throughput

The throughput indicates the maximum bit rate and mean bit rate as listed below:

1) *Peak Throughput* – 9 classes (8, 16, 32, 64, 128, 256, 512, 1024, 2048 kbps)
2) *Mean Throughput* – 19 classes (best effort, … , 111 kbps)

6.5 AVAILABILITY OF END DEVICES

The GPRS fundamental requirements for mobile phones emphasize on lightweight, light resources and power conscious to being able to handle frequent outages, unstable communications and synchronization effects. However, the end devices that are currently available for GPRS commercial use is very limited in displaying capabilities with low graphic power and resolution to display images, fonts, colors and animations. These devices also allow restricted human interface to input data with moderate battery capacity to handle faster and higher data transmissions. This condition though will change in timely manner as the phone providers are searching for an appropriate solution to improve the capabilities of end devices. Other significant issue is how to bring the Internet contents and advanced data services to mobile terminals and to implement appropriate global wireless protocol specifications. One example is to find a fit Operating System (O/S) that can handle mobile environment for such applications. Some that are being implemented includes the PalmOS by 3COM and the WindowsCE by Microsoft [1].

Chapter 7

TECHNICAL LIMITATIONS

As regards to the claims made by most GPRS providers, main benefits of the network is that it reserves radio resources only when data is to be sent, which tends to reduce reliance on traditional CS network elements. Consequently, the increased functionality of GPRS will increase the penetration of data services among users, which in turn will decrease the incremental cost to provide data services. In addition, it will also improve the QoS in terms of its reliability, response time, and features supported. Therefore, the intended purposes of GPRS to provide effective use of the scarce resources and to support the high demand of data services more efficiently will be accomplished.

Nonetheless, these high expectations from the operators contradict the actual take up of GPRS usage. It is still ambiguous on the actual total costs for terminals and network usage that will be charged to users. Furthermore, it has been intricate to estimate the capacity that will be available to the subscribers due to the inherent limitations in the network architecture. For example, the bandwidth that will be available to the users will actually modest in size and vary significantly, depending on the time, number of users and current geographical location. Therefore, the statement made for instant and constant GPRS connection might leave subscribers with high expectation despite the reality that eventually will occur. This chapter will discuss the various issues and limitations of the current implementation faced by the GPRS network.

7.1 CAPACITY

The maximum theoretical data rates of 171.2 kbps for GPRS require an optimal use of the CSs, especially the CS-4. Even then, the maximum speeds must be checked against the actual constraints in the network and terminals. In reality, mobile networks will always face lower transmission speeds as compared to the fixed network. Increase data rates can be achieved through improvement of the CSs and support of multiple timeslots. However, the issues are far more complicated considering the limited time slots allocation, terminal restriction as well as the availability of the CSs.

7.1.1 Allocation of Time Slots

As mentioned earlier, maximum theoretical bandwidth capacity that can be achieved is 171.2 kbps with the promising 8 timeslots allocated in one particular time. Therefore, the data transmission speeds when connected to the global Internet are 14.4 kbps in single slot and 115.2 kbps in multislots. Theoretically, it leads to the three times faster data transmission as compared to the normal fixed networks and ten times faster than the CSD on GSM networks, which tends to reduce the cost drastically [4]. However, in real network implementation this may never be possible in the existing infrastructure. In order to allow 8 timeslots to transmit voices and packets at one time major upgrade to the existing infrastructure is necessary thus resulted in high cost consumption.

It is important to note that the timeslots have to be shared simultaneously by the GSM and the GPRS. Added to this, the GSM traffics in any condition will have precedence over the GPRS traffics. It is possible that may be less than two timeslots will be assigned statically to GPRS, whereas the others will be shared dynamically between the two traffics. Hence, resulted in varying amount of capacity that can be offered by the packet traffics.

7.1.2 Restriction in Terminals

As mentioned earlier, the GPRS will most likely have to support multiple timeslots simultaneously to take advantage of higher data transmission speeds. In theory, to achieve maximum speed the terminals must incorporate transmission and reception of all 8 timeslots in both uplink and downlink directions. However, in practice it is not as simple as the promise. The existing network terminals will not be able to support 8 timeslots in one direction. It is not even fast enough to handle the present of 5 timeslots in one direction.

As to this date, it is indicated that the terminals will initially support 1 timeslot in the uplink and 3 timeslots the most in the downlink [6]. Amazingly, as stated by the providers and operators the GPRS terminal will soon increase their capabilities to 2 timeslots in the uplink and 4 timeslots in the downlink [4]. It is still unclear however how this promise can be achieved, as it is extremely complicated to incorporate more than 4 timeslots in either direction. Despite all, it is still impossible to utilize all the 8 timeslots at one given time.

7.1.3 Availability of Coding Schemes

There are 4 coding schemes that are currently available in the existing GSM infrastructure, CS-1, CS-2, CS-3 and CS-4. Each with the capacity as described in Table 4 previously. However, practically the CS-3 and the CS-4 will never be implemented due to resource and capacity restriction. Thus, left the network with only two CSs to support all transmissions and limits the maximum available capacity to the multiple of 13.4 kbps on CS-2. The maximum throughput is estimated to be 53.6 kbps. However since the radio resources are shared with the GSM cell, the actual throughput would only be in between 20 to 30 kbps. The timeslots to the Abis circuit has to be broken, requiring 2 Abis interface for each timeslots if CS-3 and CS-4 are to be incorporated into the architecture. Besides, it is uneconomical for the total upgrade to the link just to implement the CS-3 and CS-4. Hence, even if all GPRS terminals are said to be CS-3 and CS-4 capable, no major providers have planned to incorporate CS-3 and CS-4 due to its complexity and high cost consumption. It might be worth to wait and move directly to the UMTS or the EDGE networks in the future.

7.2 CELL SHARING

Because of the limited radio resources, use for one purpose constrains simultaneous the use of the other. For example, using the SMS in GPRS will preclude voice traffic, which might be the priority. Clearly the operators will not allow all cells to be occupied by a single GPRS user as explained previously. Such GPRS application is now becoming a complementary bearer, which require different type of radio resources to be transmitted [19]. Thus, cell division is an important parameter in the network.

7.2.1 Cell Division

The smaller cell size provides greater capacity for data traffics. However, as more base stations are implemented to provide smaller cell structures with greater capacity, the ratio between expenditure and traffic increases, and lead to the point where financial considerations simply exceed the expected revenue. Furthermore, as people tend to move from one cell to another, the amount of signaling needed increase, which increase the hand-over rates exponentially. The issue however rises on dividing the cell capacity between the GSM and GPRS services in order to prevent congestion in traffic that may be caused by the mobility of users.

In order to allow sharing of cell capacity between GSM and GPRS, cell-partitioning strategies are introduced. This is illustrated in Figure 5.

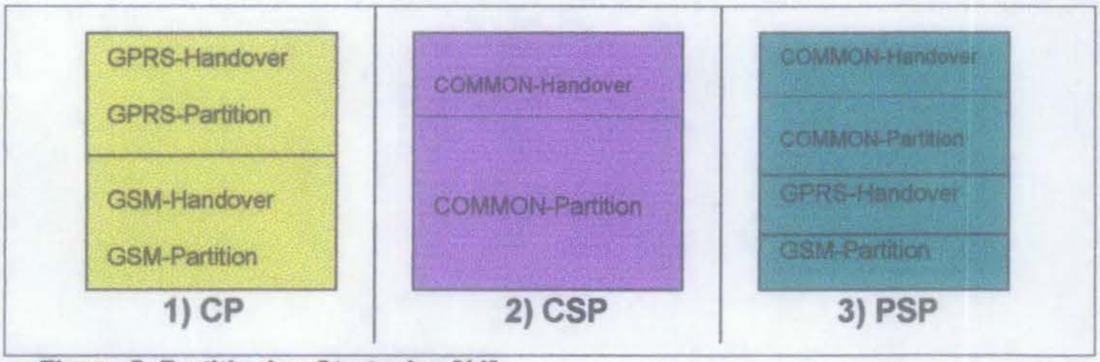


Figure 5: Partitioning Strategies [11].

There are three techniques to partition the cell [11]. 1) The *Complete Partitioning (CP)* where total cell is divided into two parts for GSM and GPRS respectively and both perform tasks individually. Each partition resources have to be reserved for incoming hand-over calls. The advantage is low utilization because no sharing of resources across the partition border. 2) The *Complete Sharing Partition (CSP)* where no capacity is assigned exclusively to either GSM or GPRS but highest priority is reserved for voice calls, thus, promising a slightest effect of the GPRS over GSM. 3) The *Partial Sharing Partition (PSP)* where cell is divided into three sections exclusively for GSM, GPRS and common partition that is shared by the two traffics. The technique requires the GPRS partition to be large enough to guarantee QoS yet small enough to prevent bandwidth waste.

As in the CP, PSP strategy guarantees the QoS because minimum capacity is allocated specifically for GPRS traffics. However, the PSP results in higher utilization than the CP because of common resource partitions. Considering the intended purpose of the GPRS to only utilize the cell when data is to be sent, the most appropriate strategy is the CSP where no cell is dedicated to any of the two traffics. Besides, it also contributes better utilization over the GSM even for low priority data.

7.3 TRANSIT DELAYS

The average voice call holding time is a major factor that affects delay and throughput performance in cellular voice network. When heavy traffics take place, the available channels become momentarily less and cause the users to experience an enormous delay [19]. It is determined that in any packet transmission, packets are sent in all different direction to reach one destination, which could likely open up a possibility that packet might be lost or corrupted during the journey over the radio link. Referred to the GPRS network, when all channels are utilized for voice calls, it tends to increase the trunking efficiency due to increase in a fixed voice blocking that caused delay in packet transmission. This trunking condition will also occur if more channels are made available in the network. Another issue is the high latency during peak time plus the low bandwidth that may cause this delay, which resulted in a slow packet transmission.

The MDBS, assisted by the MAC protocol, detects free channel and uses its bandwidth for packet transmissions without provoking the circuit switched services. As explained previously, in best traffic condition with 8 free channels, less delay is expected to occur. Conversely, in worst condition where no available channel for packet transmission, large delay will occur even before the transmission. The domination of voice traffics over the channels is certainly a fundamental factor that contributes to GPRS delay. The input of data traffic is proved not to be the cause of delay, instead the voice traffic is dynamically the major determinant [19].

In a worst scenario, at a given time whenever any channel that is used for packet is taken back for voice transmission, packet transmission is interrupted. It will either be directed to another free channel or wait in the queue for retransmission if no free channel is available. Normally this will cause a delay of 90 seconds in average [19], which is a considerably long delay if the packet content is high priority. For the downlink transmission, packets will be queued before retransmitted to any free channels. On the other hand, for the uplink transmission, the MS will randomly detect available channel and contend others for packet access through that channel.

The GPRS standards overcome these issues by incorporating data integrity and retransmission strategies. Unfortunately, this will still result in potential transit delays. As come to this, it might be wise to incorporate the next network technology, High Speed CSD (HSCSD) which allow user to take over up to four separate channels at the same time so delay will be less likely to occur [4]. At the moment, there is less need to build an idle channel that will only be used in peak hours to improve the transmission capacity. Therefore, it is wise to consider employment of new protocols or procedures that capable of overcoming these issues.

7.3.1 Acknowledge Procedure

Implementation of the Acknowledge Procedures (ARQ) at the RLC level is seen as one of the possible solutions [2]. It tends to reduce number of control blocks (Ack/Nack) used in the RLC, thus, reduces transmission delay. A set of average time out rate is predetermined at the RLC layer in order to maximize the end-to-end throughput, which role is to allow retransmission before the TCP-ARQ times out in the TCP layer. This will ensure that the TCP, in most cases, observes just packet delays rather than packet losses. Therefore, the TCP will not automatically perform retransmission as though the packet was lost when in reality the packet could only be delayed on the radio interface. The delays are bounded in such a way that the TCP time out is less likely to occur, which tend to eliminate end-to-end connection delay for users.

7.3.2 Priority access

This procedure focuses on setting up priority classes to the data blocks before it can access the channels. The classes are ranked into three categories from low to moderate to high priority [19]. It tends to improve data transmissions during peak time because low priority packet will be blocked and consequently reduce the tendency for delay to occur. The only disadvantage is that once low priority block is accepted it will be treated equally as the high priority block because the technique pursues the best effort method.

7.3.3 Silence detection

As mentioned earlier, packet data delay is normally caused by long voice call holding time (approximately 90 seconds). Therefore, this approach suggests a multiplexing of voice traffics where the voice will have to go through a silent period at which no signal will be transmitted on the channels during this period [19]. This could also be a possible solution to reduce the co-channel interference issue.

7.4 QUALITY OF SERVICES

Quality of Service (QoS) is the most important aspect in implementing GPRS network as to guarantee the packet transmissions because applications that run over the network are time varying and subjected to interference and fading [1]. Clearly, delay and variation conditions on radio interface will degrade user's experience to a greater degree with moving image transmission than with file transfers [22].

Similarly, it could be argued that web browsing is somewhat sensitive to delays, whereas e-mail is less prone to delays but needs strict requirements on reliability. Therefore, basic goal of the QoS is to effectively differentiate different types of applications in term of capacity and service handling. On the other side, the bit transferred based billing will certainly require a degree of QoS mechanism to quantify the actual performance of the transmission.

In the next section, the concept of QoS in the GPRS Phase 1 context and its issues regarded to the QoS will be discussed. Later, improvement on the QoS standards will be covered as proposed by the ETSI body to encounter the issues. The specifications of the QoS architecture discuss in the next sections are referred to the ETSI Phase 1 and Phase 2 standards.

7.4.1 QoS in GPRS Phase 1

GPRS Phase 1 is an essential step towards standardizing the QoS in the respective network. As explained in Section 3.1, this standard includes the differentiation of types of services offered by the GPRS operators. Each GPRS subscription will be associated with one QoS profile that is stored in the HLR. In mobile network, the QoS is always correlated with the PDP context, a set of parameters related to a session between mobile and data network, containing QoS parameters, PDP type, mobile station address etc. A session is established by initiating the PDP context activation procedure. During this session, data are transferred transparently end-to-end between mobile station and external network using the tunneling techniques.

Upon the PDP context activation, the SGSN will negotiate the QoS of data flow based on the subscribed default QoS profile in the HLR, the requested QoS profile from the MS or the current availability of resources. The SGSN must at all time distribute the available resources fairly among all the PDP contexts and it may also renegotiate the QoS if necessary.

The issue rises when data packet hits the network. This is because it is almost impossible to use the existing QoS framework such as IntServ/RSVP and DiffServ in the GPRS network. The Resource Reservation Protocol (RSVP) that is intended to reserve dedicated channels within public IP network for the PTP connection do not support connectionless router networks because of its bandwidth reservation restriction. Therefore, the RSVP message will be transported to the GSN transparently causing no reservations at the intermediate nodes, and it applied the same to the DiffServ method, as the data will not be available until the packet reaches GGSN. This contradicts the essence of GPRS that requires the QoS mechanism to be accepted and supported by every element in non-voice mobile value chain, namely the infrastructure and terminal developers, mobile operators, applications developers and end users.

The GPRS network is able to differentiate QoS on the IP addressing basis but definitely not the data flows. After QoS is activated, the MS will shape the traffic but the GGSN will restrict data flows in accordance to the profile. Thus, based on the parameters set, all the traffics will be treated equally due to the best effort specification applied. This may guarantees the bandwidth utilization on the radio interface but there will be no provision on resource allocation in the core network, which promote congestion that can degrade the transmissions.

Data are transferred using the IP-based tunneling technique, which is known as the GTP, which is actually not applicable to the GPRS. Once packet reaches the GSN, it will be encapsulated into a new packet and routed to the destination. Yet, different data flows, which addressed to the one destination, are treated equally, as it is only possible to have one QoS profile for every PDP context. It simply means that one PDP address will have only one QoS profile for all its applications. For example, email and streaming audio would utilize the same QoS profile, which are inappropriate because the two applications require different specifications. The lack of differentiation between services is a serious issue that contradicts the intended purpose of QoS in the GPRS.

In forming a possible connection, different types of QoS functionality are required to interact with each other. It is unclear however how the QoS classes and its parameters in the QoS profile of Phase 1 are related. In fact some of the combinations of parameters turn out to be quite useless. Secondly, the BSS is not aware of the QoS profile, only the SSGN. Thus, restrict the ability of BSS to perform its task i.e. scheduling and resource management on the interface. This also implies that only SSGN can renegotiate the QoS profile and neither MS nor GGSN can influence the QoS profile even if they detect congestion in external networks and deals with different type of application requirements.

Moreover, issues also rise within the QoS specification itself concerning the four parameters namely delay, priority, reliability and throughput classes. Delay is an unconditional situation that possible to occur due to the uncertainty in traffic along with the throughput end-to-end delay within Um and Gi interfaces because real time multimedia traffic requires hard quantitative QoS assurance [24]. Yet, this is difficult to achieve with the specified standard. Plus, the priority elements have to deal with decreasing adherence to service commitments in the event of network malfunctioning like congestion. Reliability of packet can be affected as well due to packet corruption, loss, mis-sequencing, or duplication during the session.

7.4.2 QoS Enhancement in Phase 2

Realizing the significant issues and restrictions that follow the Phase 1 Standard and the possibilities that it is not possible to achieve efficient QoS, the specification had been revised in the GPRS Phase 2 Standard. The new standard focused on enhanced applications such as multimedia that to be supported by the network. The QoS provisioning is based on a traffic classification and services that will be available in the future. The classes are described in Table 5 below.

CLASS	TRAFFIC	APPLICATIONS (examples)	CHARACTERISTICS
Conversational	Real Time applications	Voice, Video Telephony	Preserve delay variation Stringent and low delay Conversational pattern
Streaming	Real Time applications	Streaming Video	Preserve delay variation Low level retransmissions
Interactive	Internet applications	Web Browsing	Preservation of content Retransmission request Response pattern
Background	Internet applications	Files Download	Delay insensitive Preservation of content Retransmission

TABLE 5: QoS Classes for GPRS Phase 2 [ETSI Specification, Release 1999]

The four classes above form the core QoS parameters. There are nine parameters being defined for specific applications, namely traffic class, maximum bit rate, guaranteed bit rate, delivery order, SDU size information, reliability, transfer delay, traffic handling priority and allocation priority. The value of each parameter is based on the type of traffic classes. The goal is not to create a complex QoS architecture but to allow better support for different type of applications

Previous specification restricts the BSS from using the requirements for resource scheduling mechanism on a continuous data flow. The BSS do not receive any QoS information from the MS as well, thus unaware of the QoS associated with data flow on the uplink. So, BSS will not be able to control and manage the resources as it is supposed to. The new specification solves this issue by allowing the PDP context to be downloaded to the BSS by the SGSN for each packet. This way, the BSS will have the capability to trigger any modification on the profile that is associated with the ongoing packet if congestion or shortage of resources occur.

The previous specification only allow one PDP context per address and this is considered a great limitation of GPRS since different applications have to share a single QoS profile. This may lead to a serious constraint to the ISP access if for example, video-streaming application has to use the same profile as file transfer. One way to solve this lack of differentiation is by establishing multiple PDP contexts, which requires multiple PDP (IP) addresses that are not scalable so that each application will receive appropriate QoS requirements [17].

7.4.3 QoS Mechanism

Due to congestion and bandwidth reservation, QoS characteristics may change dynamically upon arriving or leaving the external Packet Data Network (PDN), such as the Internet, because the properties are different from the one in GPRS. Therefore, a mechanism is needed allowing the GGSN to map these changes in QoS parameters while handling the QoS in the PDP context. Added to this, the MS may need to modify the QoS profile in PDP context due to inherent varying radio condition. However, this is difficult to perform in the previous specifications. Therefore, the new specification in Phase 2 tend to incorporate PCP Context Modifying Request allowing the MS to obtain QoS updates and the GGSN to trigger the updates that are related to the external PDN.

Improvement on the QoS requirements in the GPRS Phase 2 may be able to resolve the issues dealing with the parameters and specifications. However, considering the fact that the Phase 2 of GPRS will not be available until 2002 and yet, the development of Phase 1 has to be carried through, appropriate mechanism should be determined to support the limitations in QoS Phase 1. Numbers of ongoing studies are conducted for solutions to support the QoS specifications before the commercial release of GPRS Phase 1. One is the *Capture Effect* mechanism that is capable to offset access collisions thus, increase network efficiency. The approach can be achieved through modification in the BS. Therefore, packets will arrive in the network in correct order even if there is another packet that is being transmitted in the same slot. This approach tends to reduce access throughput in addition to access delay and failure rate [18].

7.4.4 IntServ Approach

The next approach is to upgrade the IntServ by implementing an additional RSVP tunneling across the GPRS infrastructure to establish QoS reservation. So, even when the original RSVP is passed transparently across the network, the additional RSVP signal is used to create and maintain reservation at each node of the GPRS backbone. Thus, all uplink and downlink traffics will go through a single RSVP tunnel. The characteristic of the RSVP tunnel is determined by individual session in the tunnel. The GGSN acts as a coordinator for all reservation, as it triggers all reservations for all traffics. After receiving a signal from the MS, the GGSN will signal the SGSN with appropriate message to proceed with require reservation. The GSN profile will handle the modification of QoS profile for each particular session. This approach has an advantage in which it requires only the GGSN to be changed significantly with minor RSVP functionality upgrade in others. However it leads to scalability problem because it requires the network to introduce an additional RSVP.

7.4.5 DiffServ Approach

The other solution is to introduce the Type of Service (ToS) classes with some set up values in the IP header packet. This is employed under the DiffServ approach. The SGSN will assign the incoming IP traffic to specific classes so that each IP will have its own GPRS PDP context profile that is mapped to a particular ToS class. Note that this technique allows multiple IP addresses to be supported by one MS so it will be able to solve the lack of differentiation issue. On that account, multiple services within one PDP address can be supported without sharing a QoS profile. Two ways of handling the ToS values are by pre-installing the number of PDP Context or by request. This approach however increases resource consumption because all the components in the core GPRS infrastructure need to be upgraded. The advantage lies in its scalability because more than one IP address can be supported for each transmission.

As come to addressing all the technical limitations in GPRS context, it is important to note that the solution concepts that should be applied in the GPRS depend on the operators and providers besides the network needs. Strategies that are to be used in overcoming the technical difficulties require major consideration and trial. Along with all the implications described in this chapter, real time issues also have its impact that constraint the future growth of GPRS networks. These issues will be covered in the next chapter. It is almost time for the GPRS applications to be release for commercial use though it is too early to remark the effectiveness of technology as being claimed by most of the providers.

Chapter 8

REAL TIME LIMITATIONS

The real time issues involve non-technical issues that may occur along the implementation of the GPRS technology. Ominously, most of the issues are inherently raised from the technical difficulties especially the QoS. Obviously, all these limitations will tend to restrain the network capacity and therefore requires serious consideration from the operators to deal with these obstacles.

8.1 SERVICE ACCESS

The services that can be accessed to the GPRS subscribers is one issue that tailed from the ability of the network to support different type of QoS for different service access. It is understood that the global Internet applications can be accessed via corporate networks, ISPs or mobile portals such as the WAP technique. Considering the issues involved in the QoS specifications, the services are most likely to be differentiated in terms of the associated QoS profiles. However, current deployment of GPRS Phase 1 will certainly limit the types of services supported because the latest QoS differentiation aspect will not be truly effective until the GPRS Phase 2 is deployed. Added to this, the three services should be accessed by the subscribers through a variety of terminals such as laptop or individual GPRS phone. However, the access will be restricted to only one type of service access through just one device at a given time, either laptop connection to the Internet/Intranet via GPRS devices or GPRS phone usage over the WAP. Thus, the GPRS network does not provide a simultaneous connection as claimed earlier by most of the providers. The limitation in service access is also influenced by the technical difficulty factors that resulted from the technical limitation as described in the previous section.

8.1.1 Actual Service Offering

At this stage it is reasonable to presume that the operators will simplify their actual service offering to include only a possible mobile portal such as the WAP connected to the GPRS phone to access global Internet under the best effort condition. The best effort is where all traffics are treated equally without differentiation of services but with spare capacity to handle varying traffic conditions. This is for a reason to maintain the traffic without causing extreme complications to the operators as well as the subscribers. The other service accesses are presumed not to be available until the Phase 2 of GPRS is implemented or until the 3G network such as the UMTS becomes available.

8.2 SECURITY

Directed from the QoS issues, concern should also be given to the security issue that may rise. The emergence of mobile technologies will certainly promote several threats that will affect the performance of wireless communications as it involves access to the global network. It may be necessary to apply a strong cryptography algorithm that will prevent threats such as fraud or viruses that will hazardously cause damage and destruction to the network. An assurance on the current QoS by the provider raise a question on whether the data transmission is secure and reliable enough for the GPRS network.

By initiating a GPRS session, users confirm their agreement to pay for the content of delivery. In some cases, mobile terminated IP might allow unsolicited information to reach the terminal causing users to pay for the junk. Worst case scenario, distracted elements like viruses may be introduced to the terminal thus, resulted in damages to terminal, system and most likely data. To deal with this issue, Mobile Terminate mechanism in GPRS is assumed to be included to prevent unnecessary elements from entering the network. Helplessly, the Mobile Terminate requires major network upgrade, thus it is decided by the operators to exclude the mechanism for GPRS Phase 1 deployment. Consequently this rise the issue on how data transmissions and user information are protected without the initiative to include the Mobile Terminal capability in the GPRS network or devices.

8.2.1 Secure IP

Most GPRS system consists of the IP core and radio network infrastructure plus an integrated service management and billing solutions. This requires a Personal Multimedia system [7], that allows access to corporate databases or Intranet which certainly requires certain level of security to protect confidentiality of the information. As to serve this purpose, GPRS is claimed to include a secure IP connectivity by combining strong security aspects of GSM with the all-in-one routing and firewall-ing capabilities of the security platform [7]. Added to this, the Mediation mechanism used for billing purposes is asserted to be able to reduce fraud activities through its real time detection. This mechanism allows network providers to check user's available credit online, and with the ID provided they can verify the usage of the service [20]. So for instance, if the ID is used at more than one place at a time, the services can be terminated immediately. Besides, the network also utilizes the A5 Algorithm in the protocol layers to secure the transmissions. However, it is still early to estimate the strength on security level of the GPRS network.

8.3 CHARGING AND BILLING

Charging is to collect information of the subscriber's behaviors and billing is an act to invoice the customers depending on the charging of information usage. It provides a significant advantage to the network providers as they will be able to introduce a comprehensive charging that allows them to bill their customers for different type of services offered [7]. For example, the NOKIA Charging Gateway mechanism is capable of collecting, consolidating and pre-processing charging data, which tend to reduce the load on billing system [23]. It creates a single interface to the billing system where operators can change the rules' sets in every location instead of each network element. Therefore, it subjects the system to handle a higher number of charging records collected from GPRS and process them so that customers can be billed accordingly.

Despite of all the promises, it is still an open issue on how users will be billed and charged for their subscriptions. One is the issue of whether the pricing should be based on data volume or time used as in the traditional network. If the Internet over GPRS is proved to be expensive then people will rather rely on the traditional method of accessing the global Internet, which caused the light tailed distribution [7]. The holding time also has impact on the measurement at which when the holding time is at peak, the distribution of calls tend to be lighter.

8.3.1 Mediation

Most of the charging information in wireless network is generated by the SSGN and the GGSN. The method called Mediation is used, which is similar to the Call Detail Record (CDR) in switched data circuit [20]. The process of mediation involves conversion of switching outputs into billable event that will format detail records. The mechanisms include a number of fields such as the external PDN to which the connection was set up for, the volume of data that was transferred, the QoS requested and offered, the data and time of connection and the session duration to obtain all the connection-related information. The method however is more complex than the CDR as it uses the PDCHs for time slots for billing purposes. These channels are utilized to support efficient multiplexing of traffic to and from mobile terminals, which may be statically or dynamically allocated to GPRS traffic [18].

As GPRS is implemented over the GSM infrastructure, the issue rises on how to distinguish the itemized charges between the two networks because the mediation technique differs significantly from the traditional CDR. The question in tracking duration of the sessions and location of the session end-points is also another major issue. On the other hand considering the charge for location, call duration, data quantity and external PDN access point from GPRS network elements, the claims that GPRS network is also ideal for prepaid subscription method is somehow questionable as it is determined to be a complex aspect to deal with.

8.3.2 Actual Billing Offering

There is a lot to be considered to determine pricing scheme for the network usage. It is compulsory to provide users with one type of billing system that can accommodate any type of pricing model to reduce carrier risks and insulate them against uncertainty in the future [20]. Despite all, the volume based charging will certainly be implemented for services offered in the near future. As for today, the easiest approach would actually to charge a fixed fee for the GPRS network usage, similar to what many fixed line ISPs are offering. However, it should be noted that if the flat rate of charging is offered, it will tend to encourage massive network access, which in turn might seriously degrade the available capacity of network. As regard to this, there may also be a possibility that customers will be charged based on a combination of volume based and fixed fee charging later on. The GPRS is expected to provide the opportunity to always be connected to the network. Yet, whether users want to get connected all the time or not is depending on how they are billed. If the users are billed for the time connected to the network, one of the key features of GPRS will be crippled.

8.4 REAL TIME IMPLEMENTATION

In reality, the deployment of GPRS network will still require major ground considerations to tackle the technical and real time issues that restrain the capabilities that being promised to the customers. Let for example revised the GPRS development under NOKIA provision. In the year of 1999, NOKIA had announced their involvement in developing the GPRS but as of today the proposed system is still under deployment. The interview that had been conducted among the NOKIA officers, however, concluded that they were not confident that the system will be working significantly as proposed before due to the technical difficulties and limited resources of the network.

It is claimed before, not only by NOKIA but most of the GPRS providers that upgrading the GSM to the GPRS network is so simple that it only requires new software to be downloaded to the BSS with minor upgrade of the existing GSM infrastructures. It is also asserted that the management algorithm is powerful and able to provide highest capacity from the BSS plus constantly reallocates capacity between the GPRS and the GSM traffics. As referred to NOKIA, their GPRS core infrastructure is also future proof and can be used with new radio system to offer the EDGE and the UMTS services in the near future [23].

Regardless of these strong assurances, until this date, there is no progress on the NOKIA GPRS coverage. The NOKIA GPRS white paper had been removed from the Internet for a reason that there are numerous difficulties in implementing the GPRS technology, which is due mostly to the technical limitations. For the matter of fact, based on the interview conducted, NOKIA has also lost their contract with numbers of network providers because the company failed to deliver the GPRS system as promised. TELSTRA on the other hand is still giving major consideration on deploying the WAP application within GPRS. It is said that the company is most probably prepared with the newly hybrid technology but they are still trying to get more compelling content to support the design as for a reason to fulfil customer requirements [20].

Moreover, there is a limitation in mobile phones that capable to support the GPRS applications as promised. There are only two devices available that currently available, each from Motorola and Trium, both with only 2+1 capability. This means the devices will only be able to support two downlink timeslots and one uplink timeslot simultaneously. Furthermore, these devices are still in trial processes and expected to be available commercially sometimes in 2001. NOKIA on the other hand are keeping quiet and has not gone out with any updates [6].

Chapter 9

FROM 2G TO 3G

FEATURE	2G	2G+	3G
Core Network	MSC/VLR, GMSC, HLR/AuC/EIR	MSC/VLR, GMSC, SGSN, HLR/AuC/EIR, CGF	MSC/VLR (with added interworking and transcoding), GMSC, 3G-SGSN, GGSN HLR/AuC/EIR, CGF
Transport	TDM	TDM, Frame Relay	ATM, IP
Radio Access	BTS, BSC, MS	BTS, BSC, MS	Node B, RNC, MS
Technology	FDMA, TDMA, CDMA	TDMA, CDMA, EDGE	W-CDMA, CDMA2000, IWC-136
Device	Voice only terminal	Dual Mode TDMA & CDMA Voice and Data terminals WAP only	Multiple modes Voice, Data and Video terminals WAP, Multimedia
Databases	HLR, VLR, EIR, AuC	HLR, VLR, EIR, AuC	Enhanced HLR, VLR, EIR, AuC
Data Rates	Up to 9.6 kbps	Up to 57.6 kbps (HSCSD) Up to 115 kbps (GPRS) Up to 384 kbps (EDGE)	Up to 2 Mbps
Applications	Advanced voice, SMS	SMS, Internet	Internet, Multimedia
Roaming	Restricted, Not global	Restricted, Not global	Global
Compatibility	Not Compatible to 3G	Not Compatible to 3G	Compatible to 2G, 2G+ and Bluetooth
Network example	CS-GSM, PDC, AMPS	HSCSD, GPRS, EDGE	UMTS

Table 6: Comparison between 2G and 3G network [25]

The evolution from the 2G to the 3G advanced wireless mobile technologies will necessarily requires certain amount of time before it can be fully effective in use . There are numbers of qualitative and quantitative issues that have to be taken into serious consideration before the actual implementation can take place. Regardless of these critical issues that will rise definitely, the development of mobile networks will continue to emerge to an advance stage to fulfil the demand for enhanced wireless systems with wide range of application supports. Table 6 above describes the important characteristics of the evolution from one generation to another generation of network.

The 2G wireless network was based on low band digital data signaling to allow only voice centric services. The most popular technology is the GSM that is widely used nowadays, using the combination of the Frequency Division Multiple Access (FDMA) and the Time Division Multiple Access (TDMA). The GSM operates in the 900 MHz and 1.8 GHz bands throughout its implementation around the world. Another similar technologies are known as the Personal Digital Communications (PDC), which is used Japan and the Advanced Mobile Phone System (AMPS) use in North America. Both are supported with the Code Division Multiple Access (CDMA). The 2G network is a fundamental of Circuit Switched technology and capable of handling data rate of up to 9.6 kbps, but it is not suitable for Internet and multimedia applications.

The path of mobile technology is now evolved towards the 2G+ networks, namely the GPRS and proceed with the EDGE and the HSCSD. The emerging technologies are influenced by the explosion of Internet usage and demand for advanced wireless data network. The GPRS is an intermediate step in allowing the GSM to use Internet services before the deployment of 3G network. The technology uses multiple timeslots to enable data speeds of up to 115 kbps. The HSCSD on the other hand is one step towards the 3G network with improved data rate of up to 57.6 kbps by utilizing 14.4 kbps data coding and radio channels. The EDGE is an enhancement technology for both the GPRS and the HSCSD to support increase data rate for up to 384 kbps.

The concept of 3G technology represent a shift from voice based services to a multimedia oriented service. One of its important aspects is the ability to unify existing mobile standard under one roof. The network is expected to use an advance technology of the Wideband-CDMA, the CDMA2000 or the UWC-136 interfaces. It is anticipated to be compatible with the existing network infrastructure and support Bluetooth technology. This technology is a complementary standard that enables interoperability between mobile terminal and other devices. The use of the Radio Access Network (RAN) protocol is predicted to provide data rates of up to 2 Mbps. One example of the 3G network is the UMTS.

Chapter 10

CONCLUSION

Even though, the development of GPRS over GSM architecture is still under deployment and the commercial product is expected to be out for commercial use in the mid-2001, the convergence of high speed global Internet applications with mobile computing is the evolution of cellular network in the century. It will bring together the order of magnitude increases in transmission speeds, the development of end-terminal devices with human interfaces capable of displaying complex graphical presentations, and the increased dependence and preference for networked information. From global roaming to innovative applications, the next generations of wireless communications enable a higher level of mobile data connectivity and capability that is unparalleled.

When dimensioning the GPRS system, it has become obvious that the network operators must decide upon some important issues that will directly affect the capacity of the networks. Many challenges remain that require serious judgment from the operators and providers to remain competitive in providing high level data communications to the customers. Evidently, the various issues discussed in this report will certainly be the major factors that restrained the growth in mobile network especially in the deployment of the GPRS phases unless major considerations are given to tackle these limitations. It is still too early to be certain on the actual deployment and operational of the GPRS network and also the acceptance from the users. Yet, the evolution of mobile technologies will change today's network drastically. Despite all the arguments and limitations, the technologies are here to stay and emerge to an advanced stage in timely manner.

APPENDIX: ABBREVIATIONS

2G	Second Generation
3G	Third Generation
AMPS	Advanced Mobile Phone System
APN	Access Point Name
ARQ	Automatic Repeat Request
AuC	Authentication Center
BG	Border Gateway
BSC	Base Station Controller
BSS	Base Station System
BSSGP	Base Station System GPRS Protocol
BTS	Base Transceiver Station
CDMA	Code Division Multiple Access
CDPD	Cellular Digital Packet Data
CDR	Call Detail Record
CLNS	Connectionless Network Service
CP	Complete Partitioning
CS	Coding Scheme
CSP	Complete Sharing Partition
CS-GSM	Circuit Switched- GSM
CSMA/CD	Collision Sense Multiple Access with Collision Detection
DCS	Dynamic Channel Stealing
DHCP	Dynamic Host Configuration Protocol
DSMA/CD	Digital Sense Multiple Access with Collision Detection
EDGE	Enhance Data rates for GSM and TDMA Evolution
EIR	Equipment Identity Register
ETSI	European Telecommunications Standards Institute
FDMA	Frequency Division Multiple Access

FIGS	Fraud Information Gathering System
GGSN	Gateway GSN
GPRS	Global Packet Radio Service
GSM	Global System for Mobile Communications
GSN	GPRS Support Nodes
GTP	GPRS Tunnel Protocol
HLR	Home Locator Register
HSCSD	High Speed Circuit Switched Data
IANA	Internet Assigned Numbers Authority
IMEI	International Mobile Equipment Identity
IMSI	International Mobile Subscriber Identity
IH	Internet Host
IP	Internet Protocol
IrDA	Infrared Data Association
ISDN	Integrated Services Digital Network
ISP	Internet Service Provider
LAN	Local Area Network
LLC	Logical Link Control
MAC	Medium Access Control
MDBS	Mobile Data Base Station
MMM	Mobile Media Mode
MT	Mobile Terminal
MS	Mobile Stations
MSC	Mobile services Switching Center
NAT	Network Address Translation
NSS	Network and Switching Sub-system
OS	Operating System
OSI	Open System Interconnection
PCU	Packet Control Unit
PDC	Personal Digital Communications
PDCH	Packet Data Channels
PDN	Packet Data Network
PDP	Packet Data Protocol

PDU	Packet Data Unit
PLMN	Public Land Mobile Network
PS	Packet Switched
PSP	Partial Sharing Partition
PSTN	Public Switched Telephone Network
PTM	Point-to-Multipoint
PTP	Point-to-Point
QoS	Quality of Service
RADIUS	Remote Access Dial In User Service
RAN	Radio Access Network
RLC	Radio Link Control
RSVP	Resource Reservation Protocol
SIM	Subscriber Identity Module
SGSN	Serving GSN
SMG	Special Mobile Group
SMS	Short Messaging Services
SMS-GMSC	Short Message Services Gateway MSC
SMS-IWMSC	SMS Internetworking MSC
SNDCP	Sub-Network Dependent Convergence Protocol
TDMA	Time Division Multiple Access
TCP	Transmission Control Protocol
TE	Terminal Equipment
TLLI	Temporary Logical Link Identifier
ToS	Type of Service
TRX	Transceiver Unit
UDP	User Datagram Protocol
UMTS	Universal Mobile Telecommunications System
UWC	Universal Wireless Communication
VLR	Visitor Location Register
WAP	Wireless Application Protocol

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