Measuring QoS for GPRS Mobile Networks

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Abstract: By applying a packet radio service to transfer user data between the mobile stations and external networks such as the Internet or enterprise networks; the General Packet Radio Service (GPRS), as a bearer service for GSM Mobile Networks, is supposed to greatly improve the data access of mobile users those external networks. GPRS as a service by itself and as foundation for third generation mobile systems (e.g. UMTS) became an interesting area for study and evaluation mainly in the area of Quality of Services. In this paper, we present a model for GPRS QoS measurements as well as the results of accessibility parameters related to data performance in a life network.

Key-Words: **- GSM, TDMA, GPRS, UMTS, 3G, QoS – Quality of Service, KPI.**

1 Introduction

Over the last decades, Internet and Mobile Systems have been largely developed and deployed. The Internet and networking technologies; based on the Internet Protocol (IP), which is a best effort, unreliable and cost effective protocol; are packet switched networks while the Mobile Systems, like other telecom systems, are circuit switched networks. This tremendous growth of these two technologies was the main drive behind having a converged network in order to develop what so-called Mobile Internet.

The GSM cellular system provides digital switched circuits that are multiplexed both in frequency (FDMA) and time (TDMA). It also provides data capabilities through short message system (SMS), which consists of short messages (160 characters) normally transferred between two mobile stations, and data transmission at various data rate (9.6 and 14.4 kbps).

From the technical point of view, the circuit switched radio transmission was not well suited for Internet traffic and data services, the allocation of a one or multi-channels for the entire period was not efficient at all. It is obvious that for bursty traffic, packet switched bearer services have better utilization of physical channels. This is because a channel will only be allocated when needed and will be released immediately after the transmission of the data. Therefore multiple users can share the same physical channel to transmit and receive their packets (statistical multiplexing).

In order to address these inefficiencies in the GSM networks, GPRS [1], as cellular packet data technology was developed. It was originally developed for GSM, but will also be used for IS-136 [2]. With GPRS, user's packets will be directly routed from the mobile network to packet switched network. Networks based on the Internet Protocol (IP) and X.25 are supported by the current version of GPRS [3].

A brief description of the GSM system can be found in [8] and detailed description of GPRS system can be found in [9].

Users of GPRS are supposed to benefit from shorter access time, higher speed rate and lower cost than traditional GSM data access.

Since GPRS is the foundation that third generation mobile systems will be based on, performance evaluations and tests of GPRS networks is an active area of research [10]. TCP performance [4][7], buffering [5], scheduling [6] and mobility procedures have been studied through analytical analysis and simulation as well as experimental testing over deployed networks [11].

We present, in this paper, GPRS QoS performance model as well as performance results based on measurements done in a live GPRS network deployed in Lebanon. Some details and results presented in this paper are affected by implementation and configuration issues, the version, the standardization and the supplier of the GPRS networks and the terminal equipments. Therefore, we cannot claim that the presented results apply to all GPRS networks and users.

The structure of this paper is as follows. An overview of GPRS is presented in section 2. Section 3 will address the QoS from standardization points of view. A model for QoS is outlined in Section 4. Results will be presented in section 5. And section 6 will conclude by summing up and providing some guidelines for future works.

2 Overview of GPRS Mobile Network

General Packet Radio Service GPRS[3], as extension to the GSM, provides GSM users with Internet access through a Packet switched technology instead of the circuit switched access that was originally provided with the earlier releases of GSM.

With GPRS, Packet data traffic runs over a new IP backbone, which is separated from the existing GSM core network that is mainly used for speech. This improves the accessibility for the mobile users and optimizes the usage of the radio and backbone resources.

In order to integrate GPRS into the existing GSM network, two new nodes, as illustrated in Fig. 1, called GPRS support nodes (GSN) and a unit called Packet Control Unit (PCU) have been introduced [3][9]. These additional elements are mainly responsible for routing the data packets between the mobile stations and the external data networks without going through the GSM backbone.

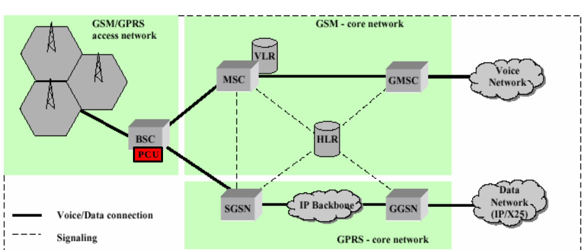

Fig. 1 – GPRS system architecture

GPRS, with a similar coding techniques to the one deployed in conventional GSM, extends the two previously defined coding schemes to four, to provide a data transfer rate from 9.05 kbps to 21.4 kbps. The different data rates are listed in Table 1.

By combing multiple time slots on the same carrier, GPRS achieves a maximum data transfer rate of 171.2 kbps. Like packet data network, many users share the same time slots.

Coding Scheme	*Data Rate*
CS-1	*9.05*
CS-2	*13.4*
CS-3	*15.6*
CS-4	*21.4*

Table 1. Coding schemes for GPRS

Coding schemes are selected based on C/I ratio, a strong signal provides a better data rate, while a low C/I will result in a low data rate. Under very good conditions a data rate of 21.4 kbps could be achieved.

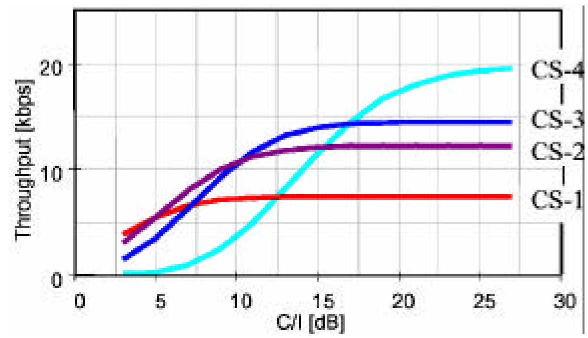

Fig. 2 – Coding schemes for GPRS

In GPRS, data has to pass through different protocol stacks before it arrive at its requested destination. These protocols, which are integrated into the network elements as depicted in Fig. 3, provide a protected and reliable transmission.

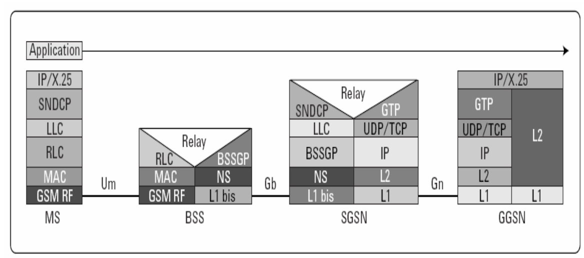

Fig. 3 – GPRS system architecture

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3 QoS from Standardization Points of View

Different organizations and bodies, such as ITU[12][13], ETSI[14] and 3GPP[16][17] have defined QoS and KPIs for GPRS and 3G mobile systems. Also projects, such as ETR[15], ALBATROS[18] and [19] have tried to define some frameworks for measuring the QoS in general and GPRS and 3G mobile systems in particular. Reference [21] presents a summary of these works, end-to-end QoS architecture and current issues for achieving end-to-end performance.

In general, QoS of GPRS mobile networks can be viewed from four different perspectives:

1 - End-to-End Performance:
- Throughput: min/avg/max, upload/download
- Round Trip Time (RTT) – delay
- Packet Loss
- Retransmission
- Throughput, retransmission per application
- TCP/UDP performance
- MMS performance

2 - Accessibility:
- PDP Context activation parameters
- Attach success rate
- Connection success rate (IP Address)
- Connection setup time (IP Address)
- Session status
- Application connection success rate
- Application connection time

3 - Mobility:
- Cell update success ratio
- Cell reselection success ratio
- Routing area update success ratio

4 - Retainability
- Network initiated deactivation rate by SGSN, GGSN, HLR
- Dropped contexts per application

The end-to-end QoS architecture, over wireless network, such as GPRS and 3G, is a complicated issue, because the service is spread over many domains: Mobile Network Provider(s): Mobile Domain, Data Network Provider(s): IP Domain and Service Provider(s): Application Domain [21]. Measuring related KPIs will involve the performance of all these domains: an issue that is quite complicated. However measuring the KPIs related to the other areas – Accessibility, Mobility and Retainability – involve only the access mobile network such as GPRS. This paper focuses on measuring KPIs related to these areas.

4 GPRS QoS Measurement Model

The measurements model, used to evaluate the GPRS performance, is illustrated in Fig. 4. This model is divided into three categories: data performance, signal quality, and RF performance.

The relationship between the GPRS measurement model for data performance and the various protocol stacks is shown in Fig. 5 Performance is measured at three layers: end-to-end data performance at the application layer; GPRS layers data performance at the GPRS layers; and RF quality performance at the air interface.

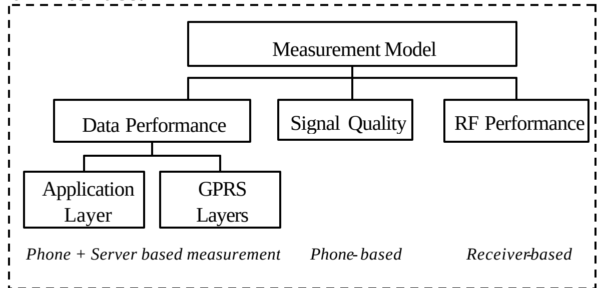

Fig. 4 – GPRS QoS measurement model

End-to-end data performance measurements are performed between the mobile (client) and a server and may involve different domains depending on where the server is placed: within the mobile domain; IP domain; or application domain. An application at one “end” or node (e.g. the mobile or PC connected to GPRS via a MS) communicates, using TCP or UDP, with a similar application at the other “end” (e.g. an application server. Figure 6 illustrates the case where the application is on the GGSN server located in the Mobile Domain).

Performance measurements at the GPRS layers could be very complex and may involve different protocol layers (e.g. RLC, MAC, LLC, etc…) to be working simultaneously and data packets may travel through different nodes (e.g. BSS, SGSN, GGSN, PDN).

Usually there are two ways to carry out data performance measurements at the application layer: the loop back method and the end-to-end measurement method.

The loop back approach requires a fixed unit in the network sending back the data received from the mobile (creating a loopback). Performance measurements are done by comparing the received data with the ones that have been sent. Figure 6 shows the data transfer mechanism at the Application and IP layers.

A major issue with this approach is to determine if the problems, that arise, are on the uplink or the downlink.

In the other approach, the receiving node measures the performance.

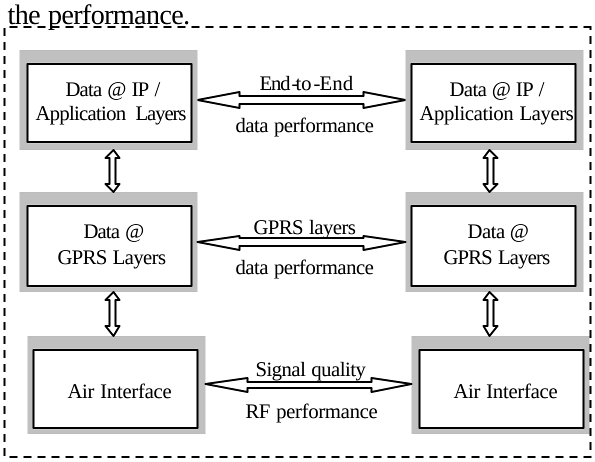

Fig. 5 – GPRS measurement model on the protocol stacks

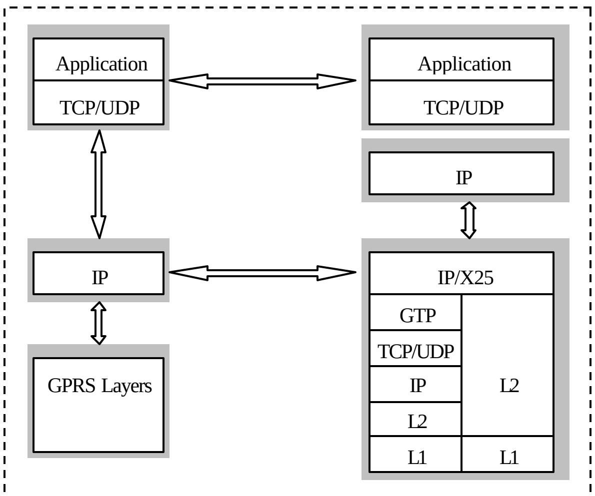

Fig. 6 – Data transfer at the Application and IP layers

5 Results

Measurements have been performed in a live network in Lebanon with a configuration that provides CS-4 capability with no dedicated data channel. TEMS investigation, a tool from Ericsson with R520m mobile stations, was used to perform these tests. Point-to-Point Protocol (PPP) was used to handle the connection from the computer to the mobile phones via a serial connection.

Results of 50 different tests in four different locations are presented bellow.

5.1 GPRS Attach Ratio

The attach procedure was typically used at the beginning of GPRS network. Today all the MS that support the GPRS service are automatically attached to the network. However, during our test period, we encountered 5 detaches messages at different times and locations. Their corresponding attaches' setup times vary between 2.09 and 33.1 seconds.

5.2 Accessibility parameters

Fig.7 presents the mean values and Fig.8 shows the results per location of the following accessibility parameters:

- PDP Context Activation Failure Ratio
- Data Transfer Cut-off Ratio
- Service Accessibility Ratio
- IP Service Access Ratio
- Completed Session Ratio

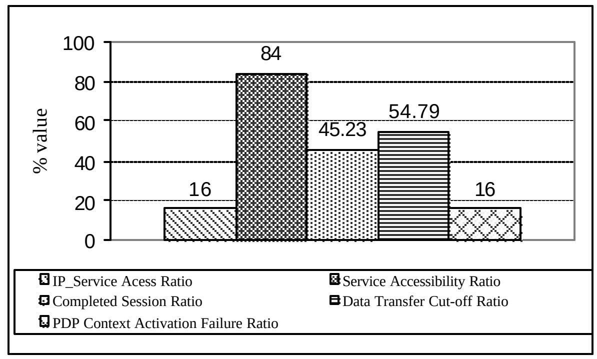

Fig. 7 – Mean GPRS Accessibility parameters

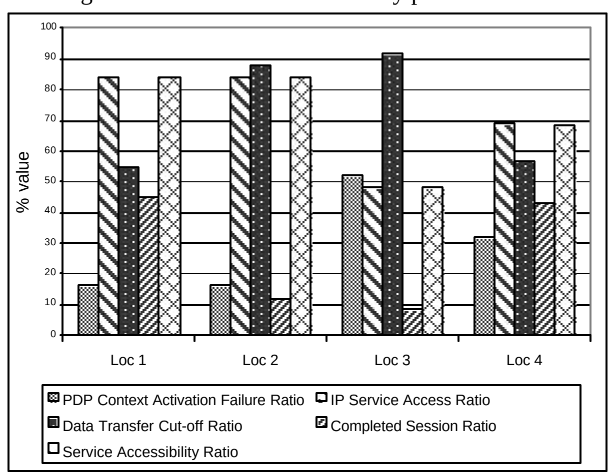

Fig. 8 – GPRS Accessibility parameters per Location

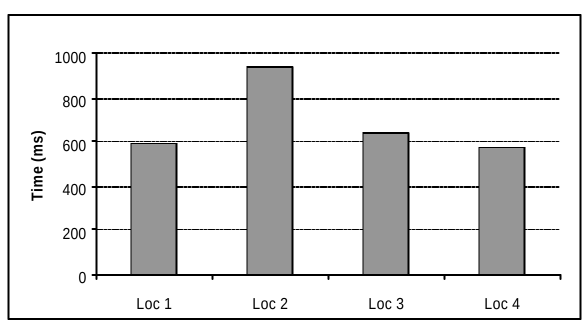

Fig. 9 – PDP Context Activation Time

The results show that these parameters vary between the different locations. Also the Data Transfer Cut-off Ratio is quite high in all locations, varying from 54.7% in Loc 1 to as high as 91.7% in Loc 3.

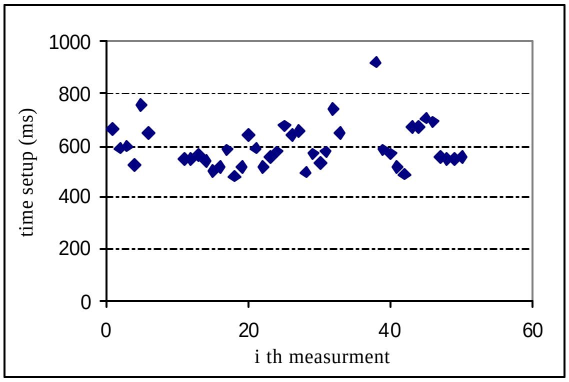

Fig. 10 – PDP Context Activation Time

The means PDP Context Activation Time are presented in Fig. 9, while Fig. 10 shows the times for all measurements in Loc 1.

Even though the accessibility parameters, in Loc 2, are quite good; the PDP Context Activation Time is the highest, close to 1 sec. compared to less than 600 msec in Loc 4.

5.3 File downloading

The results of downloading files with different sizes, presented in Fig. 11, show that the Complete Session Ratio is inversely proportional to the file size while the Data Cut-off Ratio is proportionally to the file size. We could not manage to download files bigger than 1 MB.

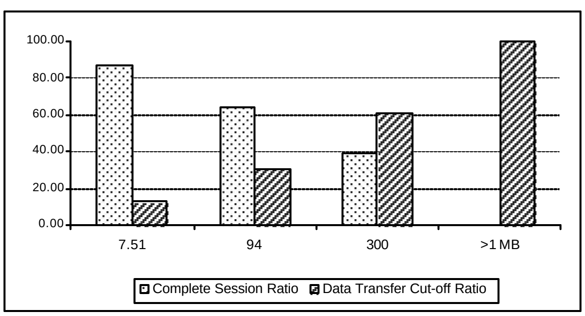

Fig. 11 – PDP Context Activation Time

5.4 Packet Loss

The results of Packet Loss in relation to packet size, presented in Fig. 12, shows that less than 5% of the packets are lost regardless on the size of the packets being transmitted.

5.5 Round Trip Time – RTT

Fig. 13 presents the measurements of the RTT in relation to the packet size. In average, RTT increases when the packet size increases with maximum values reaching 7 sec.

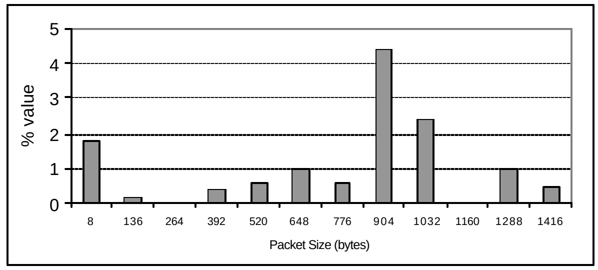

Fig. 12 – Packet Loss

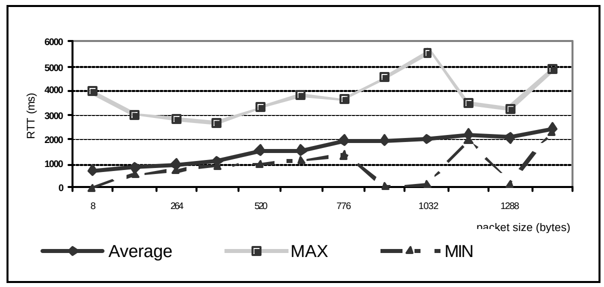

Fig. 13 – Round Trip Time – RTT

6 Conclusion

The results show that the performance of GPRS is way bellow what it has been expected with some instability and inconsistency. Most Accessibility parameters vary from one location to another with Data Transfer Cut-off ratio reaching 91.7% in one location which makes downloading big files almost impossible. The results also show that these parameters vary randomly and independently of each other, for example, the PDPD Context Activation Time, in Location 1, varies from 480 msec to almost its double 919 msec, and the accessibility parameters are the best in Location 2 while the PDP Context Activation Time is the worst in that location.

The measurements of file downloads showed that the GPRS performance decreases with the increase of the files being downloaded which makes it un-usable for big files such as multimedia files.

Even though the performance of the GPRS is not as promised and expected, it is a good step towards what so-called Mobile Internet and the drive for 3G systems.

However, measurements of different KPIs under different scenarios such as performances of specific applications (e.g. image transmission, VoIP, Video streaming and conferencing), TCP/UDP performances, MMS performances, retransmission, the impacts of the connectivity and handover between the different domains (Mobile, IP and Application) in the end-to-end system as well as the KPIs related to different perspectives such as mobility and retainability shall be carried out in order to locate the different issues and bottlenecks in the QoS performances and to propose the necessary improvements to the end-to-end system as a whole and GPRS as the access network.

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