# CHARACTERIZATION OF THE GPRS RADIO INTERFACE BY MEANS OF A STATISTICAL MODEL

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**Abstract: General Packet Radio Service (GPRS) is the packet switched data service for GSM. The typical Internet applications like WWW, FTP and e-mail will work over GPRS and it is therefore important to know their performance in this system. In order to accomplish this objective, a simulator of the GPRS system is necessary. The fixed network nodes introduced by GPRS are easy to simulate, but the main problem appears when we try to simulate the GPRS radio interface. In this paper we present useful types of results of the GPRS radio interface which facilitates the GPRS emulation.**

## I. INTRODUCTION

The General Packet Radio Service (GPRS) is a 2.5G system based on GSM (Global System for Mobile Communications) that was standardized by the European Telecommunications Standards Institute (ETSI). Unlike GSM that was designed for voice services and requires a circuit switching transmission mode, GPRS provides a packet switching transmission mode. This feature allows an easy adaptation to the bursty traffic generated by Internet applications like e-mail, WWW and FTP. In comparison with the 9.6 Kbit/s data transmission rate of GSM, GPRS offers a maximum theoretical data transmission rate of 172.4 kbit/s. GPRS uses the GSM infrastructure, but it makes some changes to the radio interface and adds two new nodes: the Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN).

In order to analyze the GPRS performance, the SGSN and GGSN behaviour can be simulated in a simple way. The problem arises when we try to simulate the radio interface, because this type of simulation is slow and, as a result, it is difficult to simulate an end-to-end Internet connection through GPRS with the radio interface simulation running. In this paper we propose a simple statistical model of the GPRS radio interface that considers all the different parameters relevant to the physical and link layers characterization, for instance, the number of users, the channel coding, the C/I ratio, the number of PDCHs, the type of service offered and the transmission direction. Unlike the results obtained in previous GPRS simulations [1] [2] [3] [4], in which the GPRS radio interface is analized mainly in terms of throughput, the type of radio link results obtained in this paper, PER and the cumulative distribution function of the packet delay, allows an accurate and rapid simulation of a FTP Internet connection through the GPRS network.

The rest of this paper is organized as follows: Section II presents a brief description of the GPRS system. Section III describes the simulator structure used for the study presented in the paper. In Section IV simulation results are given and finally, conclusions are derived in section V.

## II. GENERAL PACKET RADIO SERVICE

### A. Network Architecture

In order to work with the existing GSM infrastructure and give access to a external Packet Data Network (PDN), GPRS adds two new nodes: SGSN and GGSN. The SGSN is connected to the Base Transceiver Station (BTS) through a Base Station Controller (BSC); the Mobile Station is connected to the BTS through the radio interface. The SGSN routes the incoming data to the right BSC. Within the GPRS network, the SGSN is the main partner for the Mobile Station, because it is in charge of the following functions: mobility management, charging information related to the usage of the air interface and cell change. The SGSN is connected to the GGSN through an Internet IP backbone. The GGSN is the gateway to external PDNs (e.g. Internet) and it collects charging information based on the usage of external network resources. Figure 1 shows the basic nodes that take part in a packet transmission in the GPRS network.

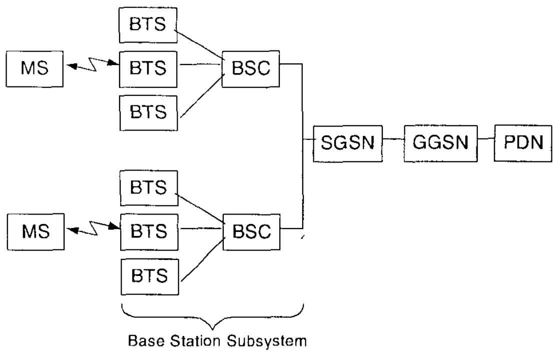



**Figure 1: GPRS network architecture.**

B. GPRS Radio Interface

The basic structure of the protocol stack for the GPRS radio interface is shown in Figure 2. The Subnetwork Dependent Convergence Protocol (SNDCP) is used between the SGSN and the MS. It maps network-level characteristics onto the characteristics of the LLC layer. The Logical Link Control (LLC) protocol provides a highly reliable ciphered logical link between the MS and the SGSN. It provides flow control, in-order delivery, sequence control, detection of transmission errors and retransmission. The Base Station System GPRS Protocol (BSSGP) conveys routing and QoS-related information between the BSS and the SGSN. The Network Service Protocol is based on the Frame Relay Protocol. The Radio Link Control (RLC) protocol establishes a reliable link between the MS and the BSS. Its functionality includes the segmentation and reassembly of LLC frames into Radio Link Control (RLC) data blocks and retransmission of corrupted and lost blocks using an Automatic Repeat reQuest ( ARQ) mechanism. The Medium Access Control (MAC) protocol controls the access signalling procedures for the radio channel (request and grant). The GSM RF layer is similar to the physical layer in GSM.

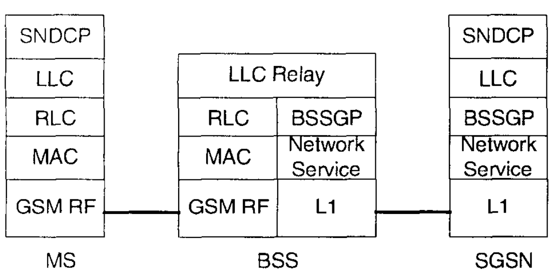
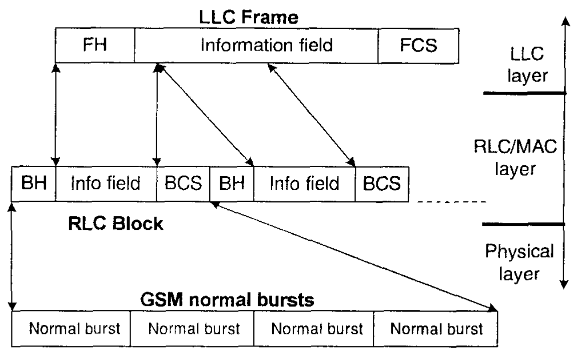



**Figure 2: GPRS protocol structure.**

Figure 3 lends more details to the radio part by showing the data flow from the LLC layer to the physical layer [5]. The RLC/MAC layer transforms the LLC frames into RLC data blocks which are formatted to GSM normal bursts. Each block comprises four bursts sent in consecutive TDMA frames.




FH: Frame Header FCS: Frame Check Sequence
BH: Block Header BCS: Block Check Sequence

**Figure 3: Packet transformation data flow.**

Four coding schemes are defined for channel coding of the RLC blocks, CS1-CS4. The details of the codes is shown in Table 1. CS1-CS3 are based on a convolutional code, CS-4 is uncoded. The payload per block depends upon the channel coding scheme.

| Coding Scheme | Convolutional code rate | Payload per block (bits) | User bit rate (kbps) |
|---|---|---|---|
| CS1 | 1/2 | 181 | 9.05 |
| CS2 | ~2/3 | 268 | 13.4 |
| CS3 | ~3/4 | 312 | 15.6 |
| CS4 | 1 | 428 | 21.4 |

**Table 1. GPRS coding schemes.**

## III. SIMULATOR STRUCTURE

The GPRS radio link simulation model has been created with the event driven simulator Cadence Bones Designer. This software supports three programming modes: a block oriented hierarchical system modeling approach, a Finite State Machine (FSM) model and the C++ programming language. Figure 4 shows the top-level of the simulator, it includes the BSS, the radio link and the MSs.

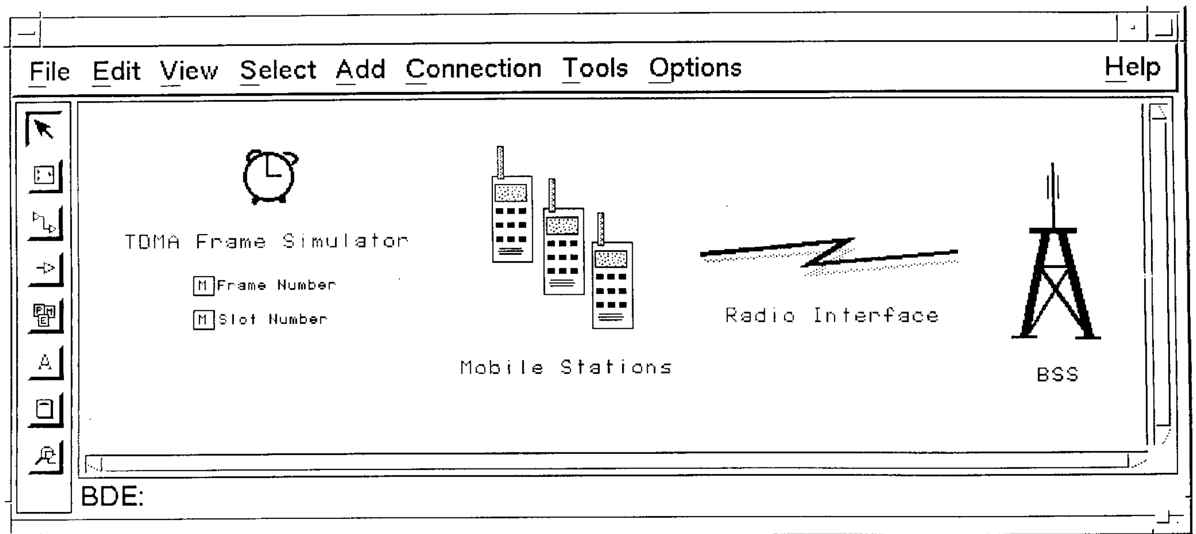



**Figure 4: Graphical Interface of the GPRS Radio Simulation Tool**

### A. GPRS Radio Interface Model

In the radio link a transmission at the Logical Link Control (LLC) layer has been simulated. The LLC layer has been simulated operating in unacknowledged mode. The RLC/MAC layer has been implemented in detail following the ETSI technical specifications [6]. The MAC layer uses the slotted Aloha access mechanism. A Round Robin scheduling method without priorities is assumed. The RLC layer uses a Selective-Repeat ARQ mechanism. The physical layer is implemented with results that appear in related pre-simulations [7]. These results for each coding scheme determine the block error probability for a RLC block received with a certain C/I. A Typical Urban (TU) environment with a vehicle speed of 3 Km/h and frequency hopping was assumed.

### B. Internet Traffic Models.

Three types of bursty traffic have been considered in the paper, namely: e-mail, WWW and FTP. We have distributed the type of users in the following form: 50% e-mail, 30% WWW and 20% FTP. The traffic generated for e-mail is similar to the Funet traffic model, whereas the traffic generated for WWW and FTP services has been modeled using the ETSI model [8].

### C. Performance Metrics

In the simulator we can vary mainly the number of users, the coding-scheme, the channel conditions (C/I) and the number of PDCHs. For this analysis we consider the type of service offered (WWW, FTP or e-mail) fixed. Then for each assumed set of parameters, the LLC Packet Error Rate (PER) and the cumulative distribution function of the LLC frame delays are obtained. In particular, we consider for the analysis of the results that a LLC frame is equivalent to a packet. Table 2 summarizes the most important simulation parameters.

| Parameter | Value |
|---|---|
| Max. number of retransmissions per frame | 10 |
| Max. time waiting for an AGN (access grant notification) | 0.1 sec |
| Max. time waiting for random access attempts per frame | 0.3 sec |
| Max. time awaiting for an acknowledgment | 0.1 sec |
| E-Mail generation frequency | 5 messag./hour |
| WWW pages generation frequency | 3 bursts/hour |
| Number of WWW pages per burst | 5 pages/burst |
| Time between WWW pages | 412 sec |
| Number of frames per WWW page | 25 frames/page |
| Time between WWW frames | 0.125 sec |
| FTP burst generation frequency | 6 bursts/hour |
| Mean LLC packet size | 480 bytes |
| PRACH blocks | 0; 6 |
| Number of Mobile Stations | 10-15 |
| Number of PDCHs | 1, 2 or 4 |
| Simulation time | 100 - 120 min. |

**Table 2: Simulation Parameters.**

## IV. SIMULATION RESULTS.

Using the aforementioned simulator a statistical model of the GPRS radio interface is obtained varying the following parameters: Number of PDCHs (1, 2 or 4), C/I relation (2 per coding scheme, one appropriate and the other inappropriate, coding scheme (4) and number of Mobile Stations (10 or 15). Even though three types of traffic were generated, we have consider for this analysis the results corresponding to the FTP traffic. 48 simulations results for FTP traffic were obtained in all. For each combination of input parameters we obtain two output values: the PER and the cdf of the LLC frames delays.

The following results show the GPRS radio layer behaviour for a FTP connection. We believe these types of results are useful for an easy simulation of the GPRS radio layer.

First we will show a comparison of the statistics when we vary the number of PDCHs. Figure 5 shows a downlink simulation with 1,2 and 4 PDCHs, a C/I relation of 12dB, CS-1 and 15 Mobile Hosts. The x-axis of the graph uses the block period as a time metric. Each block period is equivalent to 18.46 ms. As it is foreseeable, the PER and delay decrease as the number of PDCHs increases. The delay values for this simulation are notable. For 4 PDCHs the maximum delay is around 400 block periods, which is around 7.38 seconds. The high delay value that appears in the results and therefore a low throughput are due to the high number of MSs present in the system (15). As it was shown in [9], the throughput decreases drastically when the system has more than a certain number of MSs.

As it can be seen also in Figure 5, the PER values are less than 5%. This magnitude is similar to the PER values defined in the QoS reliability class 3 of GPRS [10].

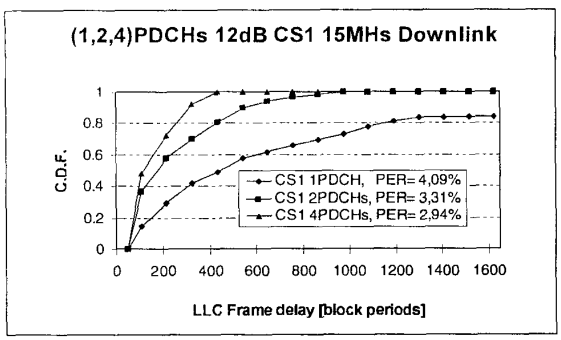



**Figure 5: (1,2,4) PDCHs, 12dB, CS1 and 15MHs.**

Figure 6 shows the results for the coding scheme 3. It is interesting to observe that the delay for 2 and 4 PDCHs are quite similar. This means that for these values of simulation parameters 2 PDCHs are enough in order to have the maximum performance and it is not necessary to add more PDCHs.

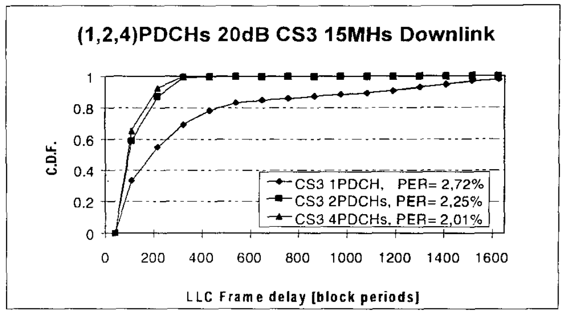



**Figure 6: (1,2,4) PDCHs, 20dB, CS3 and 15MHs.**

In Figure 7 we appreciate the influence of the C/I relation in the delay and PER. The importance of the C/I value for each coding scheme was mentioned in previous studies [2]. For a C/I value of 12 the delay and PER are much bigger than for a C/I value of 16. In the case of CS3 the difference is not so big, as it appears in Figure 8. Every code has its own C/I values with which it reaches its maximum throughput. In the case of CS2 of Figure 7 the variation of passing from 12dB to 16dB is important. However, this is not so in the case of Figure 8 with CS3, because the transmission with CS3 is stable with these values of C/I (16 and 20dB) and with these channel conditions (4 PDCHs and 15 MHs).

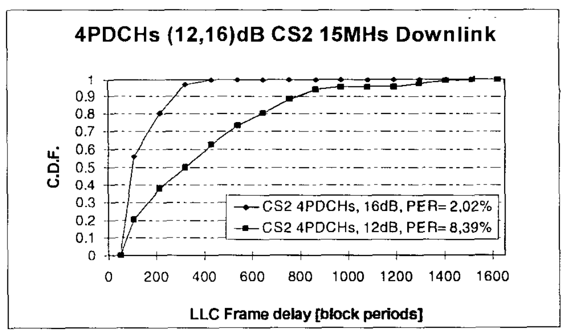



**Figure 7: 4 PDCHs, (12,16)dB, CS2 and 15MHs.**

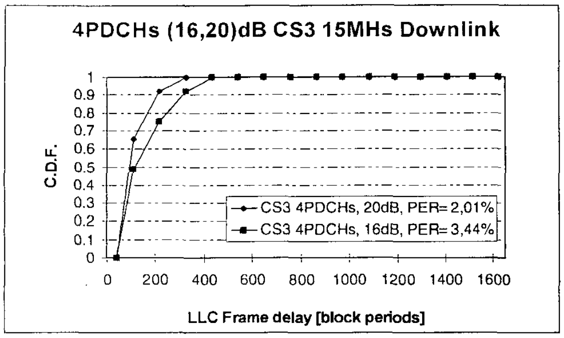



**Figure 8: 4 PDCHs, (16,20)dB, CS3 and 15MHs.**

It is not worthless to mention here that GPRS radio interface results from other studies, e.g. [1], show the throughput, the blocking rate and the frame transfer delay depending on the offered load. These results explain the behaviour of the GPRS radio interface system in general, but not for a single user.

Then, the results presented in this paper can be used for simulating the impact of the GPRS performance on the TCP segments sent through the air interface. Certainly, first according to the PER value it is decided if the LLC frame is correctly received or discarded. If the LLC frame is selected as correctly received, then its block delay, evaluated according to the cdf statistic, is determined.

We have developed a generic model that considers different radio parameters as well as a certain distribution of traffic generated by users (in this case 50% e-mail, 30% WWW and 20% FTP).

## V. CONCLUSIONS

The paper has presented a simulation model for the GPRS radio interface which gives useful types of results in order to simulate the transmission through the GPRS network of LLC packets for the FTP service. The simulation model gets as input the number of PDCHs, the C/I relation, the coding scheme and number of Mobile Stations. As output, it gives the PER and the cdf of the packet delay. With these type of results it is also easy to understand the importance of the parameters which have more influence in the PER and packet delay in the GPRS radio interface.

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