IMPACT OF GPRS ON THE SIGNALLING OF A GSM-BASED NETWORK

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Abstract

With the introduction of the General Packet Radio Service (GPRS) in existing GSM-networks, data services with high bandwidth can be provided to mobile users. Although GPRS defines an IP-based backbone network for the transport of user data and signalling between the GPRS-nodes, some parts of the signalling network of the existing GSM-network will be used. The focus of this paper is on the impact of this additional signalling traffic on the performance of the signalling network caused by the introduction of GPRS. Using analytical and simulation tools, the increase in signalling traffic and response times of the signalling network, especially during high traffic load, is investigated to give some help in dimensioning a GPRS-ready signalling network.

Keywords

Signalling, GSM, GPRS.

1 INTRODUCTION

The importance in support of data communication for today's mobile communication networks, based for example on the GSM standard and being designed mainly for voice communication, is increasing. New requirements for mobile networks are risen as mobile users explore new data services, like sending and receiving E-mails, WWW-browsing or WAP access with mobile access to IP-based networks (e.g. the Internet). The increasing need for bandwidth and the special requirements of the bursty nature of data traffic cannot be adequately fulfilled by the GSM standard.

The General Packet Radio Service (GPRS, [1]), as an extension to second-generation GSM, provides short connection setup times, virtual connections, and data rates up to 115 kbit/s for each user, whereas the available bandwidth can be shared among different users. The high bandwidth will be achieved by combining up to eight time slots at the radio interface, where the data is transported in a packet-oriented way.

In the core network, beside the transportation of user data, a separate signalling network, based on the Signalling System #7 (SS7), is used to support the user mobility and to access the various databases of the GSM-network. The main purpose of this paper is to take a look at the additional signalling traffic, caused by the introduction of the GPRS, in order to support the planning and dimensioning of a GPRS-ready signalling network. The two main points considered in this paper are the load of the signalling links and the response times of the network for some time critical scenarios. The load of the links are first determined analytically and are then verified by a simulation study designed mainly for the determination of the response times for GSM and GPRS scenarios.

The signalling part of communication networks, based on the SS7, was analyzed in general in various papers like [2] or [7] and with respect to new services e.g. the Intelligent Network (IN) in [8]. Some estimation about the impact of GPRS on the signalling network can be found in [3].

The remainder of the paper is organized as follows: In section 2, the GPRS System as an extension to the GSM will be described, while in section 3 the relevant signalling scenarios considered in this paper are presented. Section 4 describes the simulation environment and discusses some results of the investigations. The last section concludes the paper.

2 OVERVIEW ON GSM AND GPRS

The GSM core network, as shown in Fig.1, consists of several kinds of nodes. The most important nodes relative to this paper are the Base Transceiver Station (BTS) and the Base Station Controller (BSC), forming together the access network of the GSM/GPRS network. Further on the Mobile Switching Center (MSC), responsible e.g. for the routing of the calls, the tracking of the mobile users and security functions. The Visitor Location Register (VLR), a database storing actual user related information of the users currently served by the MSC, is often closely located to an MSC. The Home Location Register (HLR) holds further user information, like the actual location and the subscription data of the users. Signalling Transfer Points (STP), not shown in Fig.1, are used for routing signalling messages. For more details on GSM, see [5].

While the radio interface of GPRS is very much the same like in GSM, a new core network is defined in parallel to the existing GSM core network. The

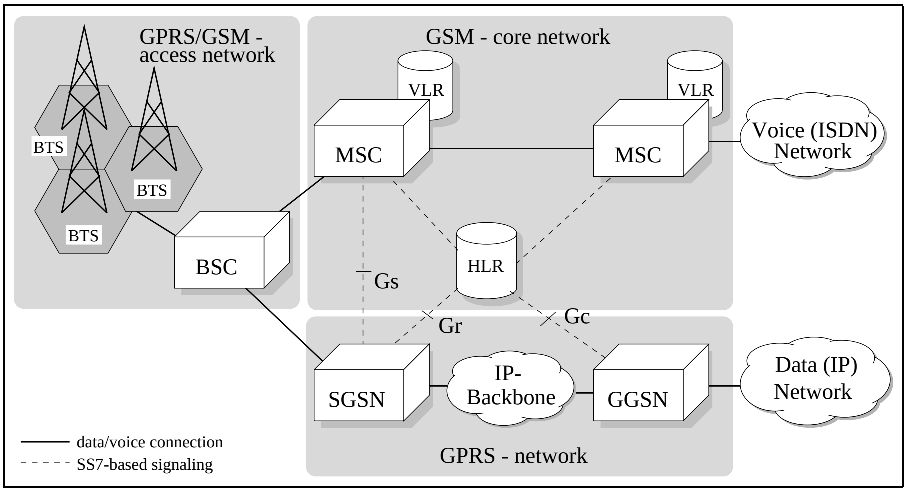


Figure 1: GSM/GPRS network architecture

BSC splits or combines (dependent on the direction) the voice and data traffic. Voice traffic is sent to a traditional ISDN-based GSM network while data traffic is transported via a separated IP-based backbone network. Two new types of nodes are introduced in GPRS, the Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN). The GGSN is responsible for the connection to other packet oriented networks and stores the information about the location of the GPRS users. The SGSN, like the MSC in the GSM-network, is responsible for the support of user mobility and the access control of users to the radio resources. The GPRS network is only connected with the GSM-network at the BSC as the connection to the Mobile Station (MS) and with signalling connections (Interfaces G_s, G_r and G_c in Fig.1).

To handle the mobility of users, mechanisms like the access to information stored in the HLR or VLR, providing the GSM mobility support, are used by GPRS. Additionally, some GPRS-specific information like the GPRS-related Subscriber Data is stored in the HLR as well. As this information can only be accessed via the SS7, the GPRS network nodes also have to use the SS7 network. Therefore the introduction of the GPRS has an impact on the existing GSM network not only at the radio interface, but at the SS7 network and the GSM databases as well.

In GPRS one or more radio cells are combined to Routing Areas (RA). Any RA is a subset of one GSM Location Area (LA) and is served by only one SGSN. However, an SGSN can serve several RA. For economic reasons, an SGSN in not combined with every RA or even every MSC. Only a few SGSN, each responsible for the area covered by some MSC, are installed in a GPRS network. Further, SGSN are often co-located with an MSC to save the costs of new SS7 links. As a consequence of this concentration of GPRS functionality to only a few MSC, the GPRS-related signalling traffic will be cumulated on the links to these combined MSC/SGSN nodes. Thus, the focus of this paper is on the signalling load of these links. Additionally of interests are the links to the HLR used for the transmission of the Subscriber Data.

3 SIGNALLING AND SIGNALLING SCENARIOS

The SS7 is used for the transport of signalling messages in GSM and GPRS networks, except for the signalling between the SGSN and GGSN, where in GPRS defined signalling messages are transported over a IP-backbone. In the investigation, only a limited number of different SS7 signalling scenarios are considered. The reason for this is to reduce the complexity of the simulation and the fact that the unconsidered scenarios are rare or light and are assumed not to generate a significant amount of signalling traffic.

In GSM, the HLR knows the actual location of a user and the MSC, the user actually belongs to, stores the user related information. In GPRS, the GGSN knows the SGSN the user is registered at and routes incoming data packets to this corresponding SGSN. If a user changes his location, so that a new MSC or SGSN is responsible for this user, information in the MSC, the SGSN, the HLR, and the GGSN must be updated, in order to correctly route calls or incoming data packets to the new location of the user.

Three modes of operation are defined for GPRS MS, which differ in the way the MS are attached to GSM and/or GPRS services:

Class-A mode The MS is attached to both GPRS and GSM services, and supports simultaneous operation of GSM and GPRS services.

Class-B mode The MS is attached to both GPRS and GSM services, but the MS can only operate on one service at a time.

Class-C mode The MS is exclusively attached to GPRS services.

Combined GSM/GPRS procedures like location update or attach procedures are defined for economic use of radio resources for MS working in Class-A or Class-B mode. In this study, it is assumed, that all GPRS MS are working in Class-A or Class-B mode therefore using the combined GSM/GPRS procedures.

The scenarios considered in this paper are (as example see Fig.2):

Calls to mobile users Signalling to establish and end a call to a mobile user located in the same network. Before the call signalling can be started, a request to the HLR for the location of the called party is started.

Calls to non-mobile (ISDN) users Signalling to establish and end a call to a non-mobile user connected to another fixed network. All MSC are assumed as working as a Gateway-MSC.

GSM (IMSI-) attachment (AT) Signalling for the GSM-only registration of an MS to the GSM network.

GSM only Location Update (LU) Signalling starting if a GSM-only attached MS changes the area of an MSC/VLR to a new one.

Combined GSM/GPRS AT Signalling for the combined GPRS/GSM registration of an MS to the GPRS/GSM network.

Combined GSM/GPRS intra SGSN LU Signalling started, when a GPRS/GSM attached MS changes the LA, but remains connected to the same SGSN.

Combined GSM/GPRS inter SGSN LU Signalling started, when a GPRS/GSM attached MS changes the LA and also gets connected to a new SGSN.

The GSM call scenarios are taken from [6], the GSM AT and LU scenarios are adapted from the ETSI GSM specifications and the GRPS-related scenarios are taken from [1]. For simplicity all scenarios neglect the security functions and only take the signalling messages between MSC/VLR, SGSN, HLR and STP nodes into account.

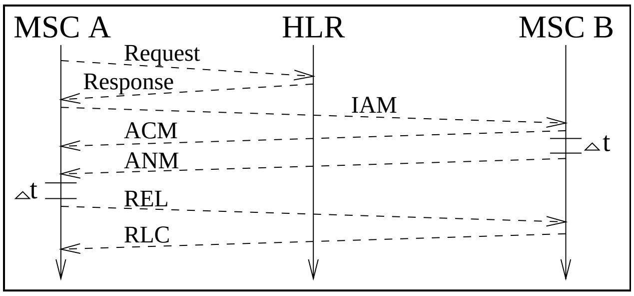


Figure 2: Example of a signalling scenario: call to a mobile user.

4 Simulation and Results

The average utilization of the signalling links with a given mean interarrival time of the invocations of the scenarios are calculated analytically for the stationary case not reflecting e.g. overload conditions. In this flow analysis, the average lengths of the messages of the scenarios on the different links are added and multiplied by the frequencies of the scenarios. The results are validated against the results of an event-driven simulation study, based on a queueing model of the SS7-network. This simulation study investigates the dynamic behavior of the signalling network under various conditions. All major aspects of the SS7 protocol, including re-routing and congestion control, are considered in the simulation. The above listed GSM and GPRS scenarios are implemented; the inter-arrival times of the invocations of the scenarios are distributed negative-exponentially with the mean value as a simulation parameter. The message lengths used in the simulation are uniformly distributed between the values listed in Table 1; they are taken partially from [4] and [3]. The *GPRS subscriber data* message mentioned in Table 1 is a GPRS related set of information stored in the HLR, which is send from the HLR to the SGSN and, using the IP-backbone, forwarded to the GGSN with every *GPRS AT* and *GPRS inter SGSN LU*.

Table 1: Assumed lengths of the signalling messages

Message	Length (octets)
IAM	60-80
other ISUP	15-25
MAP	80-120
GPRS Subscr. Data	150-250
other GRPS	80-120

Fig.3 shows the signalling network model used in simulation model A. The links offer a bi-directional bandwidth of 64 kbit/s each. The signalling scenarios for calls, GSM AT and GSM LU are distributed evenly among the five MSC. Further both HLR are used equally at the scenarios. In the GPRS scenarios, only the two MSC with co-located SGSN are involved. Exception being the GSM-parts of the combined GPRS scenarios (the GSM AT is part of the GPRS AT, for example), which are again distributed over all MSC. In simulation model B, all MSC have a co-located SGSN (SGSN with dashed lines in Fig.3), so the GPRS scenarios are spread over all MSC evenly.

In the simulation, the overall number of scenarios per second remained fixed. 50% of all scenarios are call scenarios, 16.6% are AT scenarios and 33.4% are LU scenarios. For the percentage of GPRS scenarios on all administrative scenarios (AT and LU), the values 0%, 20%, 40%, 60%, 80% and 100% are taken as parameter.

Results

Fig.4 shows the results of the study of the link traffic. The results are almost identical for the analytical and the simulative study of the link-load and are therefore not presented separately. For each of the different types of links,

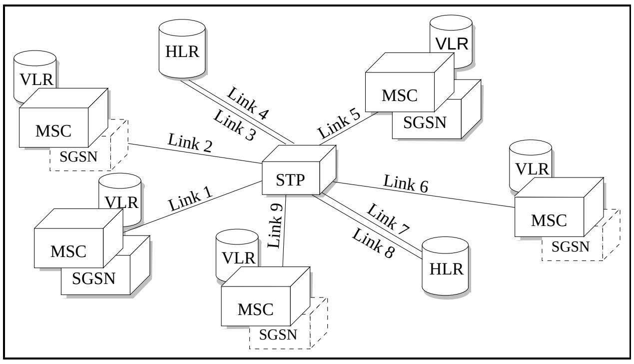


Figure 3: Network topology (simulation A), the additional SGSN of simulation model B are drawn with dashed lines.

the increase of traffic is shown as subject to the percentage of GPRS-attached MS to all MS. The increase is shown in relative to the case where no MS are GPRS-attached. The node *MSC* means an MSC without an SGSN adjacent, whereas *SGSN* means an MSC with an SGSN located nearby. As the scenarios to and from an MSC without an SGSN are symmetrical, the link-load to and from an MSC are identical. Resulting in a twice as high traffic in for example simulation model A with 80% GPRS-attached MS on the link from the STP to the SGSN/MSC, as without GPRS-attached MS.

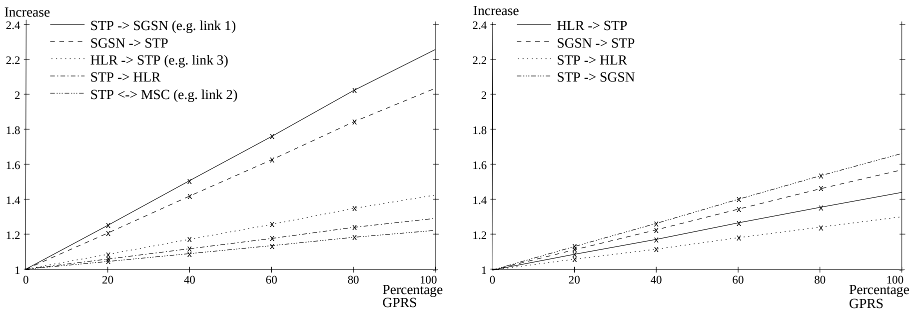
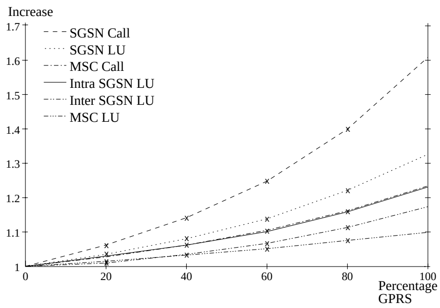


Figure 4: Increase in link-load, left side for simulation model A, right side for model B

For simulation model B, the increase in traffic load is not as high as in model A, as less concentration of the GPRS traffic occur. However, the links to the SGSN/MSC still have to carry up to 165% of the traffic subject to no GPRS-attached MS.

Fig.5 shows the simulation results of the increased time-span of some scenarios subject to the percentage of GPRS-attached MS. The network was heavily loaded so that in cases of only GPRS-attached MS, the congestion control of the SS7 put up sporadically due to an overload of the STP. *SGSN Call* means a call scenario from an MSC with an SGSN nearby, whereas *MSC Call* means a call from an MSC without an SGSN nearby.



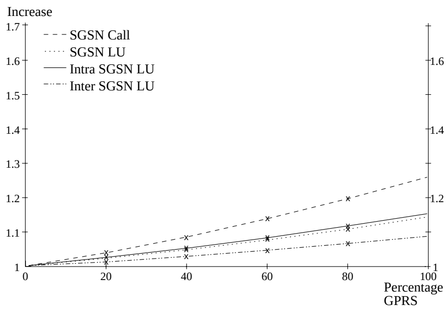


Figure 5: Increase in response times, left side for simulation model A, right side for model B

5 CONCLUSION

The introduction of GPRS in an existing GSM-network not only has impact on the radio interface, but also significantly influences the signalling network. Depending on the quantity of MS attached to GPRS, the load of some links nearly doubles. Additionally the scenarios need significantly more time to finish due to the higher load. Specially in the case when the SGSN are located to only a few MSC, a carefully dimension of the signalling links is needed due to the increase of the link-loads and therewith the nonlinear increase of the response times.

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