Final Paper submitted to

VTC2000-Spring

May 15-18, 2000, Tokyo, Japan

Topics: GPRS Network Dimensioning
On-Demand Channel Allocation

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GPRS Radio Network Capacity and Quality of Service using Fixed and On-Demand Channel Allocation Techniques

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ABSTRACT

In this paper the radio network capacity needed for the General Packet Radio Service (GPRS) in coexistence with circuit switched services and the admissible quality of service for mobile Internet users is presented. Since the GPRS is to be integrated into the GSM infrastructure, a number of physical channels has to be made available to GPRS used as fixed and on-demand Packet Data Channels (PDCH). A simulation environment for a GPRS network and its entities for an on-demand channel allocation mechanism are introduced. The simulation results comprise performance measures for the quality of service from the user's point of view and the channel utilisation for a range of load situations in order to fix the needed radio capacity regarding cell configurations with up to 8 dedicated and on-demand PDCH.

I. INTRODUCTION

Although a circuit switched data service is part of the GSM standard, there is no service optimized for data applications. Since an exclusive connection is assigned for each user, bursty traffic leads to inefficient radio resource utilization. Further disadvantages of the present service are the comparatively low transmission rate of 9.6 kbit/s and the charging, which is not oriented to the transmitted pack of data, but to the connection duration.

A service optimized on the mentioned factors is offered by the packet-oriented data service *General Packet Radio Service* (GPRS), which is specified by the *European Telecommunications Standards Institute* (ETSI). This packet data service, which will be available for users at the beginning of 2000, provides both a higher data rate and a flexible utilization of the channel capacity, because several users can share a channel. Further documentation about GPRS is available in [1, 9]. Since 1988 the ETSI performs examininations to characterize mobile data applications for future mobile radio networks [11, 12]. In congruence to these proposals network providers in Europe see Web-browsing as the main application for mobile data services in the near future. Since the GPRS will be integrated into the spectrum and the infrastructure of the existing GSM, the need of radio resources to support Internet applications over GPRS is examined.

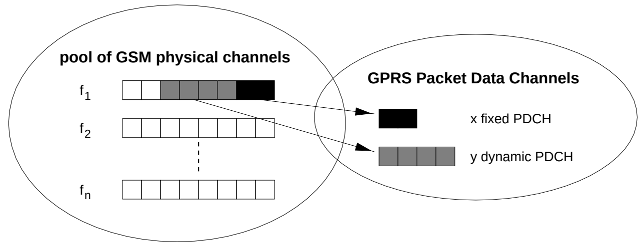

Fig. 1: Allocation of GSM physical channels for GPRS

In this paper fixed and on-demand channnel allocation mechanisms as part of the GPRS standard are introduced. After building a simulation environment it has to be examined which need of radio capacity arises with the integration of GPRS. For this aim the channel utilisation measures compared with the quality of service have to be regarded.

Following this introduction, Section II gives a description of the radio resource (RR) management principles for packet switched (PS) and circuit switched (CS) services in GSM/GPRS networks. In Section III the used simulation methodology and the simulation environment with the special focus on the resource management entities is presented. Performance evaluation, discussion and interpretation is done in Section IV. In Section V the paper is summarized.

II. RADIO RESOURCE MANAGEMENT IN GSM/GPRS NETWORKS

In the ETSI standard GSM03.64 [10] principles are described how to allocate radio resources fixed or dynamically for GPRS (see Figure 1). Details that are related to certain channel allocation strategies are left open and are implementation-specific.

A cell supporting GPRS may allocate resources on one or several physical channels in order to support the GPRS traffic. Those channels shared by the GPRS mobile stations are taken from the common pool of physical channels available in the cell. The allocation of physical channels to circuit switched services and GPRS is done dynamically according to the "capacity on demand" principles described below. Common control signalling required by GPRS in the initial phase of the packet transfer is conveyed on PC-

CCH, when allocated, or on CCCH. This allows the operator to have capacity allocated specifically to GPRS in the cell only when a packet is to be transferred. The number of allocated PDCHs in a cell can be increased or decreased on demand. The following principles can be used for the allocation. A load supervision function may monitor the load of the PDCHs and a number of allocated PDCHs in a cell can be increased or decreased on demand. A load supervision function may be implemented as a part of the Medium Access Control (MAC) functionality. The common channel allocation function located in the BSC is used for the GSM services. Unused channels can be allocated as PDCHs to increase the overall quality of service for GPRS. Upon resource demand for other services with higher priority, deallocation can take place. The fast release of PDCHs is an important feature for the possibility to dynamically share the same pool of radio resources for PS and CS services. There are the following possibilities.

- Wait for all the assignments to terminate on that PDCH
- Individually notify all the users that have assignment on that PDCH
- Broadcast the notification about deallocation

In practise, a combination of these the methods can be used.

III. SIMULATION

For this study a simulation tool named GPRSim was developed. This simulation environment allows to ascertain and to optimize properties of different protocols of the GPRS transmission plane. In addition, it gives the possibility of network capacity and quality of service planning by performance evaluation in certain simulation scenarios. The simulator is developed as a pure software solution in the programming language C++. For implementation of the simulation model in C++ the *Communications Network Class Library* (CNCL) [4], which was developed at the Chair of Communication Networks, is utilized. This allows an object oriented structure of programs and is especially applicable for event-driven simulations. The regarded protocols were specified with the Specification and Description Language (SDL) and mapped on executable C++ code using the code generator SDL2CNCL [7]. The software architecture of the GPRSim and the information flow between the modules is shown in Figure 2.

The simulator comprises the modules *Mobile Station* (MS), *Base Station* (BS), *Serving GPRS Support Node* (SGSN), the transmission links, the load generator, session control modules, a graphical user interface for presentation and a module for statistical evaluation. The MS, BS and SGSN are formally built similar. They contain the protocol implementations of the layers. The transmission links are separated into Uplink and Downlink. In the GPRSim simulation model only one carrier frequency is available for each the uplink and the downlink. Frequency hopping is not regarded. The mobility influence and the carrier to interference ratio is recreated by modelling the transmission

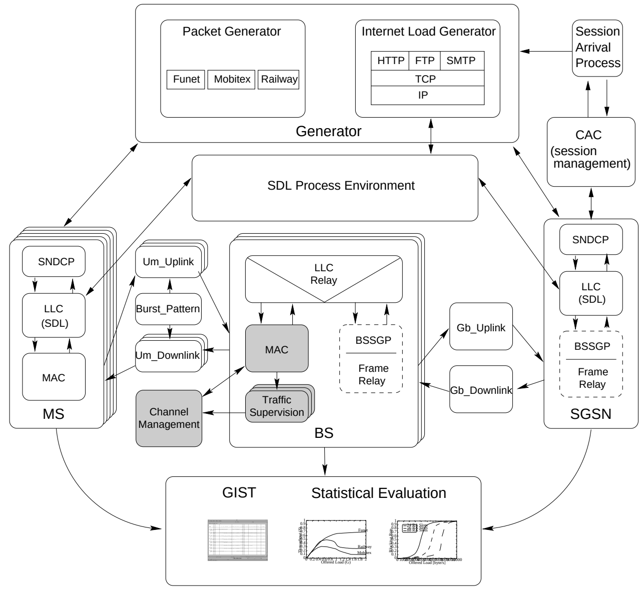

Fig. 2: The GPRS Simulator GPRSim

channel on burst level using *pattern files* [3]. For this reason parameters like timing advance and power level need not to be considered in the simulation. Battery saving and the subdivision in paging groups are also not regarded and do not have any influence on the results. As described in Section II channel allocation for GPRS is done by fixed allocation of PDCHs and by the ”capacity on demand“ principle. Allocation with the ”capacity on demand“ concept was integrated into the GPRSim for this study. An instance *Traffic Supervision* gives Reports about the load situation to the instance *Channel Management* (see Figure 3). It manages the physical channels available and decides, whether new PDCHs to be allocated or de-allocated. If the number of PDCHs for GPRS changes, this is indicated to the MAC layer. Details can be found in [5].

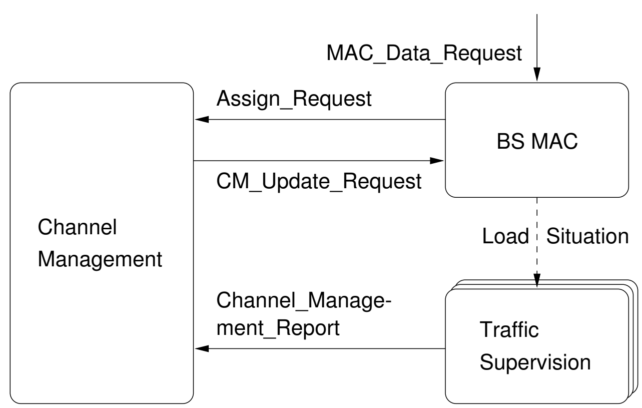

Fig. 3: The Modules Traffic Supervision and Channel Management at the Base Station

IV. SIMULATION RESULTS

A. Simulation Scenarios

During the initialization phase of a simulation the input variables are read from a configuration file. These parameters characterize the simulation scenario.

The cell configuration is given by the number of PDCHs available for GPRS, whether allocated permanently or on demand. Preferably, the simulations are executed with 0 fixed and 1, 4, and 8 on-demand PDCH.

In order to perform network capacity planning the system behaviour during the busy hour has to be regarded. The traffic load generated is characterized by the number of Internet sessions running, and being used as input variable for the GPRSim. Several load generators are defined by additional parameters to model the according Internet sessions for various applications, in this case 70 percent WWW and 30 percent e-mail. The traffic models used have been described in [8].

Throughout all simulations the MAC protocol instances utilize one *Master Packet Data Channel* (MPDCH) with three *Packet Random Access Channels* (PRACH) per 52-multiframe. Logical signalling channels are mapped fix onto the downlink master channel. MAC blocks that are not required for the according signalling channels may be used to transmit data blocks. The first MAC block on the master channel is a broadcast block. *Coding Scheme 2* (CS-2) has been chosen with a *MAC Service Data Unit* (SDU) length of 294 bit. All conventional MAC requests use priority 1 and are served following the FIFO principle. The current MAC implementation establishes one *Temporary Block Flow* (TBF) for each LLC frame. The LLC window size is 16, with an MTU of 1520 byte. No IP header compression is used within the SNDCP. There is no segmentation of LLC frames within SNDCP since TCP uses the usual maximum segment size of 536 byte.

All simulations use a discrete random process with a *Packet Error Ratio* that has previously been determined by measurements of the real channel in an urban environment. Thus, C/I values can be mapped on PER by means of reference functions. A C/I of 12 dB, respective an ideal channel, are regarded.

B. Simulation Results

Starting point is the quality of service from the user's point of view, the mean user data throughput for 1, 2 and 4 fixed PDCHs shown in Figure 4 used by one-slot mobiles. Here, the throughput decreases from about 800 byte/s for one sole mobile station in the cell to between 700 and 100 byte/s for ten stations performing Internet applications.

The effects of on-demand channel allocation with no fixed PDCH on the crucial QoS parameter IP data throughput is shown in Figure 5.

Exceptionally remarkable is the incursion of both values in case of a sole mobile station. This is apparently an outcome of the, in this case, inappropriate algorithm used by

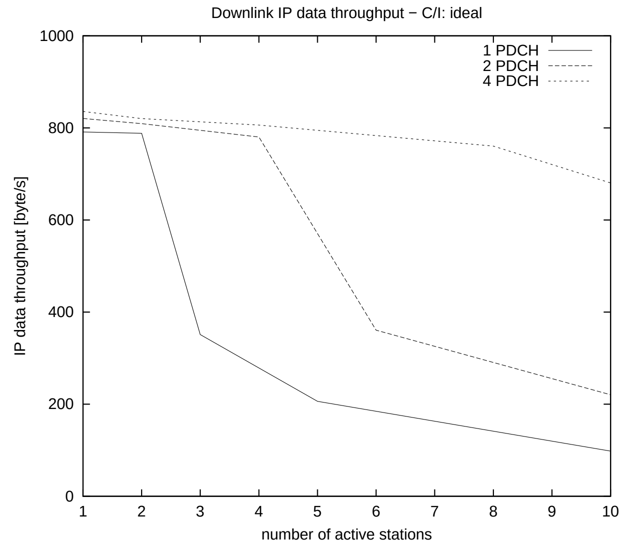

Fig. 4: Downlink IP data throughput for 1, 2 und 4 PDCH (C/I ideal)

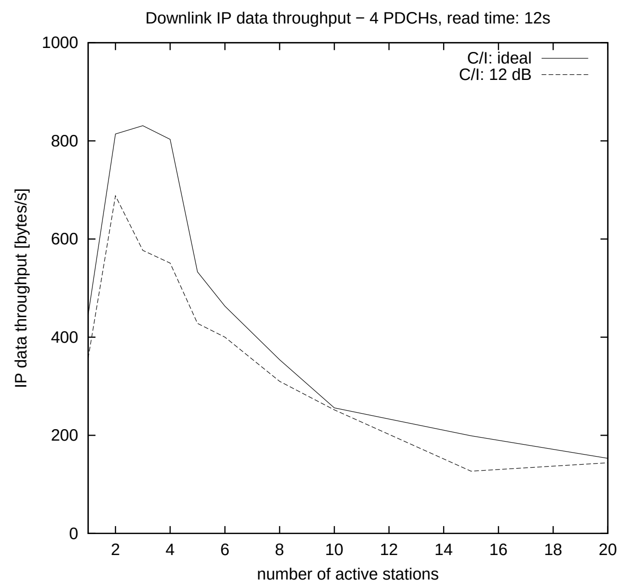

Fig. 5: Downlink IP data throughput for four on-demand PDCH for different C/I conditions

the instance Channel Management to release PDCHs. An adaptation of the respective threshold values should result in a significant improvement. Release of the last PDCH should be delayed until there is definitely no more traffic expected for a reasonably long period, i.e., until the forthcoming traffic amount is estimated zero several times.

If these on-demand channels are also used by CS services, it is important to know how the channels are utilised and allocated by GPRS and to determine the duration of the periods when the channels are not allocated for GPRS. Figure 6 shows the overall channel utilisation subject to the

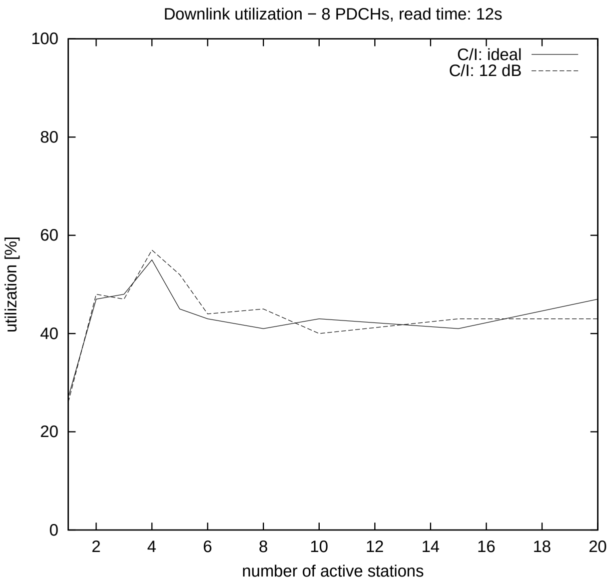

Fig. 6: Overall Downlink channel utilization for eight on-demand PDCHs

number of active stations. Only those channels currently allocated for GPRS are regarded in order to determine the respective utilization.

Figure 7 displays the allocation time of exemplarily selected channels, in dependence of the number of mobile stations and HTTP read times, i.e., the mean time a user spends for reading through a web page before doing the next request.

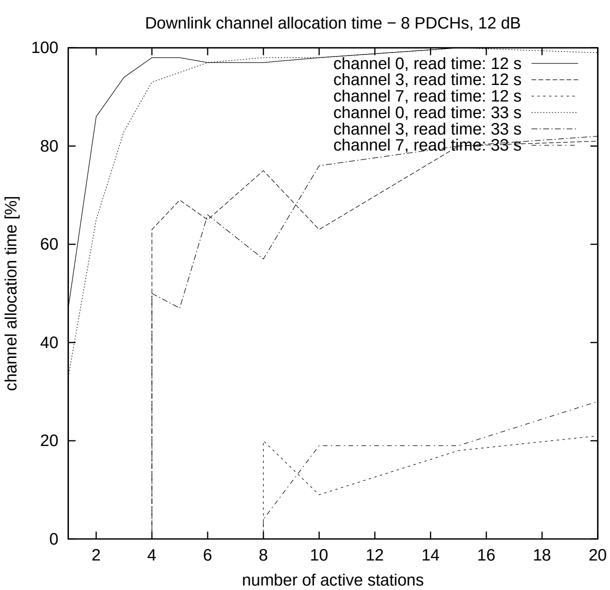

Fig. 7: Allocation times of selected channels (in % of overall simulation duration) for eight on-demand PDCHs subject to HTTP read times, C/I: 12 dB

The term "channel allocation time" shall be defined as the percentage of the overall simulation time that a specific channel is assigned for GPRS and therefore not available for use by circuit-switched services.

Number and length of the periods a channel is not needed by GPRS (i.e. released) can be gathered from Figure 8 and 9.

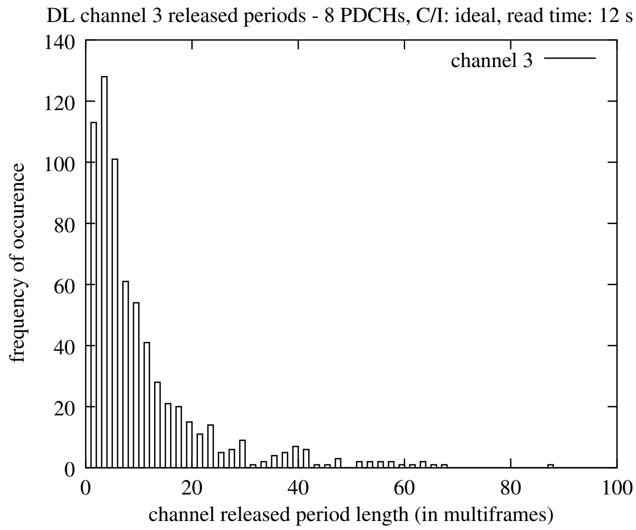

Fig. 8: Distribution of released-period lengths of downlink PDCH 3 (in multiframes)

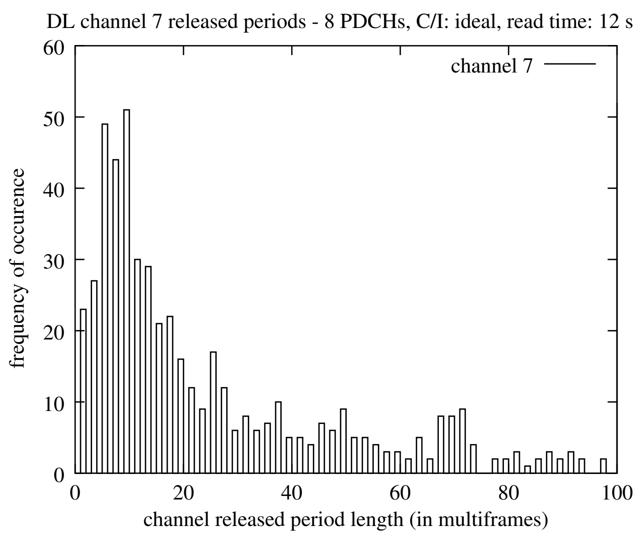

Fig. 9: Distribution of released-period lengths of downlink PDCH 7 (in multiframes)

Within the multi-PDCH configurations the channel with the topmost channel number (here 7) has to be paid attention to in particular. Compared to others, this channel shows more frequent and longer periods where it is not assigned for use by GPRS.

The allocation times for channels not displayed can be linearily interpolated inbetween the graphs shown in good approximation.

It has become evident that in a single-PDCH configuration the first channel (the MPDCH) is utilised to an amount of 80 percent yet with only two mobile stations being active. In conjunction with the QoS problems for few traffic pointed out above in Figure 5 it seems not recommendable to provide this configuration with on-demand channel allocation techniques. Rather, a fixed allocation of this sole channel should be considered.

V. CONCLUSIONS

This paper comprises examinations of the radio capacity needed for GPRS in coexistence with CS services in GSM. Additionally, the quality of service, which can be offered with these resources is shown. The services that are the object of these examinations are Internet applications comprising WWW surfing and electronic mail. These results are suitable for radio network dimensioning to integrate GPRS into the GSM.

Future work should first of all concentrate on implementing and integrating load generators for circuit switched services into the GPRSim. With this being accomplished it will be possible to examine the co-existence of packet data and priorized circuit-switched services vital for further network capacity planning. The third step would then be the implementation of further on-demand channel allocation methods and their parameterization according to optimal radio resource utilization and QoS.

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