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GPRS Radio Network Capacity Considering Coexisting Circuit Switched Traffic Sources

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ABSTRACT

In this paper the radio network capacity needed for the General Packet Radio Service (GPRS) in coexistence with conventional circuit-switched voice 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 have to be made available to GPRS used as fixed and on-demand Packet Data Channels (PDCHs). A simulation environment for a GPRS network and its traffic sources based on Internet traffic models and on a Poisson process for the coexisting circuit-switched applications are introduced. Simulation results comprise performance measures for the quality of service from the user's point of view, the system throughput per cell and the channel utilization for a range of load situations in order to fix the needed radio capacity regarding cell configurations with 1 to 5 transceivers (TRX) and up to 8 on-demand PDCHs.

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 on the connection duration.

A service optimized with respect to 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 in 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 [7, 5]. 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 in coexistence with conventional circuit-switched applications is examined. While simulation results for Internet applications using dedicated PDCHs for GPRS are available in recent publications [4, 3], GPRS performance of Internet over GPRS in coexistence with circuit-switched applications is novel.

Following this introduction, Section II gives a summarized 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 special focus on the resource management entities and the load generators 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 GSM 03.64 [6], 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 radio 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

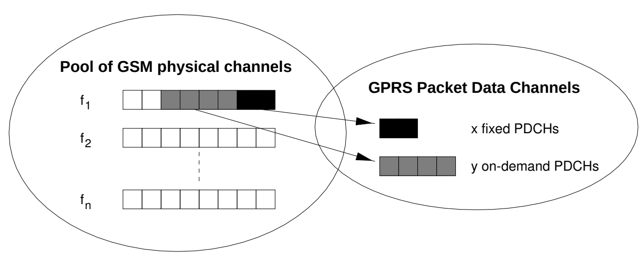

Fig. 1: Allocation of GSM physical channels for GPRS

GPRS in the initial phase of the packet transfer is conveyed on PCCCH, 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. At least one PDCH, acting as a master, accomodates *Packet Common Control Channels* (PCCCH) that carry the necessary control and signalling information to initiate a packet transfer whenever that signalling is not carried by the existing CCCH, as well as user data and dedicated signalling (i.e. PDTCH and PACCH). Other PDCHs, acting as slaves, are used for user data transfer and for dedicated signalling. The GPRS does not require permanently allocated PDCHs. The allocation of capacity for GPRS can be based on the needs for actual packet transfers, which is here referred to as the capacity on demand principle. The operator can, as well, decide to dedicate permanently or temporarily physical channels for the GPRS traffic (see Figure 1). In this context GSM physical channels that are allocated permanently for GPRS are called *fixed PDCHs*, channels that are allocated temporarily for GPRS are called *on-demand PDCHs*. When the PDCHs are congested due to the GPRS traffic load and more resources are available in the cell, the Network can allocate more physical channels as PDCHs. However, the existence of PDCH(s) does not imply the existence of PCCCH. When no PCCCH is allocated in a cell, all GPRS attached MSs camp on the CCCH. In response to a Packet Channel Request sent on CCCH from the MS that wants to transmit GPRS packets, the network can assign resources on PDCHs for the uplink transfer. After the transfer, the MS returns to CCCH. When PCCCH is allocated in a cell, all GPRS attached MSs camp on it. PCCCH can be allocated either as the result of the increased demand for packet data transfers or whenever there is enough available physical channels in a cell (to increase the quality of service). The information about PCCCH is broadcast on BCCH. When the PCCCH capacity is inadequate, it is possible to allocate additional PCCCH resources on one or several PDCHs.

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 *Communication Networks Class Library* (CNCL) [1], 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 [2].

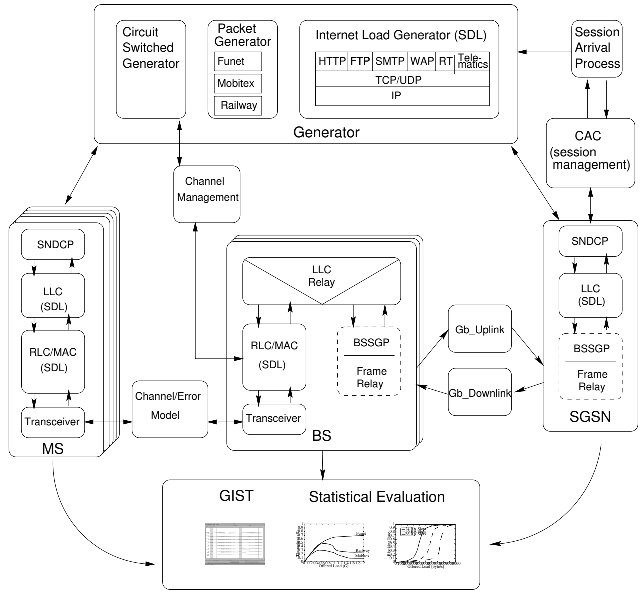

Fig. 2: The structure of the GPRS Simulator

The software architecture of the GPRS Simulator 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 recreated by simple error models. While the G_b Interface is regarded as ideal, block errors on the radio interface U_m can be simulated with look-up-tables, which map the carrier-to-interference ratio on block error probabilities. The generator comprises Internet applications (WWW, E-Mail, FTP, WAP, Telematics, Real-Time and Streaming applications), the packet traffic models FUNET, Mobitex and Railway proposed by ETSI for performance analysis and a circuit switched generator to model coexisting speech traffic. The module *Channel Management* supervises the physical GSM channels available in the cell and allocates channels for the GPRS resource management entity, if they are not used by circuit switched services or if they are allocated as dedicated PDCHs for GPRS. The layers BSSGP and Frame Relay are not modelled in the GPRSim because the focus was set on the radio interface. These classes do not provide any functionality and simply forward the service data units to the peer entity. The output of the simulator comprises a graphical presentation of the protocol cycle and the statistical evaluations of the performance measures.

IV. SIMULATION RESULTS

To obtain predictions about system capacity and quality of service of the GPRS in coexistence with circuit-switched traffic load, there are scenarios examined characterized by the number of transceiver (TRX) units in a cell. One transceiver unit corresponds, depending on the scenario, to 6–8 physical GSM channels that have to be shared by packet- and circuit-switched traffic. There is a maximum of eight PDCHs available for packet-switched traffic within each scenario. Thus, the number of on-demand PDCHs calculates to: $8 -$ number of fixed PDCHs. Here a cell configuration with 2 transceiver units is regarded. The Carrier-to-Interference Ratio is set to 12 dB, which is mapped to a RLC/MAC block error probability of 13.5 %.

For GPRS the maximum possible number of on-demand PDCHs is made available as long as they are not required for the transmission of CS traffic. When a request for a CS transmission resource can not be served by a free TCH, there is instantly a channel detracted from the pool of on-demand PDCHs and utilized as TCH.

The packet-switched traffic to be generated for GPRS is composed of one third WWW and two-thirds e-mail sessions. For the creation of coexisting circuit-switched traffic load the CS generator is used that models a Poisson process for arriving calls. The relative quantity of CS traffic is the same throughout all simulations. It is set in such a way as, dependent on the number of TCHs available, a Grade of Service of 1 % can be guaranteed.

While the performance measures downlink IP throughput during data transmission and IP packet delay are shown in the Figures 3 and 4, the system measures namely the average number of PDCHs that are assigned for GPRS and the mean DL PDCH utilization is shown in the Figures 5 and 6.

The mean number of PDCHs allocated for GPRS that is theoretically available after the Erlang Formula is 6.61 channels. This value is conform with the simulative value in Figure 5. The gain of throughput per user between 1 fixed PDCHs and 0 fixed PDCHs is between 10 % and 28 % and between 2 fixed PDCHs and 0 fixed PDCHs is between 15 % and 33 %. This can be seen in Figure 3. The throughput per user in this cell configuration with 0 fixed PDCHs ranges from ca. 23 kbit/s with an offer of 1 kbits/s and ca. 15 kbit/s with an offer of 10 kbit/s.

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 object of these examinations are Internet applications comprising WWW surfing and electronic mail. With these results GPRS radio network dimensioning regarding conventional circuit-switched voice services and new GPRS-based data services can be performed.

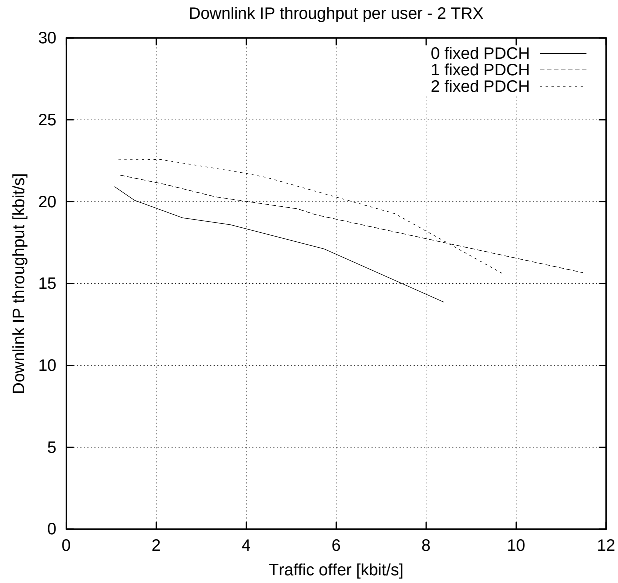

Fig. 3: Downlink IP throughput per user

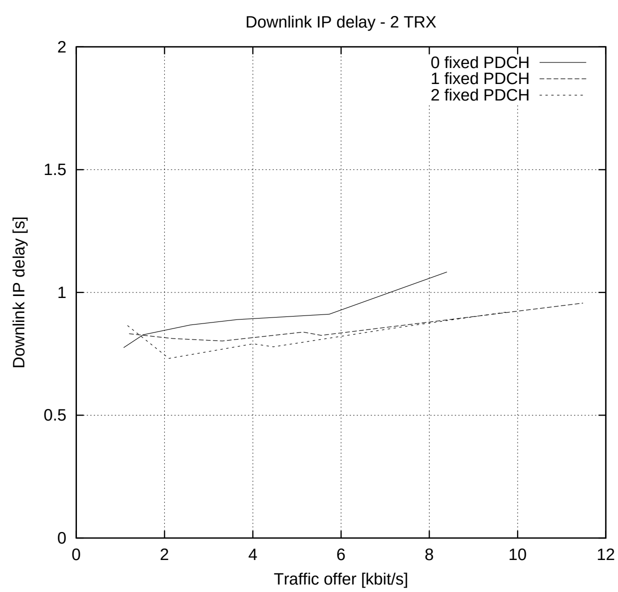

Fig. 4: Downlink IP packet delay

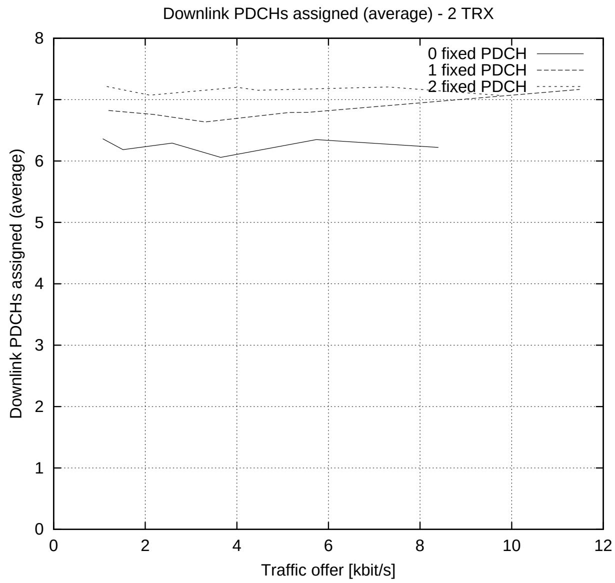

Fig. 5: Average Number of PDCHs assigned for GPRS

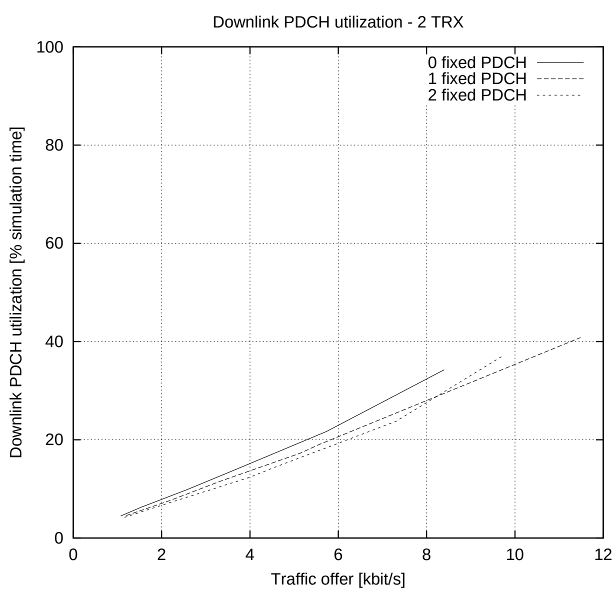

Fig. 6: Downlink PDCH utilization

The results comprise two main cognitions. Since the lower TCH range stays mostly available for GPRS, if the radio network is dimensioned for GoS of 1 %, the performance gain for GPRS achieved by the allocation of fixed PDCHs is only small. While for 1 TRX cells no improvement is measured, the improvement for cells with more than 1 TRX from 10 % up to 30 % is measured. The main cognition is that GPRS remains available with small QoS losses even if there are interceptions enforced by CS connections and the PDCHs are only available on demand. Besides the reason that there is a high probability that a number of channels remains available for GPRS, the flexibility of GPRS has to be mentioned. TBFs can be redistributed on other PDCHs still available. PDCHs can be used, if they are available. If PDCHs are detracted for a certain period, TBFs can share the resources that are still available and can utilize the resources again after they are reallocated after the CS connection release. With a higher traffic offer for GPRS, however, more collicions with CS connections are expected. It has to be examined, if the QoS for throughput- and delay-sensitive applications can be ensured and guaranteed for higher load situations by QoS management mechanisms with the distinction of application types and which capacity gain can be achieved by QoS management.

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