# Dimensioning issue in GPRS (EGPRS) and its concepts

*Amir Abdollahi, Mahdi Khabziyon*
*ITRC*
*( Iranian Telecommunication Research Center)*
Amir@itrc.ac.ir, mkh@itrc.ac.ir

In this paper radio network dimensioning rules for GSM/GPRS networks focussing on Internet applications are presented. Taking simulation results for GPRS introduction and evolution scenarios as the basis, the radio resources needed for a given offered traffic and for given quality of service requirements can be estimated. Both circuit-switched voice traffic and packet switched Internet traffic sources are considered that is sharing the radio resources available in a GSM radio cell. To achieve this, a simulation area has been written under Matlab software for estimating dimensioning criteria, which has been offered in this paper.

## 1. Introduction

In the context of the evolution towards 3rd Generation (3G) mobile radio networks, packet-switched data services like the General Packet Radio Service (GPRS) and the Enhanced GPRS (EGPRS) are presently introduced into GSM system worldwide. For network operators, equipment vendors, and system integrators dimensioning rules have to be developed to plan and estimate the radio capacity that is needed for the predicted amount of user data, when the radio resources are shared between circuit- and packet-switched services. For circuit-switched networks the Erlang-B-Formula has been successfully applied over decades, while for packet switched networks such an applicable capacity model is still missing. The analytical description of statistical multiplexing and Internet and Multimedia traffic modeling are more complex than for circuit-switched networks and have risen to a great challenge in traffic engineering.
Several papers concerning GPRS performance analysis were published in the last years [1, 2, 3]. They do not contain results for on-demand channel configurations with co-existing circuit-switched traffic sources, which are the typical configurations in GPRS introduction and evolution scenarios.
In Section 2 after this introduction the problem of GPRS radio network dimensioning is introduced. After the description of the simulation environment in Section 3, GPRS dimensioning rules are presented on-demand channel configurations in Section 4.

## 2. Radio Network Dimensioning

A suitable dimensioning approach for the busy hour is based on the number of active users and the corresponding applications and user behavior. These parameters characterize the offered traffic that has to be served by the network. Second the quality of service, which the operator wants to offer his customers has to be defined. Giving these two dimensioning criteria as the input parameters to an adequate capacity model the needed radio capacity can be determined.

### 2.1. Methodology

Since GPRS networks are presently introduced, performance results are needed very fast, so that capacity and performance estimations can be done for GPRS introduction and evolution scenarios.
Producing performance results by measurements in the existing GPRS networks is not easily possible, since scenarios with well-defined traffic load are hard to set-up, the calculation of performance and system measures are very limited, and the analysis of different alternative protocol implementations is not possible with the existing network equipment.
Therefore computer simulation with prototypical implementation of the standardized GPRS protocols and the Internet protocols, traffic generators for the regarded applications and a

simple model for the radio channel is chosen as the methodology to get the needed results rapidly.

### 2.2. GPRS Radio Resources

In GPRS networks a radio cell 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 GSM physical channels available in the radio cell. The allocation of physical channels to circuit-switched services and GPRS is done dynamically according to the ”capacity on demand” principle [6]. The operator can decide to dedicate permanently or temporarily physical channels for the GPRS traffic. In this context GSM physical channels allocated permanently for GPRS are called *fixed Packet Data Channels (PDCHs)*, channels allocated temporarily for GPRS are called *on-demand PDCHs*.
Simulation results [7] have shown that the performance for GPRS-based services does not increase dramatically, when few fixed instead of on-demand PDCHs are used. If the cell capacity is dimensioned with a low blocking probability, e.g., 1 %, for voice services, the use of on-demand PDCHs makes sense. This is plausible, since the probability that more than 2 channels are unused by voice services is around 90 %. On the other hand operators might allocate fixed PDCHs to be able to guarantee the availablity of GPRS. So dimensioning rules for both fixed and on-demand configurations as well as for mixed configurations with a combination of fixed and on-demand PDCHs have to be developed. In this paper dynamic allocation has been considered, since full description of fixed PDCH had been developed in their related references.

## 3. Simulation Environment

The capacity model for this examination is represented by the Matlab software which was developed with its protocol architecture, the radio channel attributes and protocol specific traffic sources. Based on this model it is possible to create dimensioning graphs with the paradigm of Erlang_B Tables and the Erlang-Formula, so that network dimensioning can be performed.
Up to now models of Mobile Station (MS), Base Station (BS), their traffic generator nodes, channel characteristics model and measurement tools are implemented. The simulator offers interfaces to be upgraded by additional modules. The real protocol stacks of (E)GPRS are used during system simulation and statistically analyzed under a well-defined traffic load.

### 3.1. Packet Traffic Generators

Internet sessions consist of the applications World Wide Web (WWW) and electronic mail (e-mail). Therefore Internet traffic models are necessary for simulative examinations of the performance of data services of mobile radio networks.
In the following, model parameters of these two applications and their distributions for generating protocol specific traffic are presented.

#### *3.1.1. WWW Model*

WWW sessions consist of requests for a number of *pages*. These pages consist of a number of *objects* with a dedicated *object size*. Another characteristic parameter is the delay between two pages depending on the user’s behavior to surf around the Web [12, 14]. Table 1 gives an overview of the WWW parameters.
The small number of objects per page (2.5 objects), and the small object size (3700 byte) were chosen, since Web pages with a large number of objects or large objects are not suitable for wireless clients.

#### *3.1.2. E-mail Model*

The e-mail model describes the traffic arising with the transfer of a message downloaded from a mail server by an electronic mail user. The only parameter is the amount of data per e-mail.
A constant base quota of 300 byte is added to this size [13]. The parameters of this distribution are shown in Table 1. The value of 10000 byte as the e-mail size is chosen, since it is assumed that no e-mails with large attachments will be downloaded on mobile devices.

Top

### *3.1.3. Wireless Application Protocol (WAP) Model*

A WAP traffic model was developed and applied in [15]. The main characteristics of the model are very small packet sizes (511 byte) approximately following a log2-normal distribution and a limited value of the packet size (1400 byte).

Table 1: Model parameters of Internet applications

| **WWW Parameter** | **Distribution** | **Mean** |
|---|---|---|
| Pages per session | geometric | 5.0 |
| Intervals between pages | Negative exponential | 12.0 |
| Objects per page | Geometric | 2.5 |
| Object size [byte] | log -Erlang-k | 3700 |
| **e-mail Parameter** | **Distribution** | **Mean** |
| e-mail size [byte] | log –normal | 10000 |
| Base quota [byte] | Base quota [byte] const. | 300 |

### 3.2. Circuit-switched Traffic Generator

The circuit-switched traffic generator generates events with an inter-arrival time determined by a exponential distribution.
These events correspond to calls initiated in a cell. The traffic value in Erlang is given by the two configurable mean values of the call inter-arrival and the call duration times.

### 3.3. Air Interface Error Model

Within the air interface error model the decision is made if a received data or control block is either error free or defective.
To decide this a set of mapping curves is used. These curves are gained from link level simulations and allow the mapping of C/I values onto the corresponding block error probabilities (BLEPs) for every radio block [17, 18, 19]. In Figure 1 the BLEP versus C/I reference function, which is taken from link level simulations, is shown.

## 4. Dimensioning Rules

### 4.1. Simulation Scenarios

The cell configuration is defined by the number of GSM singlecarrier transmitter-receiver units (TRXs) and the number of PDCHs allocated fixed or on-demand for GPRS.
The air interface error model is characterized by a constant RLC/MAC block error probability of 13.5 % corresponding to a C/I of 12 dB. This parameter corresponds to a typical coverage planning value widely used by operators for GSM networks. As the coding scheme for user data CS-2 is used. Since CS-2 is a relatively robust Coding Scheme and the average C/I of 12 dB is a worst case estimation, capacity limitations caused by co-channel interference in high load conditions can be neglected.

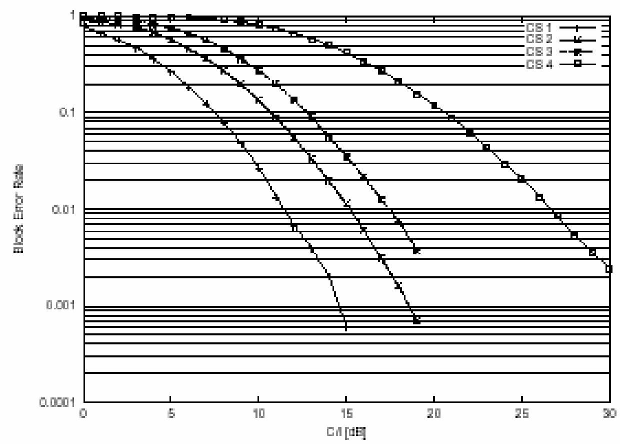


Figure 1: BLEP over C/I reference function used for the air interface error model

LLC and RLC/MAC are operating in acknowledged mode. The MAC protocol instances are operating with 3 random access subchannels per 52-frame. All conventional MAC requests have the radio priority level 1 and are scheduled with a FIFO strategy.
Ongoing Temporary Block Flows (TBFs) in uplink and downlink are served with a Round Robin strategy.
The transmission delay in the core network and externel networks, i.e. the public Internet is neglected. The focus lies on the radio network and not on the core network, since radio resources are scarce and representing the system bottleneck assuming that the core network is well dimensioned.
The Internet traffic is composed of mail sessions and WWW sessions with random distribution.(see

Table 1). For simulations with coexisting circuit-switched (CS) traffic, the maximum number of on-demand PDCHs is 8. On demand PDCHs are used for both GPRS and CS services, with the restriction that CS has a higher priority and can pre-empt the on-demand PDCHs. The parameters for the CS traffic sources that are used for different blocking probability values have been calculated based on the Erlang-B-Formula. For the call blocking probability the term Grade of Service (GoS) will be used in the following [8].

### 4.2. Performance and System Measures

As the performance measure the average downlink IP throughput per user during transmission periods is regarded, During an ongoing download of a Web page or e-mail the downlink IP throughput for each user for each TDMA frame is evaluated.
This QoS measure is the most important measure for WWW and e-mail applications and is chosen here as the dimensioning criterion.

### 4.3. On-demand PDCH Configurations

Since GSM networks are dimensioned for a low blocking probability for voice calls, the probability that a few channels are unused by voice services is high. On the other hand in GPRS introduction scenarios the offered data traffic will be comparatively low. As a result the use of on-demand PDCHs that are shared between voice and data services lead to an efficient radio resource utilization [7].
A good capacity planning for on-demand configurations can be done by taking a dimensioning graph for an existing TRX scenario as the basis and finding the acceptable coexisting CS traffic (corresponding to a GoS value) so that the GPRS performance for a given offered IP traffic can be guaranteed. As an example based on the 3 TRX scenario (see Figure 2,3) this can be performed after the following steps:

- estimate the GoS for the related TRX scenario for CS traffic, which is expected for the planning scenario. Here 1.5 % GoS is assumed as an example value.
- estimate the number of GPRS users per cell: user = 10.
- calculate the total offered traffic per cell: offered traffic/user = 540 Kbyte/h = 1.2 Kbit/S total offered traffic =10*1.2 Kbit/S = 12 Kbit/S
- define the desired average user performance the operator wants to guarantee (here 12.5 kbit/s).
- regard the operating point p defined by the desired user performance on the y-axis and the total offered traffic on the x-axis and choose the adequate GoS curve as the next that lies above this operating point p. Here p equals (x = 12 kbit/s, y = 12.5 kbit/s).

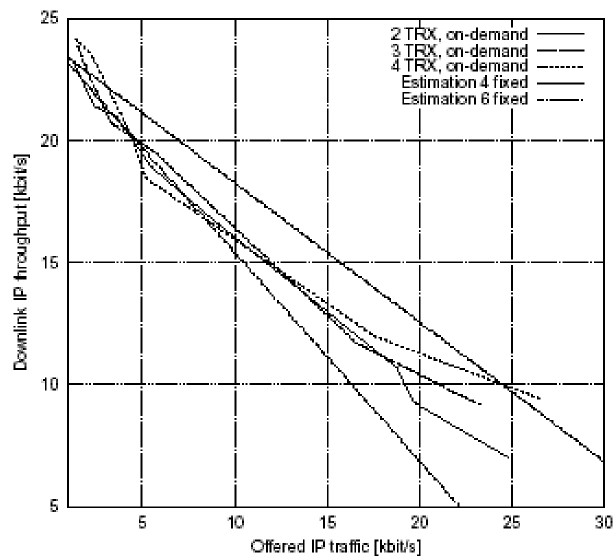


Figure 2: Estimation with an equivalent fixed and on_demand PDCH configuration.

If the offered CS traffic corresponding to this GoS is predicted to be exceeded a new TRX should be added. Here p is just below the 2 % GoS curve that means that coexisting CS traffic corresponding up to 2 % GoS for this scenario is acceptable. Since a GoS of 1.5 % is assumed an additional TRX is not necessary in this example.
To be able to guarantee the availability of GPRS-based services an operator might provide 1, 2 or more fixed PDCHs and the rest up to 8 as on-demand PDCHs. In these cases the pure ondemand configurations can be taken as a worst case estimation. Figure (2) shows this scenario for 4 and

Top

6 fixed PDCH assignment. In this case the capacity can be also estimated by a configuration with the allocated number of fixed and on-demand PDCHs.

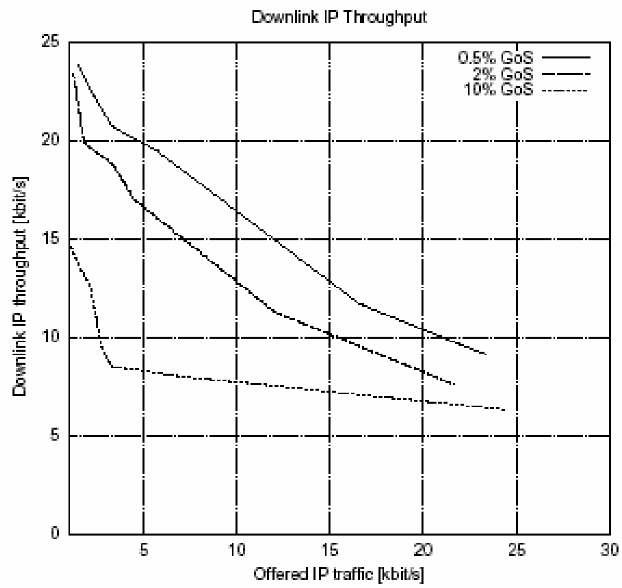


Figure 3: Dimensioning graph for on-demand PDCH configurations

## 5. CONCLUSIONS

In this paper dimensioning rules for GPRS networks for on-demand PDCH configurations were presented.

The dimensioning graph is based on simulation results for different load scenarios and profits by nearly linear correlation between downlink IP throughput and the offered IP traffic in the radio cell. For on-demand configurations dimensioning graphs based on the simulation results for different CS load scenarios can be used to determine, if a new TRX has to be installed to serve the GPRS traffic with a desired QoS.

## 6. References


[1] G. Brasche and B. Walke, "Concepts, Services and Protocols of the New GSM Phase 2+ General Packet Radio Service," *IEEE Communications Magazine*, vol. 35, 1997.

[2] J. Cai and D. Goodman, "General Packet Radio Service in GSM," *IEEE Communications Magazine*, vol. 10, 1997.

[3] R. Kalden, I. Meireck, and M. Meyer, "Wireless Internet Access Based on GPRS," *IEEE Personal Communications*, vol. 4, 2000.

[4] S. Ni and S. H¨aggmann, "GPRS Performance Estimation in a GSM Voice and GPRS Shared Resource System," in *Proc. of IEEE WCNC '99*, pp. 1417–1421, 1999.

[5] K. C. Budka, "Cellular Digital Packet Data: Channel Availability," *IEEE Transactions on Vehicular Technology*, vol. 46, Feb. 1997.

[6] ETSI TC-SMG, "Digital Cellular Telecommunications System (Phase 2+); GPRS Overall Description of the GPRS Radio Interface; Stage 2 (GSM 03.64 Ver.8.3.0 Rel. 1999),"

[7] P. Stuckmann and F. M¨uller, "GPRS Radio Network Capacity Considering Coexisting Circuit-Switched Traffic Sources," in *Proc. of European Conference on Wireless Technology (ECWT 2000)*, 2000.

[8] P. Stuckmann, "Simulation Environment GPRSim: Tool for Performance Analysis, Capacity Planning and QoS Enhancement in GPRS/EDGE Networks," Technical Report, http://www.comnets.rwth-aachen.de/pst.

[9] J. Wigard, T. T. Nielesen, P. H. Michaelsen, and P. Mogensen, "BER and FER of Control and Traffic Channels for a GSM Type of Air-Interface," in *Vehicular Technology Conference (VTC)*, 1998.

[10] M. Steppler, "Performance Analysis of Communication Systems Formally Specified in SDL," in *Proc. of The First International Workshop on Simulation and Performance '98 (WOSP '98)*, pp. 49–62, 1998.

[11] Aixcom GmbH. http://www.aixcom.com/Produkte_e.php.

[12] M. F. Arlitt and C. L. Williamson, "A Synthetic Workload Model for Internet Mosaic Traffic." Department of Computer Science, University of Saskatchewan, Saskatoon, SK, Canada S7N 5A9, 1995. Proceedings of the 1995 Summer Computer Simulation Conference, Ottawa, Canada, July, pp. 24–26.

[13] V. Paxson, "Empirically-Derived Analytic Models of Wide-Area TCP Connections." Lawrence Berkeley Laboratory and EECS Division, University of California, Berkeley, March 1994. IEEE/ACM Transactions on Networking, 2 (4), pp. 316–336, August 1994; ftp://ftp.ee.lbl.gov/papers/WAN-TCP-models.ps.Z.

[14] ETSI 3GPP, "Selection Procedures for the Choice of Radio Transmission Technologies of the Universal Mobile Telecommunication System UMTS (UMTS 30.03, 3G TR 101 112)," technical report, European Telecommunications Standards Institute, Sophia Antipolis, France, April 1998.

[15] P. Stuckmann, H. Finck, and T. Bahls, "A WAP Traffic Model and its Appliance for the Performance Analysis of WAP over GPRS," in *Proc. of the IEEE International Conference on Third Generation Wireless and Beyond (3Gwireless '01)*, (San Francisco, USA), June 2001.

[16] R. Stevens, *TCP/IP Illustrated*, vol. 1. Massachusetts: Addison-Wesley, October 1996.

[17] A. Furusk¨ar, S. Mazur, F. M¨uller, and H. Olofsson, "EDGE: Enhanced Data Rates for GSM and TDMA/136 Evolution," *IEEE Personal Communications*, pp. 56–65, June 1999.

[18] J.Wigard and P. Mogensen, "A Simple Mapping from C/I to FER and BER for a GSM Type of Air-Interface," in *Vehicular Technology Conference (VTC)*, 1996.