GPRS Traffic Performance Measurements

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ABSTRACT

With the commercial deployment of the General Packet Radio Service (GPRS) in Europe in 2001, traffic performance measurements in the field have become possible. In this paper selected traffic performance measurement results are presented and compared to the traffic performance of fixed narrowband access technologies like ISDN and analog modem. They are based on a setup measuring the quality of service perceived by one and several mobile GPRS users running WWW and e-mail applications on laptops connected to GPRS terminals in one radio cell of the Vodafone NL GSM/GPRS network in Maastricht. They give an indication of the capabilities of the packet data service and can help to identify the system bottlenecks regarding end-to-end performance. The measurements were executed in the GPRS network and with GPRS-terminals, which were operational at that time but still in stages of improvement.

With these cognitions protocol optimizations can be performed and software problems like unnecessary delays and instabilities can be localized and eliminated. Additionally the results can support the planning of networks and applications comparing the measured performance characteristics to the requirements of customers and applications performed. These results are compared to simulation results produced by a simulation/emulation tool that comprises load generators representing typical GPRS usage and a prototypical implementation of the GPRS protocols.

I. INTRODUCTION

The driving force for the evolution of second generation mobile communication systems such as the Global System for Mobile Communication (GSM) is the predicted user demand for mobile data services that will offer mobile Multimedia applications and mobile Internet access.

For the introduction and the evolution of GSM/GPRS networks traffic models and dimensioning guidelines are needed to describe the relationship between the offered traffic and the radio resources to be allocated to reach a desired quality of service for the different applications.

To get traffic engineering results rapidly, computer simulation based on the prototypical implementation (called emulation) of the GPRS protocols and the Internet protocols in combination with stochastical traffic generators for the regarded applications and models for the radio channel was chosen as the methodology in [9, 6, 8].

Evaluating the traffic performance accurately by measurement in the existing GPRS network is not possible, since a scenario with a well-defined traffic load is hard to set-up, the evaluation of the performance based on measurements is very difficult, and the analysis of the behavior of different protocol options is not possible in an existing radio network. Therefore, the measurement results in this paper are not suitable for accurate GPRS dimensioning and can only serve as an overview of the GPRS deployment status. Additionally the results are used to validate the simulation/emulation tool GPRSIM [6] that was the basis for the dimensioning rules presented in [9, 8].

After the introduction of the measurement setup in Section II several measurement series are presented. In Section III measurement results for the round-trip time that is one limiting factor for both transaction oriented and TCP-based applications are presented. After a measurement series for FTP applications in Section IV, Section V and Section VI comprise measurement results for WWW applications typical for laptop users and WWW and e-mail applications with small files typical for PDA users, respectively.

II. MEASUREMENT SETUP

The measurements were performed in December 2001 in the Vodafone NL building in Maastricht.

The GPRS terminals were connected to laptops. For each measurement series a unique load generator was used represented by files located on a high-speed Web server in the Internet (Ping via Local Area Network was < 40ms). For statistical evaluation WinPCap [4] was installed on each laptop, which is a freeware packet capture driver for Windows environments (see Figure 1). Capturing software enables the user to capture every packet that passes the network interface to a file. With a Perl script, performance measures could be calculated from these files generating result files that were suitable for graphical or tabular presentation.

The network configuration is shown in Table 1. The reception quality was high, the average receiving level was -55 dBm.

The main focus was set on the downlink IP throughput, therefore only incoming TCP packets were regarded. The

Table 1: Vodafone NL GPRS settings

Parameter	Value
Multislot capability (downlink)	3
Multislot capability (uplink)	1
Coding scheme	CS-2
Number of fi xed PDCHs	4
Number of on-demand PDCHs	0
RLC/MAC acknowledged	true
LLC acknowledged	false
TCP/IP header compression	off

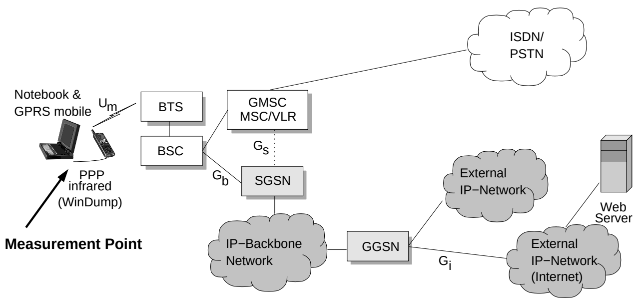

Fig. 1: GPRS traffic measurement setup

average throughput was measured in intervals of five seconds so that a time-weighted mean value could be calculated out of these samples. Since the retransmission rate for TCP packets was very low, the effective throughput on application level can easily be derived from the downlink IP throughput.

III. Round-Trip Times

The first measurement series is focussed on one of the crucial parameters for most Internet applications, the round-trip time. In these measurements, Internet Control Message Protocol (ICMP) packets were sent using the *Ping* command to the Gateway GPRS Support Node (GGSN), which is the gateway to the Internet. Once the target server receives an ICMP packet, it sends it back to the sender immediately followed by the next Ping command. From the time between sending and retrieval, the average round-trip time can be measured. Three different GPRS terminals from two different manufacturers (*MS1*, *MS2a* and *MS2b*) performed differently. While the measurements using MS2 showed a linear relationship between the packet size and the round-trip time over the whole range, MS1 behaved different with packets smaller than 300 byte (see Figure 3). Here, the initial round-trip time is very high but decreases to a lower value when reaching a certain packet size. This behavior did not occur when setting the delay time between two Pings from zero to a value greater than one second. Since TCP control segments are about 40 bytes long, this phenomenon has a significant effect on the TCP connection setup time, which is a crucial parameter in Web sessions. A reason for this effect is that an ongoing Temporary Block Flow (TBF)

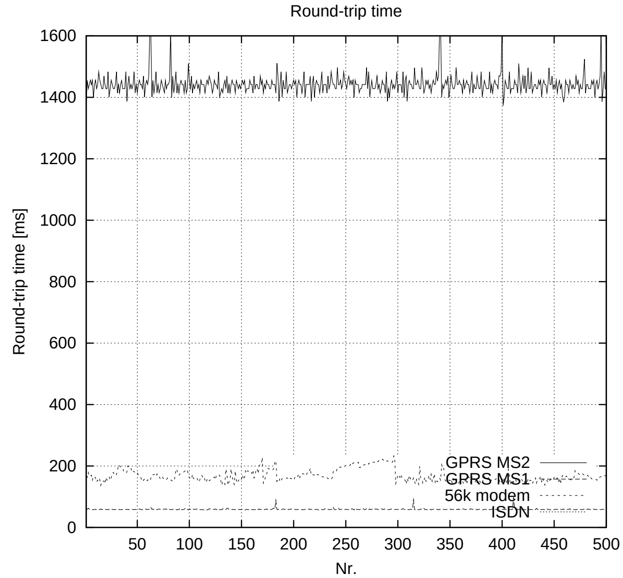

Fig. 2: Round-trip time with 32 byte packets (includes Internet delay)

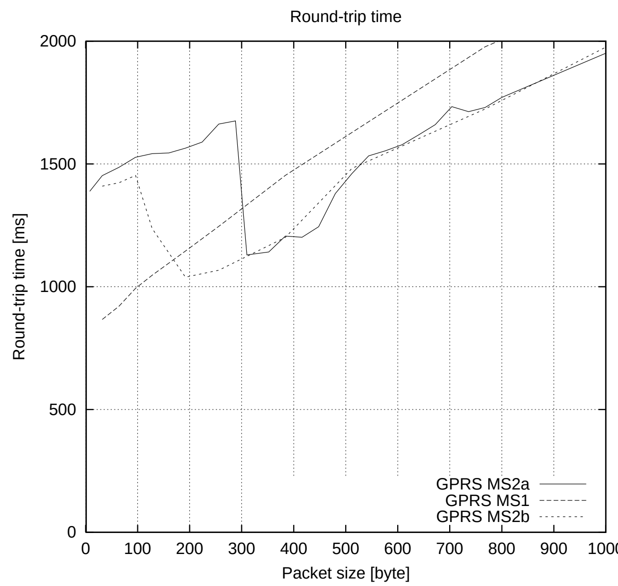

Fig. 3: Round-trip time versus packet size [MS - GGSN]

can not be reused for the following Ping command and a new TBF can not be set up for a certain time interval after the TBF release defined by the timer value T3192 [1]. Generally the high round-trip times (see Figure 2 upper two curves) compared to the performance of a 56K or ISDN modem (lower two curves) can be explained by inefficient TBF management in GPRS. It would be promising to implement open-ended TBFs in uplink and downlink that are let open for a few seconds after the transmit queue runs out of data and that can directly be reused for new data that is arriving, while the TBF is still open as proposed in [10].

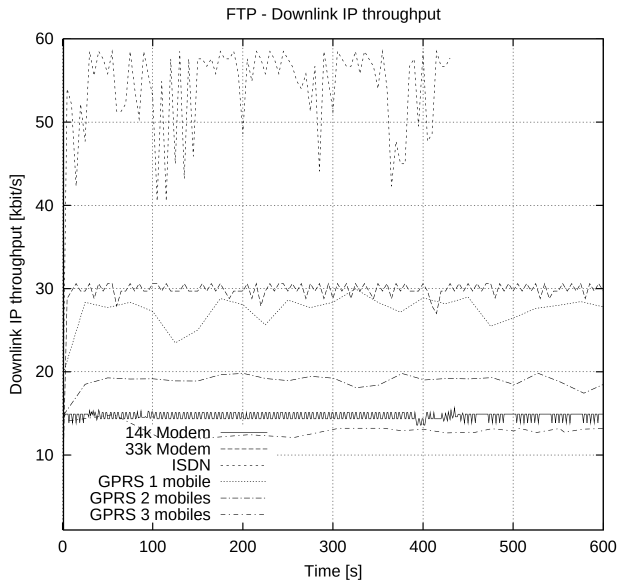

Fig. 4: FTP throughput performance

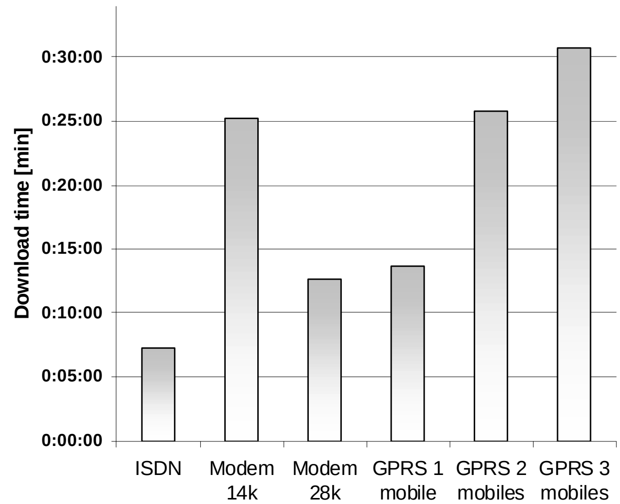

Fig. 5: FTP download time

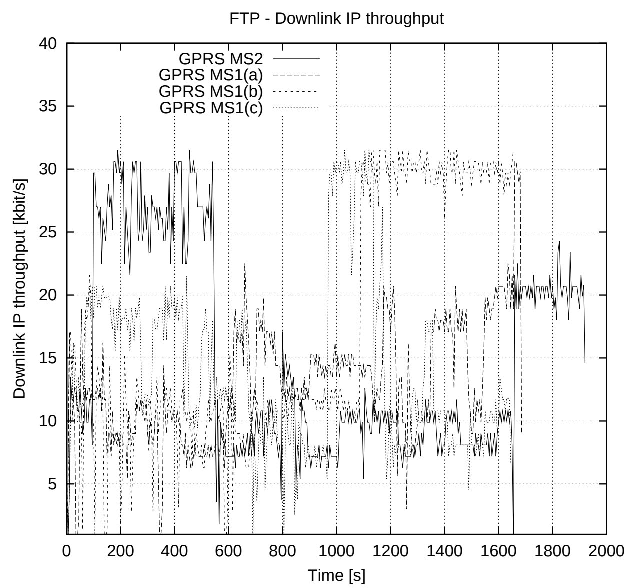

Fig. 6: FTP with cell re-selections with four active GPRS terminals

IV. FTP PERFORMANCE

A. Measurement Results

This measurement series was performed to get an overview of the maximum throughput reachable with GPRS. The File Transfer Protocol (FTP) was used to download one single file (size: 2.7 MByte) from the Internet. Considering the high round-trip times of GPRS (see Section III), the delay imposed by the Internet could be neglected. Regarding the maximum number of three downlink timeslots and the maximum throughput of 31.5 kbit/s, a maximum of 10.5 kbit/s per PDCH could be seen as the performance limit (see Figure 4). Therefore, a maximum of around 42 kbit/s can be assumed for the network at this time, if 4 downlink slots can be used in parallel, which is the current status for newer GPRS terminals. Figure 5 shows the average download times using GPRS and fixed access networks. The GPRS performance with 3 downlink slots is comparable to the performance of an 28k analog modem.

Since the regarded cell was not isolated, some cell reselections occurred with more than one GPRS terminal active. Although they could be pinpointed by counters within the BSC, this fact limited the maximum number of GPRS terminals to three for this experiment. With four terminals, the number of re-selections increased dramatically, as shown in Figure 6. It is obvious that the re-selection performed by one terminal instantly affects the performance of all other terminals within that cell, leaving more resources to the remaining stations.

For proper interpretation of the results, samples measured during time periods, where one or more terminals were connected to other cells were removed from the measurement data.

B. Comparison to GPRSIM *Results*

The settings in the GPRS simulator GPRSIM [6] were adjusted to meet the measurement conditions, e.g., downlink multislot capability 3, FTP protocol, file size, etc. The comparison shows very similar results in simulation and measurements (see Figure 7). For 1, 2 and 3 active stations the throughput is the same, while for 4 active stations the simulation result is slightly lower, which can be explained by cell re-selections with 4 active stations in the measurement scenario (see Section IV.A).

This comparison can be seen as a validation of the GPRSIM regarding the statistical multiplexing function of

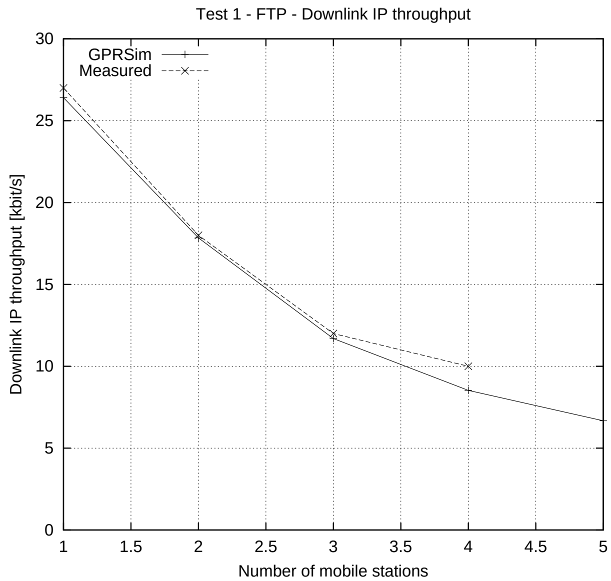

Fig. 7: FTP throughput performance compared to GPRSIM results

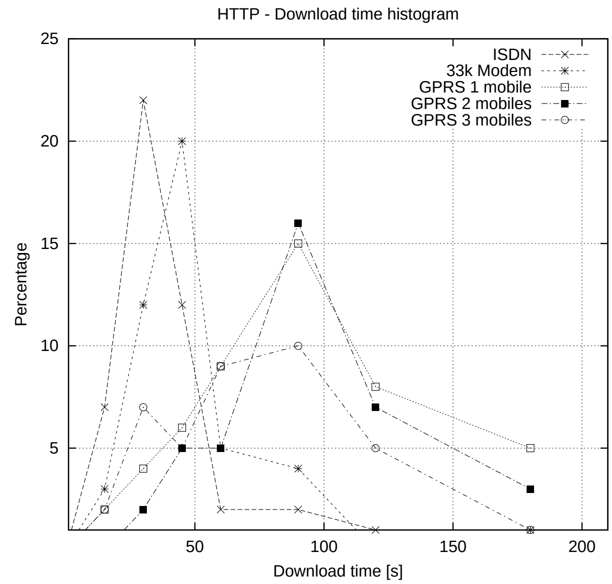

Fig. 8: WWW response time per page

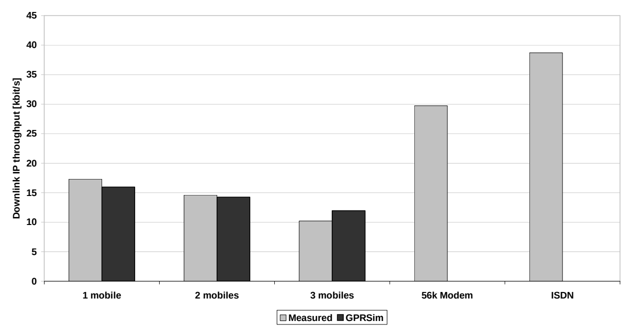

Fig. 9: WWW throughput performance

the RLC/MAC layer and the overhead and behavior of the whole protocol stack. The performance effects imposed by TBF management is not considered in this comparison, since for one FTP download no TBF re-establishment is required during the download period.

V. WWW PERFORMANCE

The workload used for this measurement was generated to model a user having a laptop connected to the GPRS terminal and surfing on the Internet as he would do having a fixed network connection. The pages were chosen using statistics of popular sites. The MS Internet Explorer was used to generate the workload. It supports three parallel TCP connections and it uses HTTP version 1.1.

Today, most web pages are designed for data services with higher data rates. Downloading this kind of large pages would lead to high response times and will probably not be acceptable for GPRS users. Even over ISDN most pages were retrieved within 15 seconds, which is reasonable for a start page (most of the objects of the following pages will be cached). With GPRS it took up to 100 seconds, which is not acceptable for Internet users (see Figure 8). This high response time can be explained by the large number of WWW objects that leads to a large number of separate TCP connections.

These measurement results are again close to the GPRSIM results for WWW throughput performance (see Figure 9), which are based on a different traffic model (see Section VI) with smaller pages that is more typical for GPRS usage.

VI. SESSIONS WITH SMALL FILE SIZES

Since large file sizes are not likely to be downloaded with GPRS because of performance limitations, a traffic model with small files was considered in ongoing GPRS research [9, 6, 8].

The GPRSIM combines a variety of workload scenarios. WWW, FTP and e-mail sessions can be modeled as well as WAP, Video and Audio Streaming and Voice over IP [6].

A. GPRSIM *Traffic Model*

The GPRSIM traffic models for WWW and e-mail are based on the measurements presented in [2] and [5]. The parameters of these models have been updated by parameters given by ETSI/3GPP propositions for the behavior of mobile Internet users [3]. All traffic models are described in detail in [6, 7].

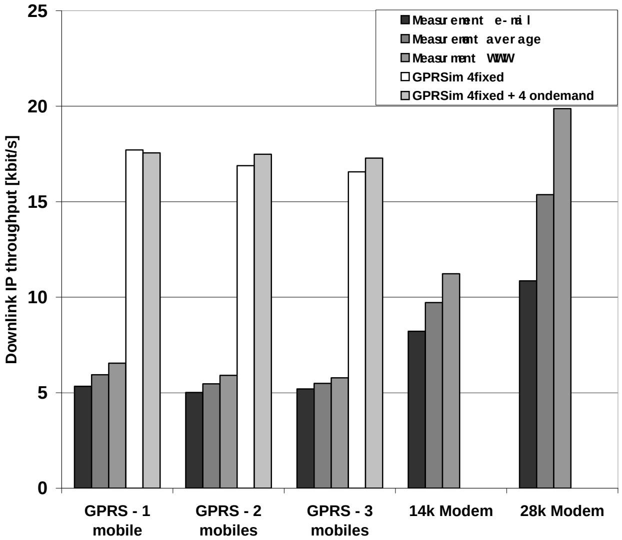

Fig. 10: Throughput performance for small files

B. Measurements

The traffic generator developed for the measurements models a WWW/e-mail traffic mix. A session generator randomly creates e-mail (70%) or WWW (30%) sessions. E-mail sessions comprise one e-mail of on average 10 kbyte from a mail server. A web session consists of five pages, with an average of 2.5 objects. Each object has an average size of 3.7 kbyte. Since it was not possible to generate files on the server dynamically, these settings were reproduced by five files on the server with sizes of 1, 2, 2.5, 5 and 10 kbyte. The idle time between two sessions as well as the read time per web page was set to twelve seconds. Thus, the traffic is comparable to the GPRSIM traffic models regarding the mean values, although it does not model the same exact statistic behavior. Some differences remained in contrast to the GPRSIM. The small delay of less than 40 ms in external networks is neglected in the simulator. The delay between two web objects was between 3 and 4 seconds, which is zero in the GPRSIM. The GPRSIM also does not model POP3 authentication.

C. Comparison to GPRSIM *Results*

The traffic performance evaluated by the GPRSIM is significantly higher than in the measurements (see Figure 10). The main reason for the difference of the throughput performance in the real network and the GPRSIM results for this traffic scenario is the high round-trip time at the radio interface of the real network at that time (see Section III), which slows down the throughput dramatically especially for small files that are regarded here. This high signaling delay in the real network will be enhanced in the next versions of the protocol software in mobile terminals and base stations in the future [10]. The GPRSIM can be regarded as representative for optimized GPRS equipment.

VII. CONCLUSIONS

In this paper the traffic performance that is typical for today's GPRS networks was evaluated by measurements. These measurement results were compared to the traffic performance achieved with other Internet access technologies like ISDN and analog modem. Furthermore the measurement results were compared to simulation results produced by the simulation/emulation tool GPRSIM.

While a maximum downlink IP throughput of 10.5 kbit/s per PDCH could be reached with FTP download, the throughput performance slows down for applications requesting smaller file sizes caused by high round-trip times of between 800 and 1000 ms.

VIII. REFERENCES

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