# Protocol Overhead in GPRS

White Paper

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# 1. Introduction

When data is transmitted over GPRS, various protocols in the GPRS protocol hierarchy add overhead to the data in the form of headers. This document examines an authentic GPRS FTP download session, comparing measured throughput rates with theoretically expected figures, and explaining where the overhead comes from.

Please note that this document concentrates on studying the presented example. The example is a highly typical one, but things such as certain header sizes are specific to the network configuration and not universally valid for the protocols in question. The bit rates achieved are naturally determined by the configuration and the user application, and should not be taken as generally indicative of the bit rates to be expected in GPRS.

# 2. GPRS Protocol Hierarchy

First, a quick review of the stack of protocols involved in a GPRS transmission, from the application level (FTP in this case) down to the GSM radio air interface:

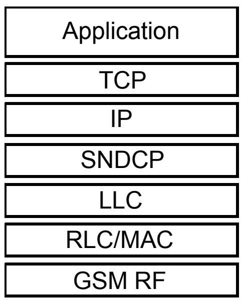


*Figure 1: The GPRS protocol hierarchy in its essentials,*

# 3. The Example Session

The example session, recorded with TEMS Investigation, was an FTP download conducted in the live GPRS network run by the Swedish operator Telia. It had the following characteristics:

- 3 downlink timeslots, coding scheme CS-2
- Mobile phone: Ericsson R520m TEMS R1E; PC OS: Windows 2000
- Negligible interference in the air interface

Since the session took place in a live network, other users were able to share network resources.

Below is a throughput plot of the session made with TEMS Investigation GSM. The application-level, LLC level and RLC/MAC level throughput are plotted. Note the ramp-up phase and the ensuing stretch of steady transfer, both characteristic of FTP (the application-level fluctuations are due to buffering).

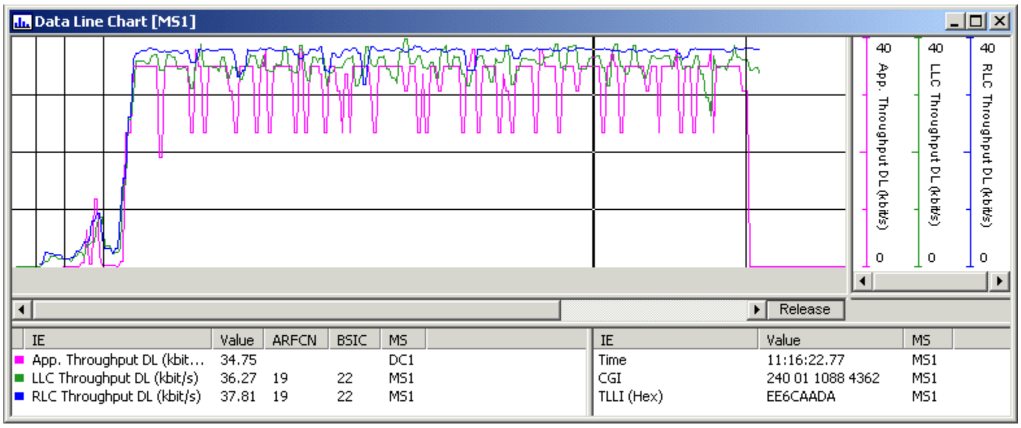


*Figure 2: Throughput plot for the FTP download. It is clear that, on average, application throughput < LLC throughput < RLC throughput, as must be the case.*

# 4. Measured Bit Rates

TEMS Investigation (in conjunction with Microsoft Excel for viewing exported text-format logfiles) was used for RLC/MAC and LLC measurements. CommView was used to inspect the TCP/IP layer.

The following average throughputs were measured, ignoring the ramp-up phase:

- Average throughput at application (FTP) level: 33.18 kbit/s
- Average throughput at LLC level: 35.32 kbit/s
- Average throughput at RLC level: 37.57 kbit/s

# 5. Protocol Overheads

## 5.1. TCP/IP

In our example, an IP packet is 1,500 bytes and includes a 32-byte TCP header and a 20-byte IP header, leaving 1,448 bytes for FTP data. The overhead is the percentage of the entire packet that is not payload, that is, 52 / 1,500 = 3.47%.

Note that on some operating systems (e.g. Windows 95) the IP packet size is not 1,500 but rather some 570 bytes, which considerably increases the overhead. It is possible to change this, for instance using Regedit, by modifying the value of the MTU (Maximum Transfer Unit) for the relevant network adapter.

  

## 5.2. SNDCP

SNDCP adds a 4-byte header to each IP packet. The overhead in this step is 4 / (1,500 + 4) = 0.266%.

## 5.3. LLC

The LLC payload size is set to 400 bytes in the Telia network. The overhead for so-called UI frames, the frame type used here, is 1 + 2 + 3 = 6 bytes (addr, control, and fcs, respectively), or in relative terms 6 / 406 = 1.48%.

## 5.4. Application Level through LLC

The total relative overhead accumulated from the application level down to the LLC layer is

$$\text{ovh}_{\text{App–LLC}} = \frac{\text{ovh}_{abs}\text{TCP/IP} + \text{ovh}_{abs}\text{SNDCP} + \text{ovh}_{abs}\text{LLC}}{\text{data size}_{\text{LLC}}}$$

where $\text{ovh}_{abs}$ represents absolute overheads per IP packet and $\text{data size}_{\text{LLC}}$ denotes the number of bytes accumulated at the LLC level when starting with one IP packet at the application level. That is, referring to the above calculations,

$$\text{ovh}_{\text{App–LLC}} = \frac{52 + 4 + 6 \cdot \frac{1504}{400}}{1448 + 52 + 4 + 6 \cdot \frac{1504}{400}} = 5.15\%$$ [1]

With an application-level throughput of 33.18 kbit/s, this theoretical overhead would give an LLC throughput of $33.18/(1 - 0.0515) = 34.98$ kbit/s; compare with the measured LLC throughput of 35.32 kbit/s. Reasons for the deviation are given in section 7.

The theoretical maximum LLC throughput with 3 timeslots and CS-2 is 36.0 kbit/s.

## 5.5. RLC/MAC

In the RLC/MAC layer, 3 bytes are added to each block of 30 bytes. When measuring the throughput, however, the 1-byte MAC header is ignored, so the overhead in the present context is 2 / 32 = 6.25%. An LLC throughput of 35.32 kbit/s would then grow to $35.32/(1 - 0.0625) = 37.67$ kbit/s at the RLC/MAC level. This is very close to the measured 37.57 kbit/s.

1. The scaling factor 1,504/400 derives from the sizes of the IP packet, SNDCP header, and LLC payload (see above).

# 6. RLC/MAC Signaling

The maximum RLC throughput for 3 timeslots and CS-2 is 38.4 kbit/s. The reason that this figure is not attained is that some data transfer capacity is "stolen" by RLC/MAC *signaling* (which has nothing to do with the RLC/MAC *headers* just discussed). The percentage of the data transfer taken up by signaling was measured and found to be 2.69%. This agrees reasonably well with the measured throughput: $38.4 \cdot (1 - 0.0269) = 37.37$ kbit/s (measured 37.57 kbit/s).

Beneath the RLC/MAC layer is the GSM radio air interface, so our descent down the protocol stack is now finished.

# 7. Reasons for Deviations

As we have seen, the measured bit rates in the example do not match the overhead sizes perfectly. This was due to a combination of factors, but mainly to the fact that the throughput at all levels (particularly at the application level), fluctuated a great deal during the session – as is evident from Figure 2. Therefore, when selecting the “steady-state” segment from which to calculate the throughput averages, it was not possible to ensure that this segment exhibited precisely the same bit rate relationships as the session taken as a whole.

  