GPRS Measurements in TEMS Products

White Paper

ascom

Contents

1. Introduction

1.1. General

This chapter gives an introduction to the frame structure and channel coding in GPRS, also showing how data blocks are mapped onto the frame structure.

The GPRS protocol stack is described, and various theoretical maximum throughput values are explained for the RLC/MAC layer. The other chapters will refer to this chapter when calculating the throughput, retransmission, and decode error figures presented in the TEMS products.

1.2. The GPRS Protocol Stack

Figure 1 below shows the GPRS protocol stack layers, indicating which layers are located in the PC and which are in the mobile phone. PC user applications could be e.g. FTP, HTTP, or mail transfer protocols.

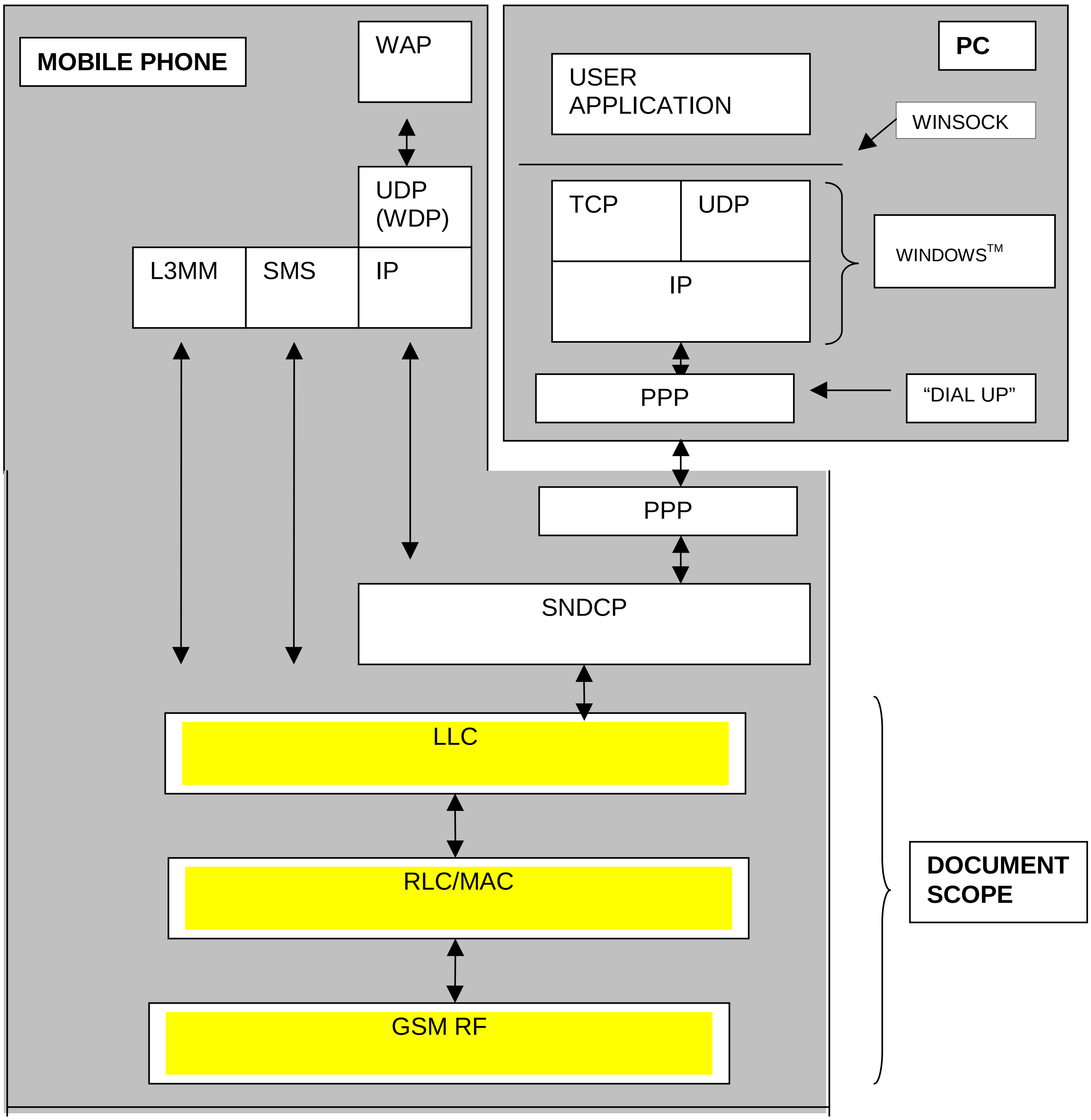


Figure 1 The GPRS protocol stack.

1.3. The GPRS Protocol Reference Model

Figure 2 shows the protocol stacks and layers in GPRS and the interfaces between the stacks. The RLC/MAC layer is handled in the BSS by the packet control unit, PCU, which receives LLC frames, builds RLC/MAC radio blocks, and handles retransmissions due to errors in the air interface (Um). The PCU could be located in the BTS, in the BSC, or even in the SGSN (in the latter case the Gb interface is “inside” the SGSN node). The application layer on top of IP could be TCP or UDP, handling user applications such as FTP or HTTP.

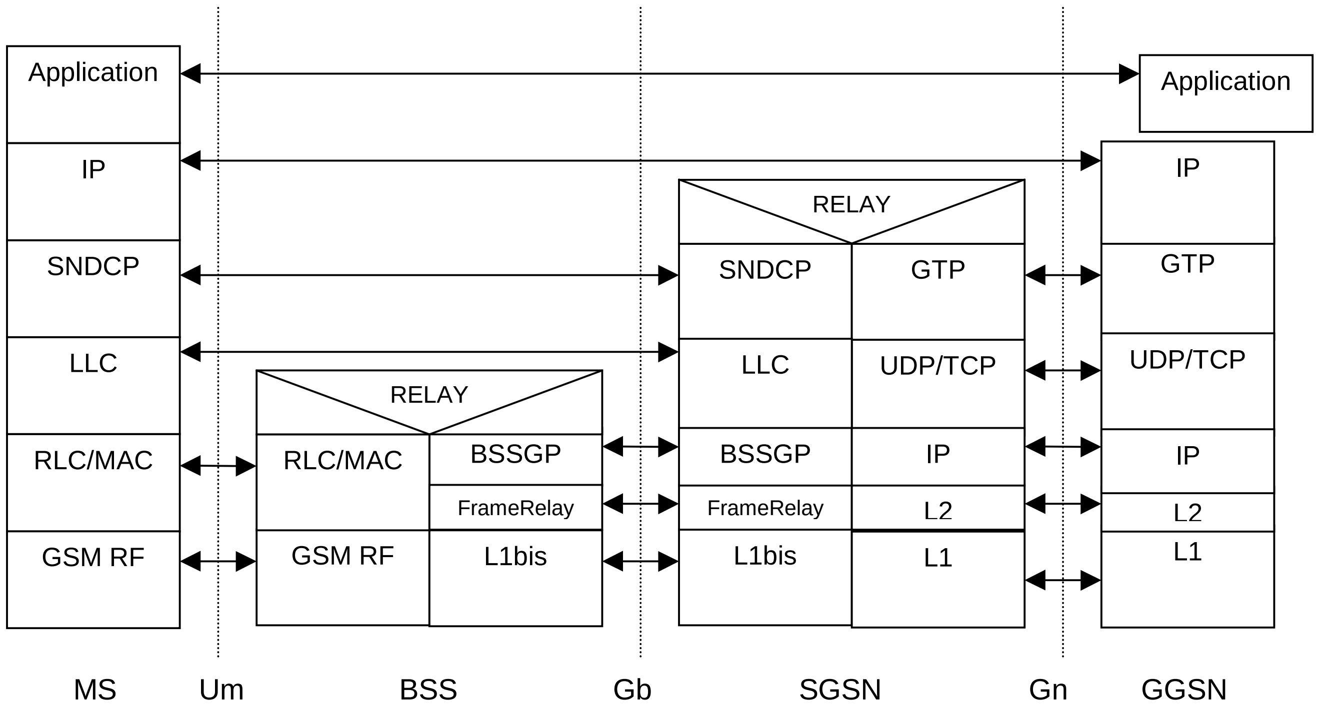


Figure 2 The GPRS Protocol Reference Model

1.4. The GPRS Frame Structure

A GSM TDMA frame is built up by eight consecutive timeslots. Each timeslot will build up a logical frame structure, used for carrying e.g. BCCH information, paging information, speech, or data. In the GPRS case, each timeslot used for data could be shared by several simultaneous users by assigning different TFIs, temporary flow identities, to the users. Also one user can be assigned one or several timeslots.

Forming the 52-multiframe

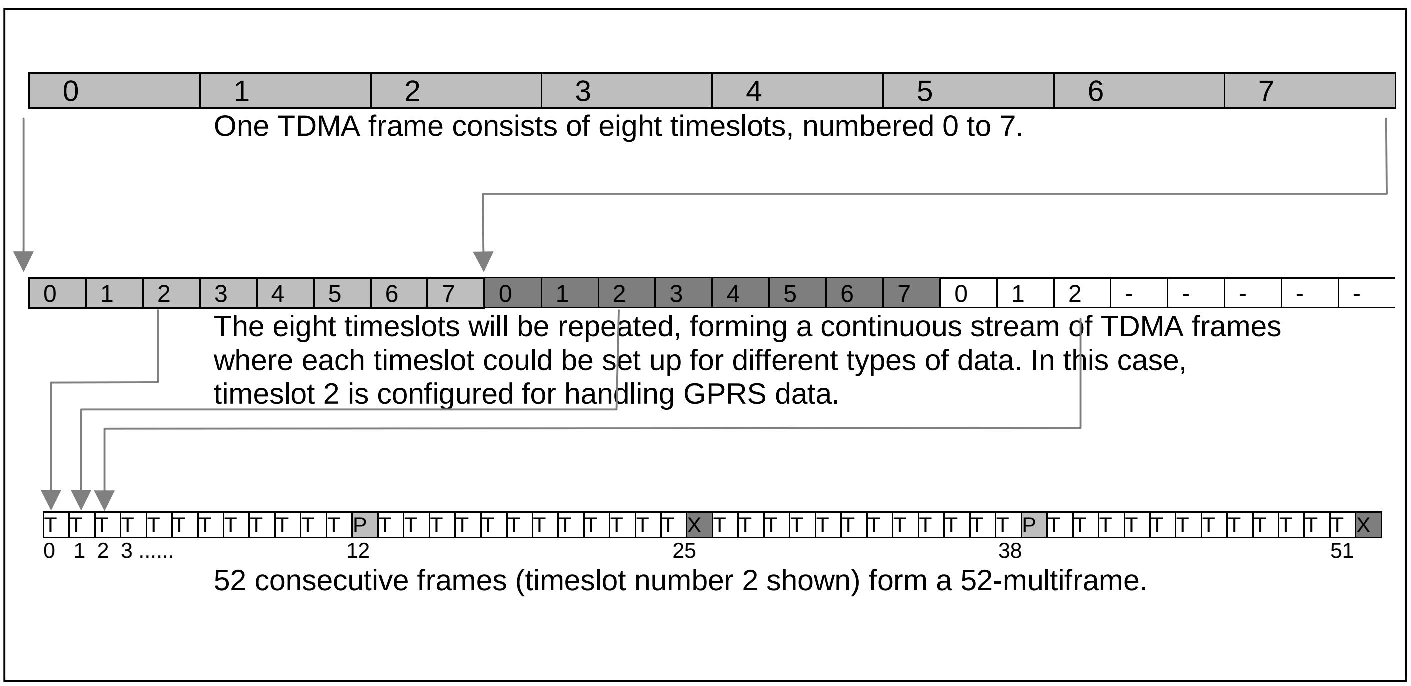


Figure 3 The 52 multiframe used in GPRS.

The 52-multiframe consists of 52 consecutive assigned timeslots with the same number (e.g. TS 2 as in Figure 3 Of the 52 timeslots, 48 are used for sending the actual GPRS data. Of the remaining four, the two timeslots marked ‘X’ (nos. 25 and 51) are used for neighbour cell identification, similar to the IDLE frame in the 26 multiframe in the speech case. The mobile searches the SCH burst that holds the BSIC and timing information for the neighbour. During the ‘X’ timeslot, the serving cell does not receive or transmit anything. Finally, the two timeslots marked ‘P’ (nos. 12 and 38) form the PTCCH channel used for timing advance regulation.

1.5. Channel Coding of the RLC/MAC Layer

The RLC/MAC data is transmitted in radio blocks, the structure of which is defined in GSM specification 04.60. Both control blocks (with signalling information) and data blocks (with user data) uses a structure with a MAC header of one octet, followed by RLC data. The MAC header structure differs between the uplink- and downlink. The RLC data structure depends on the type of data in the block (control or user data). For user data a two octet RLC header is followed by the RLC data field containing the payload.

	7	6	5	4	3	2	1	0	Bit no.
Octet 1	Payload Type		RRBP		S/P	USF			MAC Header
Octet 2									RLC Header
Octet 3									
Octet 4 . . . Octet N									RLC Payload

Figure 4 The GPRS radio block structure for downlink user data.

The size of the radio blocks (N) depends on the coding scheme used when transmitting the block. The value of N corresponds to the number of bytes (octets) and differs between the different coding schemes according to Table 1 below. A control block is always coded with CS-1 while data can be coded using any of the four coding schemes.

Coding Scheme	N (including MAC header)	RLC Payload data block size
CS-1	23	20
CS-2	33	30
CS-3	39	36
CS-4	53	50

Table 1 The size of the radio block for each coding scheme.

Each radio block is assembled differently depending on the coding scheme used. However, regardless of coding scheme, each radio block must be made 456 bits long in the end in order to fit it into the GSM bursts, as explained in section 1.6 below.

Before the application of channel coding, each radio block is assembled according to the table below. The “spare bits added” are padding needed to adapt the radio block size to the channel coder.

	Radio block size	Spare bits added	Radioblock size excl. USF	USF	Precoded USF	BCS	Tail	Total no of bits per radioblock
CS-1	23*8	0	23*8 + 0 – 3 = 181	3	3	40	4	181+3+40 +4 = 228
CS-2	33*8	7	33*8 + 7 – 3 = 268	3	6	16	4	268+6+16 +4 = 294
CS-3	39*8	3	39*8 + 3 – 3 = 312	3	6	16	4	312+6+16 +4 = 338
CS-4	53*8	7	53*8 + 7 – 3 = 428	3	12	16	0	428+12+ 16+0=456

Table 2 Structure of radio block prior to channel coding.

The USF is precoded with a block code in the CS-2, CS-3, and CS-4 case in order to detect any errors in it. The block check sequence (BCS) is a block code for the whole radio block used for error detection. The rightmost column shows the total number of bits per radio block before it is put into the channel coder. CS-4 is a bit special since no channel coding is used at all; the bits are sent over the air interface with no protection. The channel coder used in CS-1, CS-2, and CS-3 is the same convolutional encoder as the one used for GSM signalling (i.e. SACCH, BCCH, FACCH etc.)

The channel encoder doubles the number of bits in CS-1, CS-2, and CS-3 (rate ½) but leaves CS-4 uncoded. To bring down the number of bits to 456 as required, puncturing is used in CS-2 and CS-3. The resulting radio block is now ready for burst formatting.

	Total no of bits per radioblock	Code rate	Total no of bits after coding	Punctured bits	No of bits to send
CS-1	228	½	228*2 = 456	0	456–0 = 456
CS-2	294	½	294*2 = 588	132	588–132 =456
CS-3	338	½	338*2 = 676	220	676-220 = 456
CS-4	456	1	456*1 = 456	0	456–0 = 456

Table 3 Channel coding of radio blocks, each ending up 456 in length.

1.6. Mapping of Radio Blocks onto the GPRS Frame Structure

As explained in section 1.5, all GPRS blocks will end up containing 456 bits per frame, regardless of the coding scheme used. These 456 bits are split up into a number of bursts and mapped onto the 52-multiframe structure. The first thing to do is to split the 456 bits into eight parts containing 57 bits each, see Figure 5.

456

57	57	57	57	57	57	57	57

Figure 5 The 456 bits containing a coded radio block are split up into eight 57-bit blocks.

The data is then to be inserted into bursts (a burst is the data stream transmitted in one timeslot). Figure 6 below shows a “normal” burst in GSM (there are other types of bursts as well, but they will not be explained in this document). As can be seen, the normal burst has room for two data bit segments each of length 57 bits.

TAIL(3)	**DATA(57)**	FACCH FLAG(1)	TSC(26)	FACCH FLAG(1)	**DATA(57)**	TAIL(3)	GUARD (8.25)

Figure 6 The structure of the ”normal” burst in GSM.

The eight 57-bit segments constituting a radio block will thus take up four bursts. Interleaving is applied to four whole bursts at a time, i.e. to entire radio blocks.

The exact mapping can be found in Figure 7, where ‘a’–‘l’ are GPRS radio blocks.

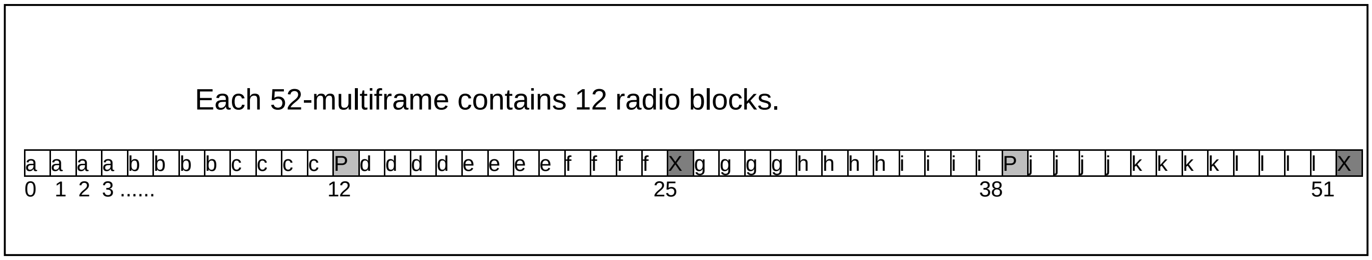


Figure 7 Distribution of radio blocks in the 52-multiframe.

1.7. RLC/MAC Throughput Calculations

In the literature, a number of different throughput values for GPRS are mentioned. This chapter intends to explain these throughput values.

Throughout the chapter, in order to calculate bits per second, use is made of the fact that 8 bits = 1 byte and that there are 50 radio blocks per second. Note that the latter is an exact value and no approximation. As seen in Figure 7 above, there are 12 blocks per 52- multiframe; one 52-multiframe is exactly 52*120/26 = 240 ms; thus there are 12 blocks every 240 ms, or 12/0.240 = 50 blocks per second. If several timeslots are assigned, the calculated throughput should be multiplied by the number of timeslots.

RLC PAYLOAD THROUGHPUT

This is the rate at which the LLC layer can receive data from and send data to the RLC/MAC layer.

Coding Scheme	N (including MAC header)	RLC Payload data block size (bytes)	RLC Payload data throughput (bit/s)[1]
CS-1	23	20	20*8*50 = 8000
CS-2	33	30	30*8*50 = 12000
CS-3	39	36	36*8*50 = 14400
CS-4	53	50	50*8*50 = 20000

1 RLC Payload data throughput (bit/s) = (RLC Payload data block size) * 8 * 50

Table 4 RLC payload throughput calculations

RADIO BLOCK THROUGHPUT WITHOUT USF
This is the throughput within the RLC/MAC layer, with the whole RLC header included (together with the MAC header), but with the uplink state flag (USF) excluded. The spare bits added for CS-2, CS-3, and CS-4 are included.

Coding Scheme	N (including MAC header)	Radio block size including spare bits but excl. USF[1]	Radio block excl. USF throughput (bit/s)[2]
CS-1	23	23*8 + 0 – 3 = 181	181*50 = 9050
CS-2	33	33*8 + 7 – 3 = 268	268*50 = 13400
CS-3	39	39*8 + 3 – 3 = 312	312*50 = 15600
CS-4	53	53*8 + 7 – 3 = 428	428*50 = 21400

1 See Table 2 on page 10

2 Throughput (bit/s) = (Radio block size including spare bits but excl. USF) * 50

Table 5 Radio block throughput calculations, without USF

RADIO BLOCK THROUGHPUT WITH SPARE BITS INCLUDED
This is the throughput within the RLC/MAC layer when the whole radio block is counted, including the whole RLC/MAC header and spare bits.

Coding Scheme	N (including MAC header)	Radio block size including spare bits	Radio block throughput (bit/s)[1]
CS-1	23	23*8 + 0 = 184	184*50 = 9200
CS-2	33	33*8 + 7 = 271	271*50 = 13550
CS-3	39	39*8 + 3 = 315	315*50 = 15750
CS-4	53	53*8 + 7 = 431	431*50 = 21550

1 Radio block throughput (bit/s) = (Radio block size including spare bits) * 50

Table 6 Radio block throughput calculations with spare bits included

RADIO BLOCK THROUGHPUT
This is the throughput within the RLC/MAC layer where the whole radio block is counted, including the whole RLC/MAC header, but excluding spare bits. This is the throughput reference for the RLC/MAC measurements in the TEMS products.

Coding Scheme	N (including MAC header)	Radio block size	Radio block throughput (bit/s)[1]
CS-1	23	23*8 = 184	184*50 = 9200
CS-2	33	33*8 = 264	264*50 = 13200
CS-3	39	39*8 = 312	312*50 = 15600
CS-4	53	53*8 = 424	424*50 = 21200

1 Radio block throughput (bit/s) = (Radio block size * 50)

Table 7 Radio block throughput calculations

The following table shows the theoretical maximum throughput values for different coding schemes and number of timeslots.

Number of timeslots	CS-1	CS-2	CS-3	CS-4
1	9200	13200	15600	21200
2	9200*2 = 18400	13200*2 = 26400	15600*2 = 31200	21200*2 = 42400
3	9200*3 = 27600	13200*3 = 39600	15600*3 = 46800	21200*3 = 63600
4	9200*4 = 36800	13200*4 = 52800	15600*4 = 62400	21200*4 = 84800

Table 8 Theoretical maximum throughput (bit/s)

2. GPRS RF Measurements

These measurements take place in the GSM RF layer in the protocol stack and are applicable to the downlink only in the TEMS products. At this protocol level, it is not possible to distinguish blocks addressed to a specific mobile; all blocks to all mobiles (all TFIs) will be counted.

In GPRS mode, FER and BER will be updated every 24 radio blocks (i.e. every two 52-multiframes, or once every 4.615*52*2 = 480 ms).

In the calculations below, 24 radio blocks are used as the reference. If the GPRS transaction does not fill two complete 52 multiframes before it is terminated, only the blocks prior to termination will be counted.

2.1. BER/Timeslot (%)

The BER/timeslot parameter gives the bit error rate for each used timeslot. It is possible to choose the timeslot by setting the argument of the information element (argument = 0 points to the first used timeslot, *not* timeslot 0, etc.)

The BER is calculated by summing the number of bit errors for each of the 24 blocks included in the BER and then dividing the sum by the total number of bits in the 24 blocks. As explained in section 1.5, each radio block consists of 456 coded bits, so the total number of bits is 456*24 = 10944.

The number of bit errors can be counted thanks to the convolutional coding which makes it possible to detect and correct bit errors (so-called forward error correction, FEC).

After the channel decoder has decoded a 456-bit block, it is encoded again in the encoder, using the same code polynomial, and the resulting 456 bits are compared with the 456 input bits. The number of bits that differ between the two 456-bit blocks corresponds to the number of bit errors in the block (at least up to a fairly high number of bit errors). The number of bit errors is accumulated in a BER sum for each report interval (i.e. two 52-multiframes). The BER sum is then divided by the total number of bits (10944) to obtain the bit error rate.

Note that the BER calculation does not take into consideration whether the block shall be discarded due to error in the block check sequence (BCS).

Also note that since CS-4 uses no convolutional coding at all but sends all bits uncoded, it is not possible to detect and count any bit errors with this coding scheme.

Range: 0 ... 100%

Calculation formula: BER (%) =

((total number of bit errors in 24 blocks) / (total number of bits in 24 blocks)) * 100

where the total number of bits in 24 blocks = 10944.

2.2. FER/Timeslot (%)

The FER/timeslot parameter gives the block error rate (BLER) for each used timeslot in the downlink direction. It is possible to choose the timeslot by setting the argument of the information element (argument = 0 points to the first used timeslot, *not* timeslot 0, etc.)

The FER is calculated as the percentage of blocks (out of a total of 24) that have an incorrect checksum in the block check sequence (BCS).

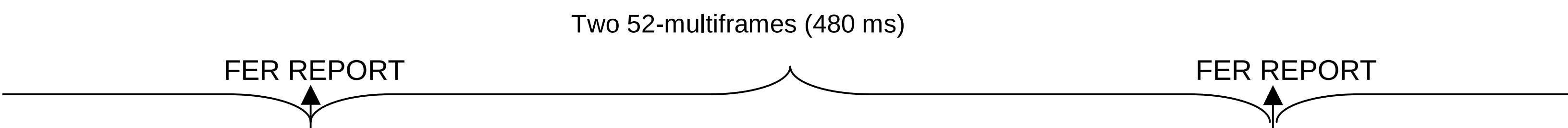
Range: 0 ... 100%

Calculated as: FER (%) =

((number of blocks with incorrect BCS) / (total number of blocks)) * 100

where total number of blocks = 24.

Example 1



Ref.	0	1	2	3	4	5	6	7	8	9		24	25	26
BCS	OK	OK	OK	FAIL	FAIL	OK	OK	OK	FAIL	OK	OK	OK	OK	OK
TFI	OWN	OWN	OWN	?	?	OWN	OWN	X	?	X	X	X	X	X
BSN	9	10	11	-	-	14	15	-	-	-	-	-	-	-

Figure 8 Example showing three erroneous radio blocks.

The FER is based on all blocks (all TFIs), not only those addressed to a particular mobile (TFI). In Figure 8 above, the three blocks with BCS failure (ref. = 3, 4, 8) will be counted as erroneous, and all other blocks (ref. = 1, 2, 5–7, and 9–24) will be counted as error-free. The FER in this case will thus be 3/24 = 12.5%.

Example 2

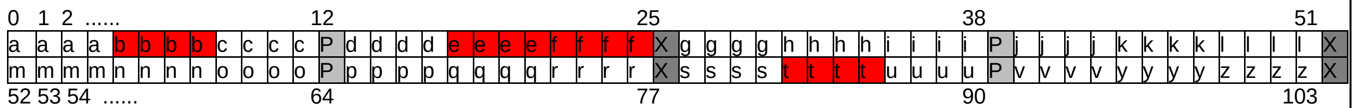


Figure 9 Example showing four erroneous blocks. The complete 52 multiframe is shown including the burst mapping.

In Figure 9 above, two complete 52-multiframes are shown. Four blocks (‘b’, ‘e’, ‘f’, and ‘t’) have an incorrect BCS. The FER for this period (480 ms) will be (4/24)*100 = 17%.

2.3. Coding Scheme Downlink Usage (%)

This parameter shows the utilisation of each coding scheme. Both signalling and data blocks are counted, and since signalling blocks are always coded with CS-1, the parameter will indicate use of CS-1 even if the cell is set up for using CS-2. The argument of the information element indicates the coding scheme (e.g. argument = 1 gives CS-1 usage).

As with the FER and BER measurements described in section 2.1 and 2.2, coding scheme downlink usage is measured on blocks addressed to all mobiles, using the actual packed data channel (PDCH).

Range: 0 ... 100%

3. RLC/MAC Layer Measurements

3.1. RLC/MAC Reports

RLC/MAC measurements take place inside the TEMS mobile which sends two reports per second to the TEMS PC application: one report for the uplink channel (mobile to GPRS network) and one for the downlink channel. Each report contains data representing the last one-second period. Note that the report interval is not in any way related to the GPRS frame structure; it is controlled by a timer which is set to expire once every second.

In order to get the throughput figures right, the exact number of TDMA frames in the measurement period is included in each report. The number of frames is converted to seconds using the following formula:

1 frame = (120/26) ms (≈ 4.615 ms)

Figure 10 Formula for calculating the TDMA frame length

Each report contains data for calculating the RLC information elements specified in section 3.2.

All counters are reset for each report, which means that the information relates to the blocks handled since the last report.

At this level, the timeslot configuration is of no importance; the RLC/MAC layer does not know about the number of used timeslots, so all physical channels are included in the measurements.

RLC UPLINK REPORT
This report contains data on the uplink (MS to BSS). Both RLC control blocks and RLC data blocks are included. Note that the number of bytes per radio block depends on the coding scheme used for each block.

The throughput should be compared to the figures in section 1.7. Since both control and data blocks are counted, signalling (which is coded with CS-1) will lower the throughput compared to the maximum throughput for data (if coded with CS-2, CS-3, or CS-4).

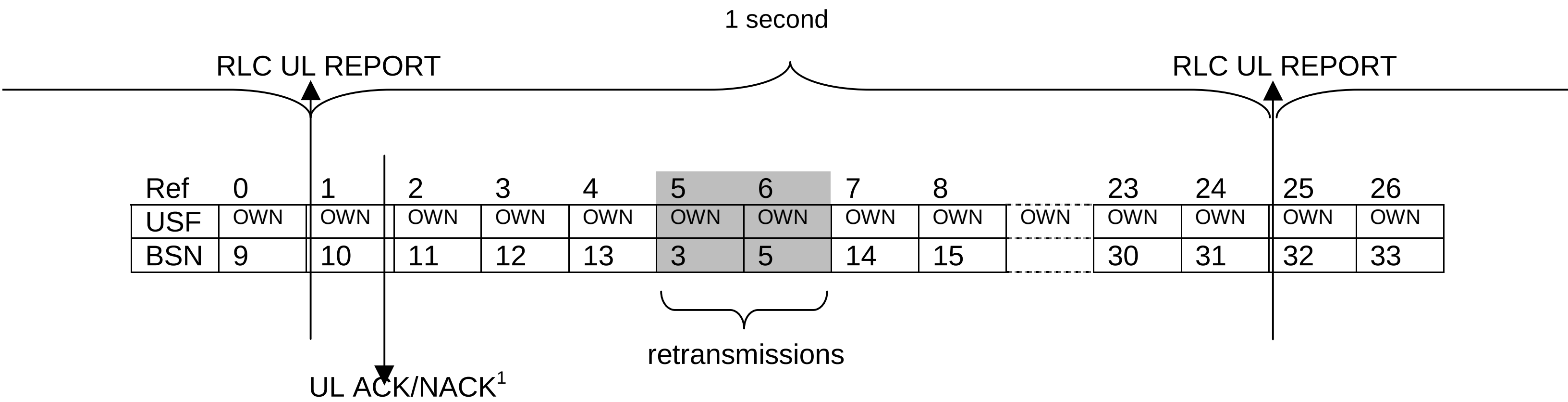
Information for throughput calculations:

- Number of TDMA frames representing the report content. Converted into seconds using the formula in Figure 10. [RLC_UL_NO_OF_SECONDS]
- Number of bytes transmitted for the first time. The bytes of each whole radio block (i.e. payload from the LLC layer, MAC and RLC headers, and RLC padding bytes [if any] to get a complete radio block) are counted according to Figure 4. Note that retransmissions are *not* included, only radio blocks transmitted for the first time. Blocks repeated as fill blocks are not counted either. The value given will always correspond to a whole number of radio blocks. [RLC_UL_NO_OF_BYTES]

Information for retransmission calculations:

- Number of radio blocks generated from payload data received from the LLC layer plus the number of RLC/MAC control blocks. No other blocks generated within the RLC/MAC layer (e.g. retransmissions or fill blocks) will be counted. [RLC_UL_NO_OF_NEW_BLOCKS]
- Number of retransmitted radio blocks. This is the number of radio blocks that the network (actually the PCU, packet control unit) requests to be retransmitted. [RLC_UL_NO_OF_RETRANSMITTED_BLOCKS]

Example 3

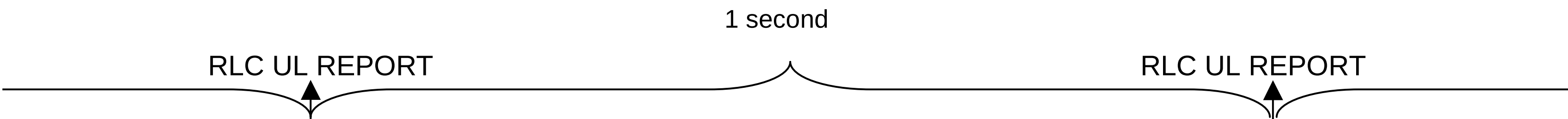


Ref	0	1	2	3	4	5	6	7	8		23	24	25	26
USF	OWN	OWN	OWN	OWN	OWN	OWN	OWN	OWN	OWN	OWN	OWN	OWN	OWN	OWN
BSN	9	10	11	12	13	3	5	14	15		30	31	32	33

1 ACK/NACK from the PCU to the mobile, all packets OK except those with BSN 3 and 5.

In the above example, the RLC UL REPORT sent at ref. 25 will indicate two retransmitted blocks (BSNs 3 and 5) and 22 radio blocks not previously transmitted (BSNs 10 to 31). The number of bytes used for throughput calculations will be the number of bytes in the 22 radio blocks. Note that the number of bytes per radio block depends on the coding scheme used for each block. The throughput should be compared to the figures in section 1.7.

Example 4



Ref.	0	1	2	3	4	5	6	7	8		23	24	25	26
USF	X	X	OWN	OWN	OWN	OWN	OWN	OWN	X	X	X	X	X	X
BSN	X	X	0	1	0	1	0	1	X		X	X	X	X

If the mobile wants to send a very short message (e.g. a GPRS attach), it will request an uplink TBF and send the message on the assigned USF (ref. 2 and 3 in the above figure). Now, only two radio blocks are needed for this message, but the mobile has to send something in the next four blocks as well (ref. 4, 5, 6, and 7). Therefore it will repeat the attach message twice as a fill block (reusing BSNs 0 and 1).

In the above example, the UL RLC REPORT sent at ref. 25 will indicate no retransmitted blocks and two blocks not previously transmitted (BSNs 0 and 1). The number of bytes used for throughput calculations will correspond to the number of bytes in these two radio blocks.

Note that as long as the PCU receives at least one of the three attach messages correctly, it will not ask for a retransmission. That is, even if the first block did not come through, no retransmission will be required as long as one of the other two (fill) blocks did. This means that the retransmission rate will be zero even if one or two radio blocks were actually lost.

RLC DOWNLINK REPORT

This report contains data on the downlink (BSS to MS). Both RLC control blocks and RLC data blocks are included. Note that the number of bytes per radio block depends on the coding scheme used for each block.

The throughput should be compared to the figures in section 1.7. Since both control and data blocks are counted, signalling (which is coded with CS-1) will lower the throughput compared to the maximum throughput for data (if coded with CS-2, CS-3, or CS-4).

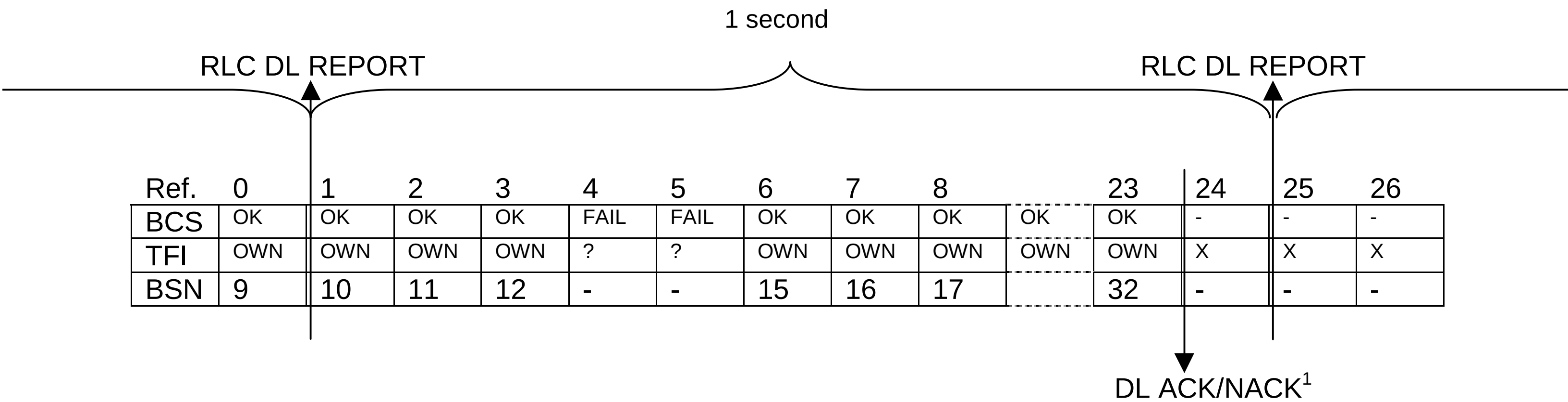
Information for throughput calculations:

- Number of TDMA frames representing the report content. Converted into seconds using the formula in Figure 10. [RLC_DL_NO_OF_SECONDS]
- Number of bytes received and addressed to this mobile, including fill bits measured on correctly received blocks ready for delivery to the LLC layer. Only unique radio blocks ready for the LLC will be counted, i.e. no fill blocks or retransmissions. The value given will always correspond to a whole number of radio blocks. [RLC_DL_NO_OF_BYTES]

Information for decode error calculations:

- Number of received radio blocks addressed to this mobile, including fill bits but not including retransmissions or fill blocks. Only radio blocks ready for the LLC will be counted, i.e. no fill blocks or retransmissions. [RLC_DL_NO_OF_NEW_BLOCKS]
- Number of radio blocks which the mobile has requested the PCU to retransmit. If transmission of a block fails several times, the block will be counted once for each retransmission requested. Note that the block check sequence is not used directly, since if this fails it is not possible to check which mobile the block was intended for. Instead the measurement is based on the ACK/NACK sent to the PCU asking for a retransmission. The ACK/NACK is based on checking the BSN (block sequence number) of the latest received block number and holes (missing BSN as exemplified in Example 5) in the BSN series. [RLC_DL_NO_OF_MISSING_BLOCKS]

Example 5



Ref.	0	1	2	3	4	5	6	7	8		23	24	25	26
BCS	OK	OK	OK	OK	FAIL	FAIL	OK	OK	OK	OK	OK	-	-	-
TFI	OWN	OWN	OWN	OWN	?	?	OWN	OWN	OWN	OWN	OWN	X	X	X
BSN	9	10	11	12	-	-	15	16	17		32	-	-	-

1 ACK/NACK from the mobile to the PCU, all packets OK except the radio block with BSN 13 and 14.

In the above example, the RLC DL REPORT sent at ref. 25 will indicate two requests for retransmission (blocks with BSNs 13 and 14) and 21 correctly received radio blocks (BSNs 10–12, 15–32). The number of bytes used for throughput calculations will be the number of bytes in the 21 correctly received radio blocks. Note that the number of bytes per radio block depends on the coding scheme used for each block. The throughput should be compared to the figures in section 1.7.

Note that for the blocks corresponding to ref. 4 and 5 it is not possible to decide the TFI. The blocks in ref. 24 to 26 have a different TFI and will not be counted.

Example 6

1 second

RLC DL REPORT

RLC DL REPORT

Ref.	0	1	2	3	4		19	20	21	22	23	24	25	26
BCS	OK	OK	FAIL	OK	-	-	-	OK	OK	FAIL	FAIL	FAIL	FAIL	FAIL
TFI	OWN	OWN	?	OWN	X	X	X	OWN	OWN	?	?	?	?	?
BSN	9	10	-	12	-		-	13	14	-	-	-	-	-

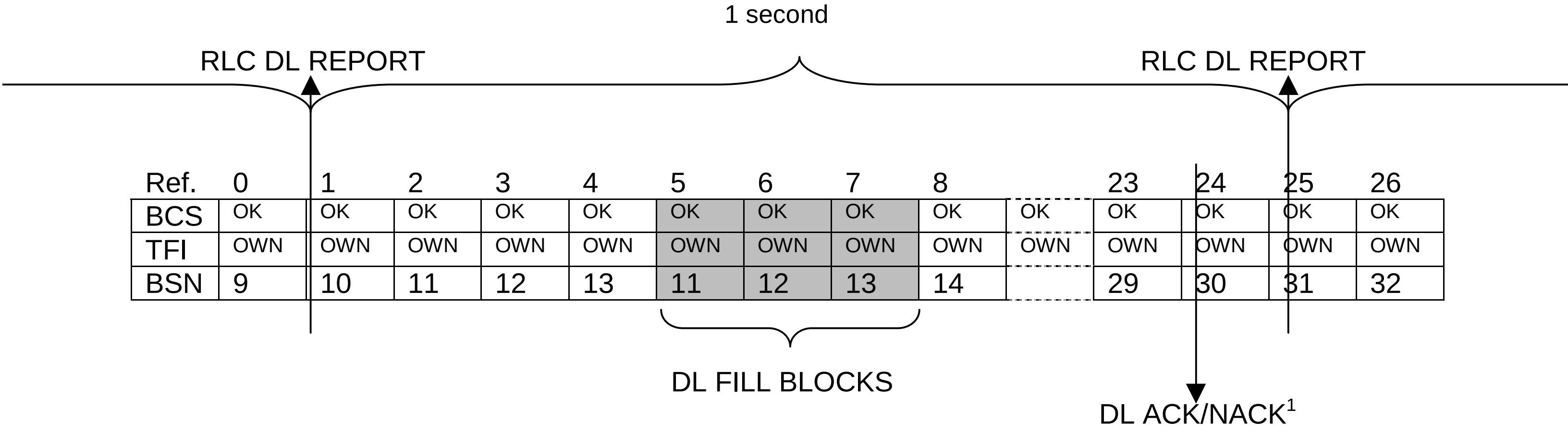
DL ACK/NACK[1]

1ACK/NACK from the mobile to the PCU, all packets OK except the packet with BSN 11. Note that the last reported block will be BSN 14 (ref. 21).

In the above example, the RLC DL REPORT sent at ref. 25 will indicate one missing block (BSN 11) and four correctly received blocks (BSN 10, 12, 13, 14). The number of bytes used for throughput calculations will be the number of bytes in the four correctly received radio blocks. Note that the number of bytes per radio block depends on the coding scheme used for each block. The throughput should be compared to the figures in section 1.7.

The radio blocks from ref. 22 on will not be handled until a block has been decoded correctly so that the BSN can be checked.

Example 7



1 ACK/NACK from the mobile to the PCU, all packets OK.

In the above example, the RLC DL REPORT sent at ref. 25 will indicate 21 correctly received radio blocks and no retransmissions. The radio blocks at ref. 5, 6, and 7 are fill blocks and have already been received, so they will not be counted again in the information element calculations, neither as retransmitted blocks nor as correctly received blocks. The throughput should be compared to the figures in section 1.7.

3.2. RLC/MAC Information Elements

In order to calculate the information elements, data from the reports explained in section 3.1 is used.

RLC Decode Errors DL (%)
Percentage of RLC/MAC blocks which the mobile has requested the PCU to retransmit, as explained in section 3.1.

Calculated as:

RLC Decode Errors DL (%) =

([RLC_DL_NO_OF_MISSING_BLOCKS] / ([RLC_DL_NO_OF_ MISSING _BLOCKS] + [RLC_DL_NO_OF_NEW_BLOCKS])) * 100

RLC Retransmissions UL (%)
Percentage of RLC/MAC blocks retransmitted on the uplink, based on data taken from the RLC UPLINK REPORT (section 3.1).

Calculated as:

RLC Retransmission UL (%) =

([RLC_UL_NO_OF_RETRANSMITTED_BLOCKS] / ([RLC_UL_NO_OF_RETRANSMITTED_BLOCKS] + [RLC_UL_NO_OF_NEW_BLOCKS])) * 100

RLC Throughput DL (kbit/s)
Throughput in the RLC/MAC radio block layer according to section 3.1. The reference throughput table can be found in section 1.7.

Calculated as:

RLC Throughput DL (kbit/s) =

([RLC_DL_NO_OF_BYTES] * 8) / ([RLC_DL_NO_OF_SECONDS] * 1000)

RLC Throughput DL (%)

Throughput (as defined in section 3.2 above) on the downlink at the RLC/MAC protocol level, compared to the theoretical maximum for the current channel setup (coding scheme and number of timeslots). During the measurement period, the coding scheme distribution is checked and the highest coding scheme used will form the basis for calculating the maximum throughput. This means that degradation both due to retransmissions and to fill blocks will be detected. In case of CS-2, CS-3, or CS-4 usage, degradation due to signalling in control blocks will also be detected. The reference throughput table for the theoretical maximum value can be found in section 1.7.

Calculated as:

RLC Throughput DL (%) =

(RLC Throughput DL / RLC Throughput DL_{max}) * 100

RLC Throughput UL (kbit/s)

Data throughput in the RLC/MAC radio block layer according to section 3.1. The reference throughput table can be found in section 1.7.

Calculated as:

RLC Throughput DL (kbit/s) =

([RLC_UL_NO_OF_BYTES] *8) / ([RLC_UL_NO_OF_SECONDS] * 1000)

RLC Throughput UL (%)

Data throughput as calculated in section 3.2 on the uplink at the RLC/MAC protocol level, compared to the theoretical maximum for the current channel setup (coding scheme and number of timeslots). Can be used to check the loss compared to an optimal radio environment for this channel configuration. The reference coding scheme used for calculating the maximum throughput will be the coding scheme assigned to the mobile for sending RLC/MAC data blocks. The reference throughput table for the theoretical maximum value can be found in section 1.7.

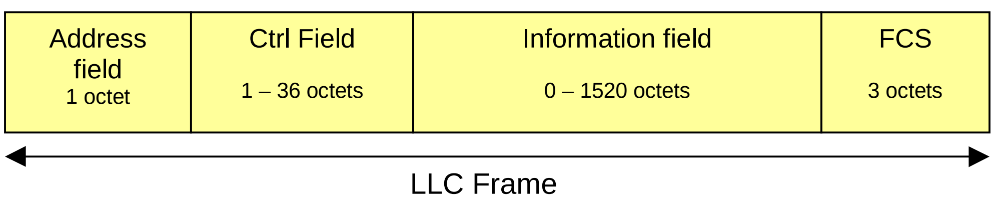
Calculated as:

RLC Throughput UL (%) = (RLC Throughput UL/RLC UL $Throughput_{max}$) * 100

4. LLC Layer Measurements

4.1. LLC Layer Description

The LLC layer provides a logical link between the mobile phone and the SGSN node, as seen in Figure 2. It is specified in GSM specification 04.64 and handles concatenation of radio blocks to/from the RLC/MAC layer into larger segments called LLC frames. An LLC frame has a variable length of 5–1560 octets and consists of a header (address + control field), an information field holding the user data to/from the upper layers (SNDCP SMS, L3MM (see Figure 1, above), and a frame check sequence field, FCS. The FCS consists of a 24-bit (3-octet) cyclic redundancy check (CRC) used for error detection.



Different LLC frames are defined for data transfer and control messages. There are four types of LLC frames:

- I-frames (Information frames) are used for transferring information between layer 3 entities with acknowledgement.
- S-frames (Supervision frames) are used to perform logical link supervisory control functions, such as acknowledging I-frames and requesting temporary shutdown of the information frame (I-frame) transmission.
- UI-frames (Unconfirmed Information frames) are used for transferring information between layer 3 entities without acknowledgement.
- U-frames (Unnumbered frames) are used to provide additional logical link control functions.

The LLC protocol can operate in acknowledged or unacknowledged mode and applies to the I- and S-frames. Acknowledged mode means that error detection and retransmission requests for erroneous I- and S-frames will be performed.

4.2. LLC Reports

LLC measurements take place inside the TEMS mobile. Two reports are sent to the TEMS PC application once every second, one for the uplink channel (mobile to GPRS network – specifically, the SGSN node) and one for the downlink channel. Each report contains data representing the last second. Note that the report interval is not in any way related to the GPRS frame structure; it is controlled by a timer which is set to expire once every second.

In order to get the throughput figures right, the exact number of TDMA frames in the measurement period is included in each report.

Each report contains data used for calculating the LLC information elements presented in the TEMS products. The LLC information elements can be found in section 4.3.

All counters are reset for each report, which means that information relates to the number of blocks handled since the last report.

Note that LLC is commonly run in unacknowledged mode; the RLC/MAC layer takes care of the retransmission of erroneous blocks. In this case, the information elements presenting the decode errors and retransmission rate will always be zero.

Each LLC report from the mobile may include multiple data or control message frames and includes the total number of bytes passed through the LLC interface to/from the RLC layer.

The following table shows the theoretical maximum throughput values for different coding schemes and number of timeslots. The calculations are based on the RLC payload throughput calculations in section 1.7 and form the base for the LLC throughput calculations.

Number of timeslots	CS-1	CS-2	CS-3	CS-4
1	8000	12000	14400	20000
2	8000*2 = 16000	12000*2 = 24000	14400*2 = 28800	20000*2 = 40000
3	8000*3 = 24000	12000*3 = 36000	14400*3 = 43200	20000*3 = 60000
4	8000*4 = 32000	12000*4 = 48000	14400*4 = 57600	20000*4 = 80000

Table 9 Theoretical maximum throughput (bit/s)

LLC UPLINK REPORT

This report contains data on the uplink (MS to SGSN). All types of LLC frames are included (I-, S-, UI-, and U-frames) and a mixture of the different types is handled as well. Note that at this level, the timeslot configuration is of no importance; the LLC layer does not know about the number of used timeslots, so all physical channels are included in the measurements.

Information for throughput calculations:

- Number of TDMA frames representing the report content. Converted into seconds using the formula in Figure 10. [LLC_UL_NO_OF_SECONDS]
- Number of bytes transmitted for the first time for each whole LLC frame. The whole LLC frame is counted, including the header (address and control field), information field (including fill bits), and the FCS. No retransmissions are counted, nor are any LLC fill frames generated within the LLC layer. The number of bytes will correspond to a whole number of LLC frames. [LLC_UL_NO_OF_BYTES]

Information for retransmission calculations:

- Number of LLC frames generated from data received from the upper layer (SNDCP, L3MM, and SMS). No frames generated within the LLC layer (e.g. retransmissions or fill frames) are counted. [LLC_UL_NO_OF_NEW_FRAMES]
- Number of retransmitted LLC frames. Frames that the network (the SGSN node) requests to be retransmitted are counted. [LLC_UL_NO_OF_MISSING_FRAMES]

LLC DOWNLINK REPORT
This report contains data on the downlink (SGSN to MS). All types of LLC frames are included (I-, S-, UI-, and U-frames). Note that at this level, the timeslot configuration is of no importance; the LLC layer does not know about the number of used timeslots, so all physical channels are included in the measurements.

Information for throughput calculations:

- Number of TDMA frames representing the report content. Converted into seconds using the formula in Figure 10. [LLC_DL_NO_OF_SECONDS]
- Number of bytes received and addressed to this mobile, including fill bits measured on correctly received blocks that are ready for delivery to the upper layers. Only unique LLC frames ready for the upper layers will be counted, not fill frames or retransmissions. The whole LLC frame is counted, including the header (address and control field), information field (including fill bits), and the FCS. The number of bytes will always correspond to a whole number of LLC frames. [LLC_DL_NO_OF_BYTES]

For retransmission calculations:

- Number of LLC frames received and addressed to this mobile measured on correctly received frames that are ready for delivery to the upper layers. Only unique LLC frames ready for the upper layers will be counted, not fill frames or retransmissions. [LLC_DL_NO_OF_NEW_FRAMES]
- Number of LLC frames that the mobile station has requested the SGSN node to retransmit. If transmission of a frame has failed several times, the frame will be counted once for each failure. [LLC_DL_NO_OF_MISSING_FRAMES]

4.3. LLC Information Elements

In order to calculate the information elements, data from the reports explained in section 4.2 is used.

LLC Decode Errors DL (%)
Percentage of LLC frames that the mobile station has requested the SGSN to retransmit, as explained in section 4.2.

Calculated as:

LLC Decode Errors DL (%) =

([LLC_DL_NO_OF_MISSING_FRAMES] / ([LLC_DL_NO_OF_ MISSING _FRAMES] + [LLC_DL_NO_OF_NEW_FRAMES])) * 100

LLC Retransmissions UL (%)
Percentage of LLC frames retransmitted on the uplink, based on data taken from the LLC UPLINK REPORT (section 4.2).

Calculated as:

LLC Retransmission UL (%) =

([LLC_UL_NO_OF_RETRANSMITTED_FRAMES] / ([LLC_UL_NO_OF_RETRANSMITTED_FRAMES] + [LLC_UL_NO_OF_NEW_FRAMES])) * 100

LLC Throughput DL (kbit/s)
Data throughput in the LLC layer according to section 4.2. The reference throughput table can also be found in section 4.2.

Calculated as:

LLC Throughput DL (kbit/s) =

([LLC_DL_NO_OF_BYTES] * 8) / ([LLC_DL_NO_OF_SECONDS] * 1000)

LLC Throughput UL (kbit/s)
Data throughput in the LLC layer according to section 4.2. The reference throughput table can also be found in section 4.2

Calculated as:

LLC Throughput DL (kbit/s) =

([LLC_UL_NO_OF_BYTES] * 8) / ([LLC_UL_NO_OF_SECONDS] * 1000)

5. Abbreviations

BCS	Block Check Sequence
BER	Bit Error Rate
BSIC	Base transceiver Station Identity Code
BSC	Base Station Controller
BSN	Block Sequence Number
BSS	Base Station System

BSSGP	BSS GRPS Protocol
BTS	Base Transceiver Station
DL	Downlink
FER	Frame Erasure Rate
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications
HTTP	Hypertext Transfer Protocol
IP	Internet Protocol
L3MM	Layer 3 Mobility Management
LLC	Logical Link Control
MAC	Medium Access Control
MS	Mobile Station
PCU	Packet Control Unit
RLC	Radio Link Control
RF	Radio Frequency
SGSN	Serving GPRS Support Node
SNDCP	Sub-network Dependent Convergence Protocol
TCP	Transmission Control Protocol
TEMS	Test Mobile System
TFI	Temporary Flow Identity
UDP	User Datagram Protocol
UL	Uplink
USF	Uplink State Flag
WAP	Wireless Application Protocol
WDP	Wireless Datagram Protocol