7

The Air-Interface of GSM

The Air-interface is the central interface of every mobile system and typically the only one to which a customer is exposed.

The physical characteristics of the Air-interface are particularly important for the quality and success of a new mobile standard. For some mobile systems, only the Air-interface was specified in the beginning, like IS-95, the standard for CDMA. Although different for GSM, the Air-interface still has received special attention. Considering the small niches of available frequency spectrum for new services, the efficiency of frequency usage plays a crucial part. Such efficiency can be expressed as the quotient of transmission rate (kilobits per second) over bandwidth (kilohertz). In other words, how much traffic data can be squeezed into a given frequency spectrum at what cost?

The answer to that question eventually will decide the winner of the recently erupted battle among the various mobile standards.

7.1 The Structure of the Air-Interface in GSM

7.1.1 The FDMA/TDMA Scheme

GSM utilizes a combination of frequency division multiple access (FDMA) and time division multiple access (TDMA) on the Air-interface. That results in a two-dimensional channel structure, which is presented in Figure 7.1. Older standards of mobile systems use only FDMA (an example for such a network is the C-Netz in Germany in the 450 MHz range). In such a pure FDMA system, one specific frequency is allocated for every user during a call. That quickly leads to overload situations in cases of high demand. GSM took into account

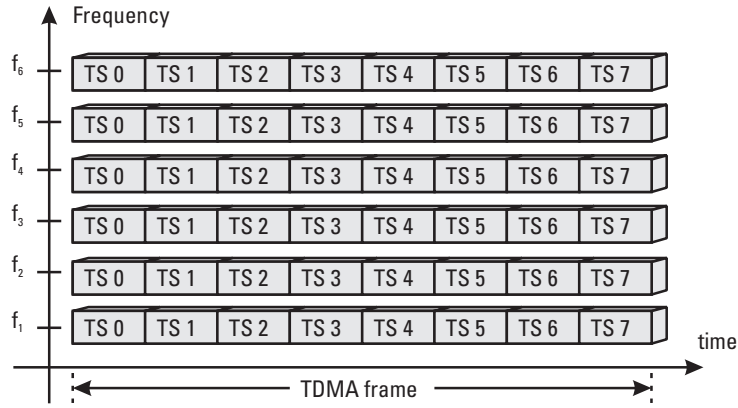

Figure 7.1 The FDMA/TDMA structure of GSM.

the overload problem, which caused most mobile communications systems to fail sooner or later, by defining a two-dimensional access scheme. In fullrate configuration, eight time slots (TSs) are mapped on every frequency; in a halfrate configuration there are 16 TSs per frequency.

In other words, in a TDMA system, each user sends an impulselike signal only periodically, while a user in a FDMA system sends the signal permanently. The difference between the two is illustrated in Figure 7.2. Frequency 1 (f1) in the figure represents a GSM frequency with one active TS, that is, where a signal is sent once per TDMA frame. That allows TDMA to simultaneously serve seven other channels on the same frequency (with fullrate configuration) and manifests the major advantage of TDMA over FDMA (f2).

The spectral implications that result from the emission of impulses are not discussed here. It needs to be mentioned that two TSs are required to support duplex service, that is, to allow for simultaneous transmission and reception. Considering that Figures 7.1 and 7.2 describe the downlink, one can imagine the uplink as a similar picture on another frequency.

GSM uses the modulation technique of Gaussian minimum shift keying (GMSK). GMSK comes with a narrow frequency spectrum and theoretically no amplitude modulation (AM) part. The Glossary provides more details on GMSK.

7.1.2 Frame Hierarchy and Frame Numbers

In GSM, every impulse on frequency 1, as shown in Figure 7.2, is called a burst. Therefore, every burst shown in Figure 7.2 corresponds to a TS. Eight bursts or TSs, numbered from 0 through 7, form a TDMA frame.

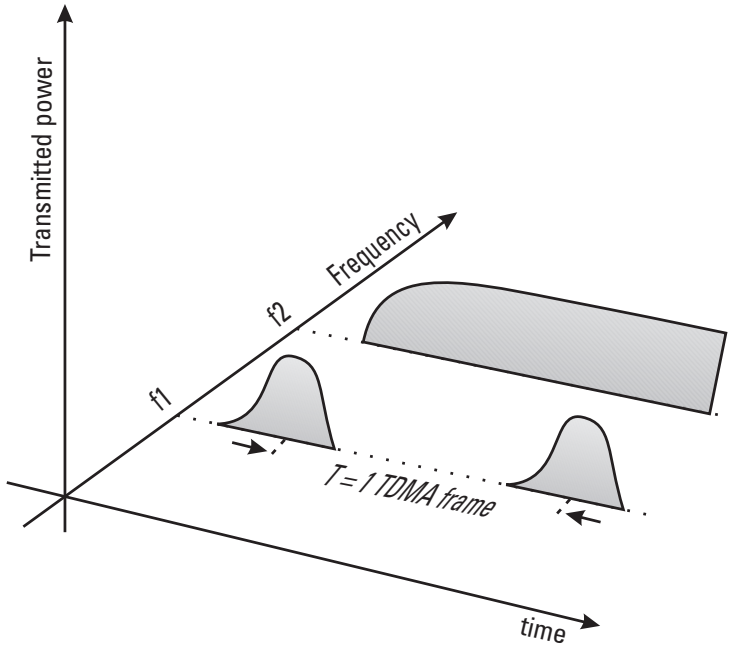

Figure 7.2 Spectral analysis of TDMA versus FDMA.

In a GSM system, every TDMA frame is assigned a fixed number, which repeats itself in a time period of 3 hours, 28 minutes, 53 seconds, and 760 milliseconds. This time period is referred to as hyperframe. Multiframe and superframe are layers of hierarchy that lie between the basic TDMA frame and the hyperframe. Figure 7.3 presents the various frame types, their periods, and other details, down to the level of a single burst as the smallest unit.

Two variants of multiframes, with different lengths, need to be distinguished. There is the 26-multiframe, which contains 26 TDMA frames with a duration of 120 ms and which carries only traffic channels and the associated control channels. The other variant is the 51-multiframe, which contains 51 TDMA frames with a duration of 235.8 ms and which carries signaling data exclusively. Each superframe consists of twenty-six 51-multiframes or fifty-one 26-multiframes. This definition is purely arbitrary and does not reflect any physical constraint. The frame hierarchy is used for synchronization between BTS and MS, channel mapping, and ciphering.

Every BTS permanently broadcasts the current frame number over the synchronization channel (SCH) and thereby forms an internal clock of the BTS. There is no coordination between BTSs; all have an independent clock, except for synchronized BTSs (see *synchronized handover* in the Glossary). An

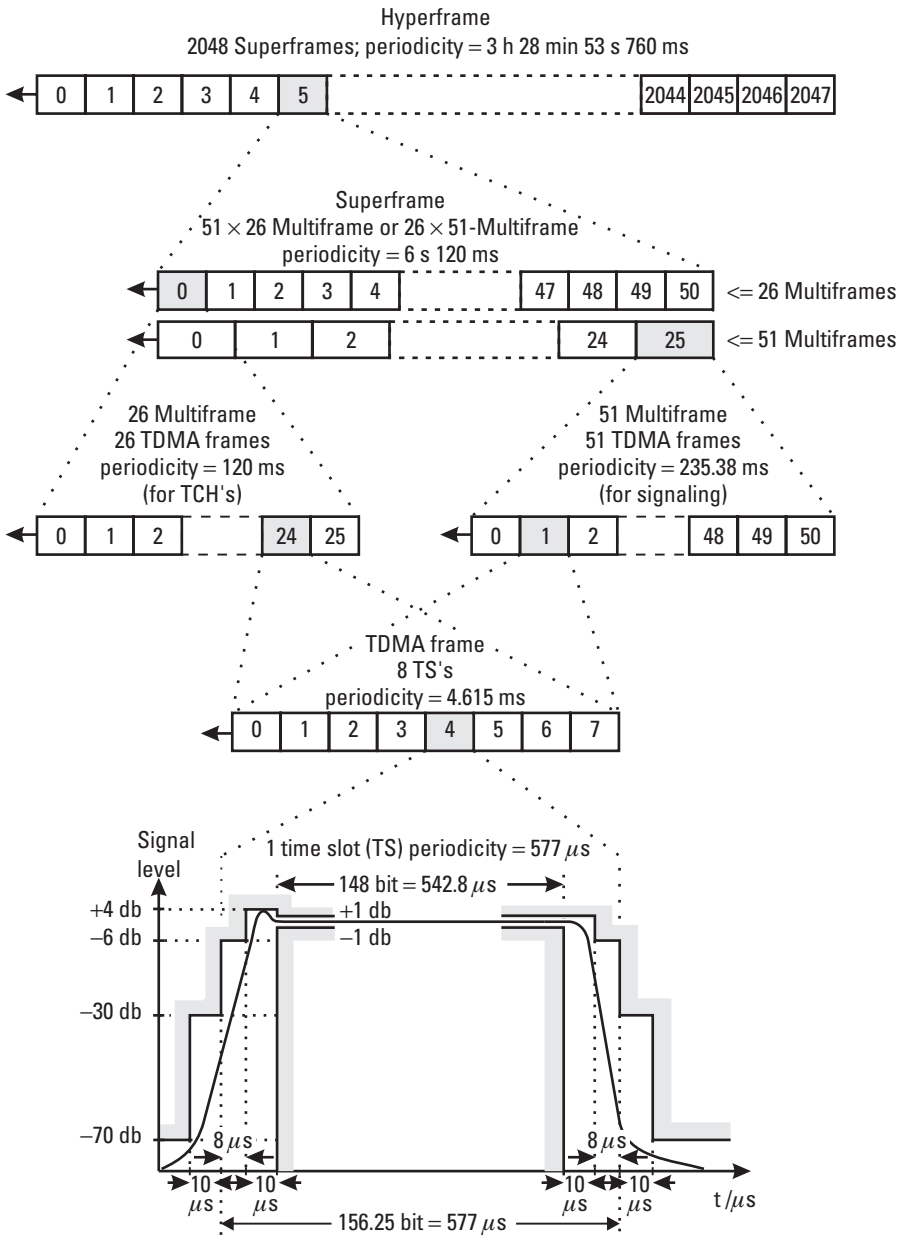

Figure 7.3 Hierarchy of frames in GSM.

MS can communicate with a BTS only after the MS has read the SCH data, which informs the MS about the frame number, which in turn indicates the

chronologic sequence of the various control channels. That information is very important, particularly during the initial access to a BTS or during handover.

Consider this example: an MS sends a channel request to the BTS at a specific moment in time, let's say frame number Y ($t = FN\ Y$). The channel request is answered with a channel assignment, after being processed by the BTS and the BSC. The MS finds its own channel assignment among all the other ones, because the channel assignment refers back to frame number Y.

The MS and the BTS also need the frame number information for the ciphering process. The hyperframe with its long duration was only defined to support ciphering, since by means of the hyperframe, a frame number is repeated only about every three hours. That makes it more difficult for hackers to intercept a call.

7.1.3 Synchronization Between Uplink and Downlink

For technical reasons, it is necessary that the MS and the BTS do not transmit simultaneously. Therefore, the MS is transmitting three timeslots after the BTS. The time between sending and receiving data is used by the MS to perform various measurements on the signal quality of the receivable neighbor cells.

As shown in Figure 7.4, the MS actually does not send exactly three timeslots after receiving data from the BTS. Depending on the distance between the two, a considerable propagation delay needs to be taken into account. That propagation delay, known as timing advance (TA), requires the MS to transmit its data a little earlier as determined by the "three timeslots delay rule."

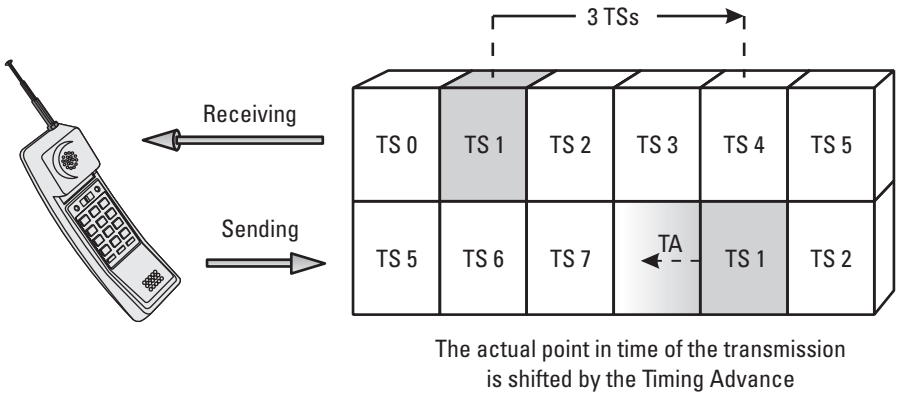

Figure 7.4 Receiving and sending from the perspective of the MS.

The larger the distance between the MS and the BTS is, the larger the TA is. More details are provided in the Glossary under *TA*.

7.2 Physical Versus Logical Channels

Because this text frequently uses the terms *physical channel* and *logical channel*, the reader should be aware of the differences between them.

- Physical channels are all the available TSs of a BTS, whereas every TS corresponds to a physical channel. Two types of channels need to be distinguished, the halfrate channel and the fullrate channel. For example, a BTS with 6 carriers, as shown in Figure 7.1, has 48 (8 times 6) physical channels (in fullrate configuration).
- Logical channels are piggybacked on the physical channels. Logical channels are, so to speak, laid over the grid of physical channels. Each logical channel performs a specific task.

Another aspect is important for the understanding of logical channels: during a call, the MS sends its signal periodically, always in a TDMA frame at the same burst position and on the same TS to the BTS (e.g., always in TS number 3). The same applies for the BTS in the reverse direction.

It is important to understand the mapping of logical channels onto available TSs (physical TSs)—which will be discussed later—because the channel mapping always applies to the same TS number of consecutive TDMA frames. (The figures do not show the other seven TSs.)

7.3 Logical-Channel Configuration

Firstly, the distinction should be made between traffic channels (TCHs) and control channels (CCHs). Distinguishing among the different TCHs is rather simple, since it only involves the various bearer services. Distinguishing among the various CCHs necessary to meet the numerous signaling needs in different situations, however, is more complex. Table 7.1 summarizes the CCH types, and the Glossary provides a detailed description of each channel and its tasks. Note that, with three exceptions, the channels are defined for either downlink or uplink only.

Table 7.1
Signaling Channels of the Air-Interface

Name	Abbreviation	Task
Frequency correction channel (DL)	FCCH	The "lighthouse" of a BTS
Synchronization channel (DL)	SCH	PLMN/base station identifier of a BTS plus synchronization information (frame number)
Broadcast common control channel (DL)	BCCH	To transmit system information 1–4, 7-8 (differs in GSM, DCS1800, and PCS1900)
Access grant channel (DL)	AGCH	SDCCH channel assignment (the AGCH carries IMM_ASS_CMD)
Paging channel (DL)	PCH	Carries the PAG_REQ message
Cell broadcast channel (DL)	CBCH	Transmits cell broadcast messages (see Glossary entry *CB*)
Standalone dedicated control channel	SDCCH	Exchange of signaling information between MS and BTS when no TCH is active
Slow associated control channel	SACCH	Transmission of signaling data during a connection (one SACCH TS every 120 ms)
Fast associated control channel	FACCH	Transmission of signaling data during a connection (used only if necessary)
Random access channel (UL)	RACH	Communication request from MS to BTS

Note: DL = downlink direction only; UL = uplink direction only.

7.3.1 Mapping of Logical Channels Onto Physical Channels

In particular, the downlink direction of TS 0 of the BCCH-TRX is used by various channels. The following channel structure can be found on TS 0 of a BCCH-TRX, depending on the actual configuration:

- FCCH;
- SCH;
- BCCH information 1–4;
- Four SDCCH subchannels (optional);
- CBCH (optional).

This multiple use is possible because the logical channels can time-share TS 0 by using different TDMA frames. A remarkable consequence of the approach is that, for example, the FCCH or the SCH of a BTS is not broadcast permanently but is there only from time to time. Time sharing of the same TS is not limited to FCCH and SCH but is widely used. Such an approach naturally results in a lower transmission capacity, which is still sufficient to convey all necessary signaling data. Furthermore, it is possible to combine up to four physical channels in consecutive TDMA frames to a block, so that it is possible for the same SDCCH to use the same physical channel in four consecutive TDMA frames, as illustrated in Figure 7.5. On the other hand, an SDCCH subchannel has to wait for a complete 51-multiframe before it can be used again.

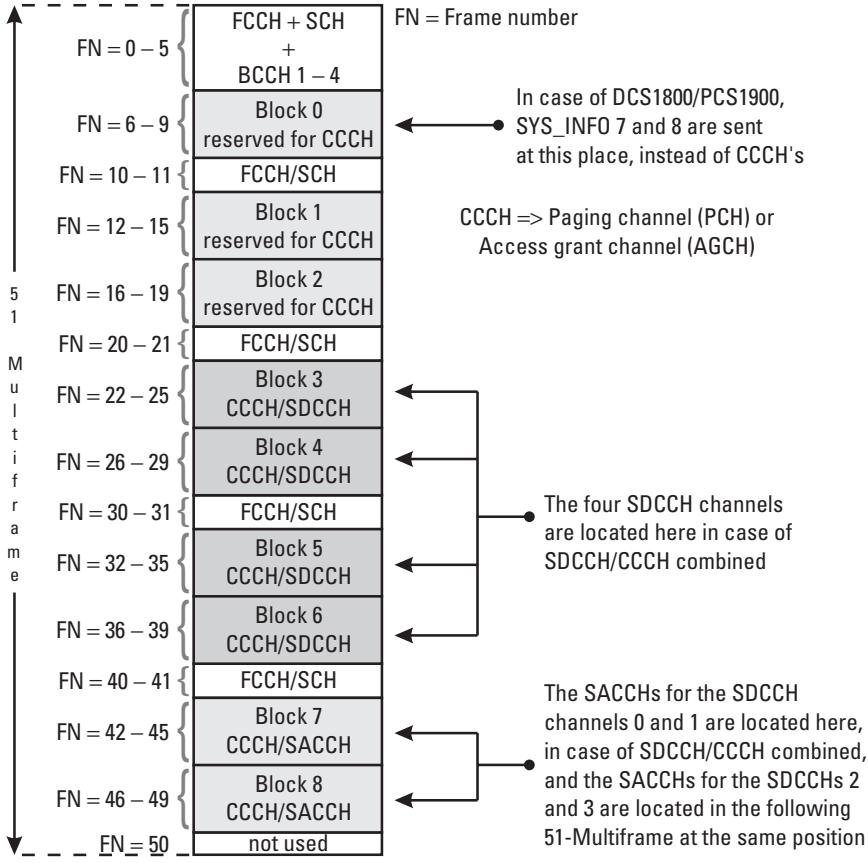

Figure 7.5 Example of the mapping of logical channels.

That clarifies another reason for the frame hierarchy of GSM. The structure of the 51-multiframe defines at which moment in time a particular control channel (logical channel) can use a physical channel (it applies similarly to the 26-multiframe).

Detailed examples are provided in Figure 7.6, for the downlink, and in Figure 7.7, for the uplink. The figures show a possible channel configuration for all eight TSs of a TRX. Both show a 51-multiframe in TSs 0 and 1, with a cycle time of 235.8 ms. Each of the remaining TSs, 2 through 7, carries two 26-multiframes, with a cycle time of $2 \cdot 120$ ms = 240 ms. That explains the difference in length between TS 0 and TS 1 on one hand and TS 2 through TS 7 on the other.

Figures 7.6 and 7.7 show that a GSM 900 system can send the BCCH SYS-INFO 1–4 only once per 51-multiframe. That BCCH information tells the registered MSs all the necessary details about the channel configuration of a BTS. That includes at which frame number a PAG_REQ is sent on the PCH and which frame numbers are available for the RACH in the uplink direction. The Glossary provides more details on the content of BCCH SYS-INFO 1–4.

The configuration presented in Figures 7.6 and 7.7 contains 11 SDCCH subchannels: 3 on TS 0 and another 8 on TS 1. SDCCH 0, 1, … refers to the SDCCH subchannel 0, 1, … on TS 0 or TS 1. The channel configuration presented in the figures also contains a CBCH on TS 0. Note that the CBCH will always be exactly at this position of TS 0 or TS 1 and occupies the frame numbers 8–11. The CBCH reduces, in both cases, the number of available SDCCH subchannels (that is why SDCCH/2 is missing in the example).

The configuration, as presented here, is best suited for a situation in which a high signaling load is expected while only a relatively small amount of payload is executed. Only the TSs 2 through 7 are configured for regular full-rate traffic.

The shaded areas indicate the so-called idle frame numbers, that is, where no information transfer occurs.

7.3.2 Possible Combinations

The freedom to define a channel configuration is restricted by a number of constraints. When configuring a cell, a network operator has to consider the peculiarities of a service area and the frequency situation, to optimize the configuration. Experience with the average and maximum loads that are expected for a BTS and how the load is shared between signaling and payload is an important factor for such consideration.

GSM 05.02 provides the following guidelines, which need to be taken into account when setting up control channels.

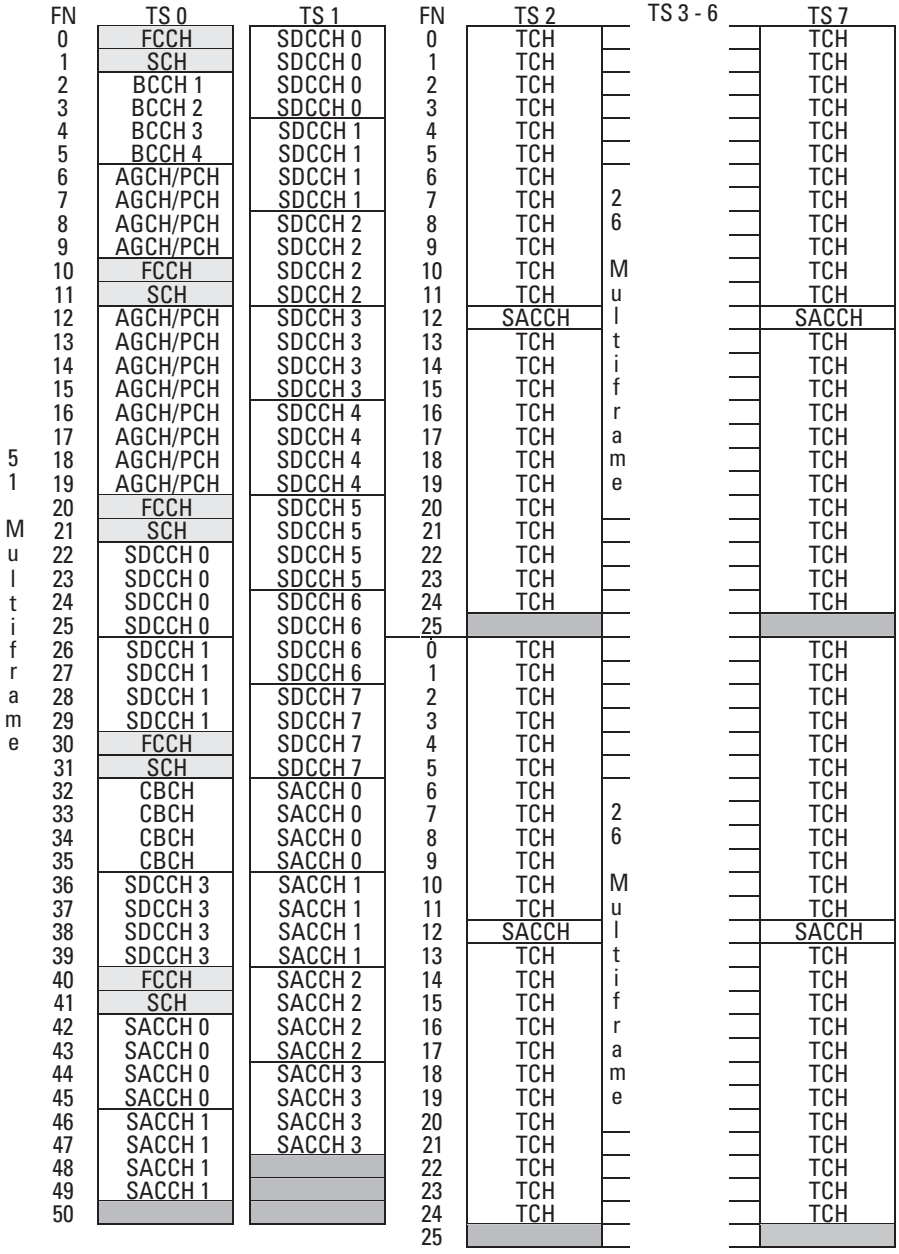

Figure 7.6 Example of the downlink part of a fullrate channel configuration of FCCH/SCH + CCCH + SDCCH/4 + CBCH on TS 0, SDCCH/8 on TS 1, and TCHs on TSs 2–7. The missing SACCHs on TS 0 and TS 1 can be found in the next multiframe, which is not shown here. There is no SDCCH/2 on TS 0, because of the CBCH.

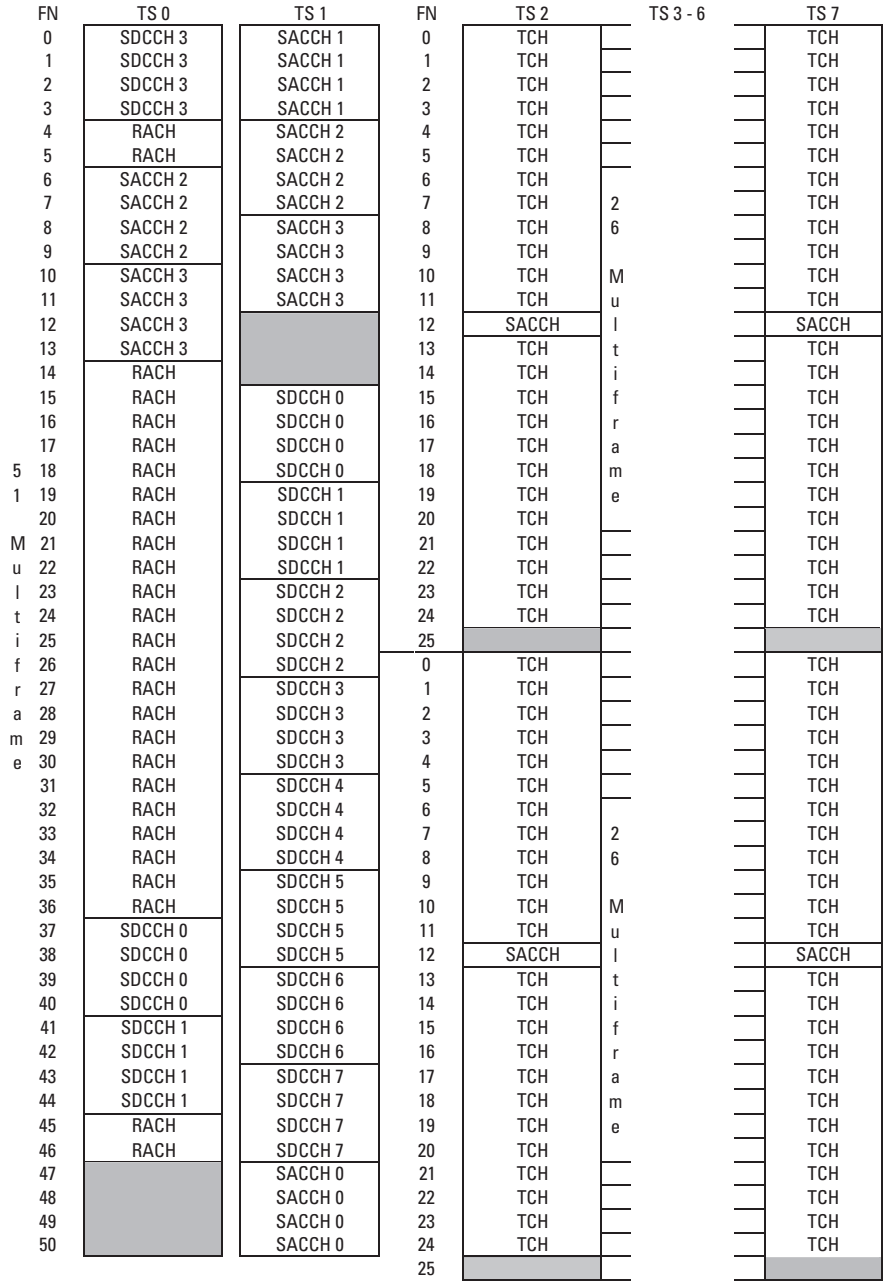

Figure 7.7 Example of the uplink part of a fullrate channel configuration. RACHs can be found only on TS 0 of the designated frame numbers. The missing SACCHs on TS 0 and TS 1 can be found in the next multiframe, which is not shown here.

- The FCCH and the SCH are always sent in TS 0 of the BCCH carrier at specific frame numbers (see Figure 7.5).
- The BCCH, RACH, PCH, and AGCH also must be assigned only to the BCCH carrier. These channels, however, allow for assignment to all even-numbered TSs, e.g., 0, 2, 4, and 6, as well as to various frame numbers.

In practice, two configurations are mainly used, which can be combined if necessary (compare Figure 7.6 and Figure 7.7):

- FCCH + SCH + BCCH + CCCH // SDCCH/8 addresses a channel configuration in which no SDCCH subchannels are available on TS 0. Eight such SDCCH subchannels are defined on TS 1. In that case, TS 1 obviously is not available as a traffic channel.
- FCCH + SCH + BCCH + CCCH + SDCCH/4 addresses a channel configuration in which all control channels are assigned to TS 0, in particular, to have TS 1 available to carry payload traffic. Because TS 0 needs to be used by the other control channels, too, it is possible to establish only four SDCCH subchannels, that is, only half the number compared to the preceding configuration.

A channel configuration is always related to a single TS and not to a complete TRX. It is not possible to combine traffic channels and SDCCHs. If necessary, a TS can be "sacrificed" to allow for additional SDCCHs.

7.4 Interleaving

The preceding descriptions were made under an assumption that is not valid for the Air-interface of GSM. That assumption is that data are transmitted in the order they were generated or received, that is, the first bit of the first (spoken) word is sent first. That is not the case for the Air-interface of GSM. Figure 7.8 illustrates the process of interleaving smaller packages of 456 bits over a larger time period, that is, distributing them in separate TSs. How the packets are spread depends on the type of application the bits represent. Signaling traffic and packets of data traffic are spread more than voice traffic. The whole process is referred to as interleaving.

The goal of interleaving is to minimize the impact of the peculiarities of the Air-interface that account for rapid, short-term changes of the quality of the

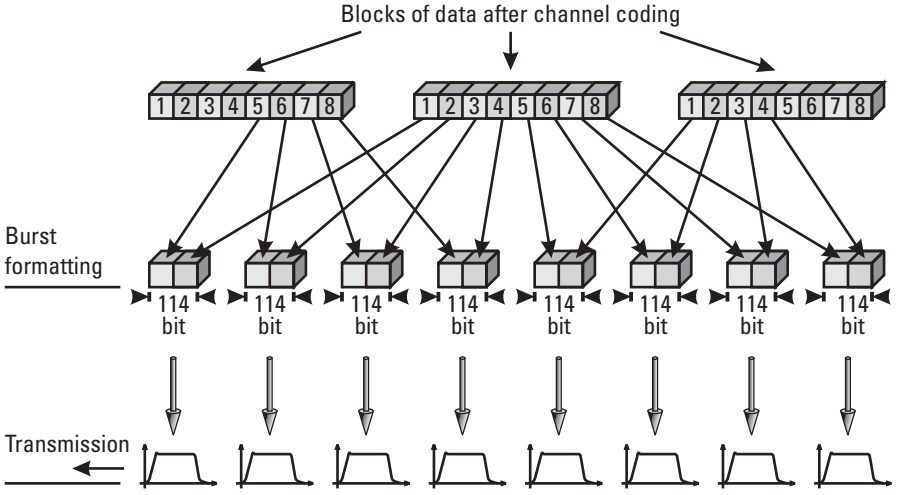

Figure 7.8 Interleaving of speech traffic.

transmission channel. It is possible that a particular channel is corrupted for a very short period of time and all the data sent during that time are lost. That could lead to loss of complete data packets of *n* times 114 bits. Interleaving does not prevent loss of bits, and if there is a loss, the same number of bits are lost. However, because of interleaving, the lost bits are part of several different packets, and each packet loses only a few bits out of a larger number of bits. The idea is that those few bits can be recovered by error-correction mechanisms.

7.5 Signaling on the Air-Interface

7.5.1 Layer 2 LAPD$_m$ Signaling

The only GSM-specific signaling of OSI Layers 1 and 2 can be found on the Air-interface, where LAPD$_m$ signaling is used. The other interfaces of GSM use already defined protocols, like LAPD and SS7.

The abbreviation LAPD$_m$ suggests that it refers to a protocol closely related to LAPD, which is correct. The "m" stands for "modified" and the frame structure already shows the closeness to LAPD. The modified version of LAPD is an optimized version for the GSM Air-interface and was particularly tailored to deal with the limited resources and the peculiarities of the radio link. All dispensable parts of the LAPD frame were removed to save resources. The

$LAPD_m$ frame, in particular, lacks the TEI, the FCS, and the flags at both ends. The $LAPD_m$ frame does not need those parts, since their task is performed by other GSM processes. The task of the FCS, for instance, to a large extent, is performed by channel coding/decoding.

7.5.1.1 The Three Formats of the $LAPD_m$ Frame

Figure 7.9 is an overview of the frame structure of $LAPD_m$. Three different formats of identical length (23 bytes) are defined; their respective uses depend on the type of information to be transferred.

- A-format. A frame in the A-format generally can be sent on any DCCH in both directions, uplink and downlink. The A-format frame is sent as a fill frame when no payload is available on an active connection, for example, in the short time period immediately after the traffic channel is connected.
- B-format. The B-format is used on the Air-interface to transport the actual signaling data; hence, every DCCH and every ACCH use this format. The maximum length of the Layer 3 information to be carried is restricted, depending on the channel type (SDCCH, FACCH, SACCH). This value is defined per channel type by the constant N201. If the information to be transmitted requires less space, this space has to be filled with fill-in octets.
- Bbis-format. For transmission of BCCH, PCH, and AGCH. There is no header in the Bbis-format that would allow for addressing or frame identification. Addressing is not necessary, since BCCH, PCH, and AGCH are CCCHs, in which addressing is not required. In contrast to the DCCH, the CCCH transports only point-to-multipoint messages.

Both frame types, the A-format and the B-format, are used in both directions, uplink and downlink. The Bbis format is required for the downlink only.

Also noteworthy is the relationship for signaling information between the maximum frame length of an $LAPD_m$ frame (= 23 byte ≡ 184 bit) and the number of input bits for channel coding (= 184 bit).

7.5.1.2 The Header of an $LAPD_m$ Frame

The Address Field

The address field starts with the bits EA and C/R, which perform the same tasks as the parameters with the same names in an LAPD frame. The same applies for SAPI, which takes on different values over the Air-interface than on

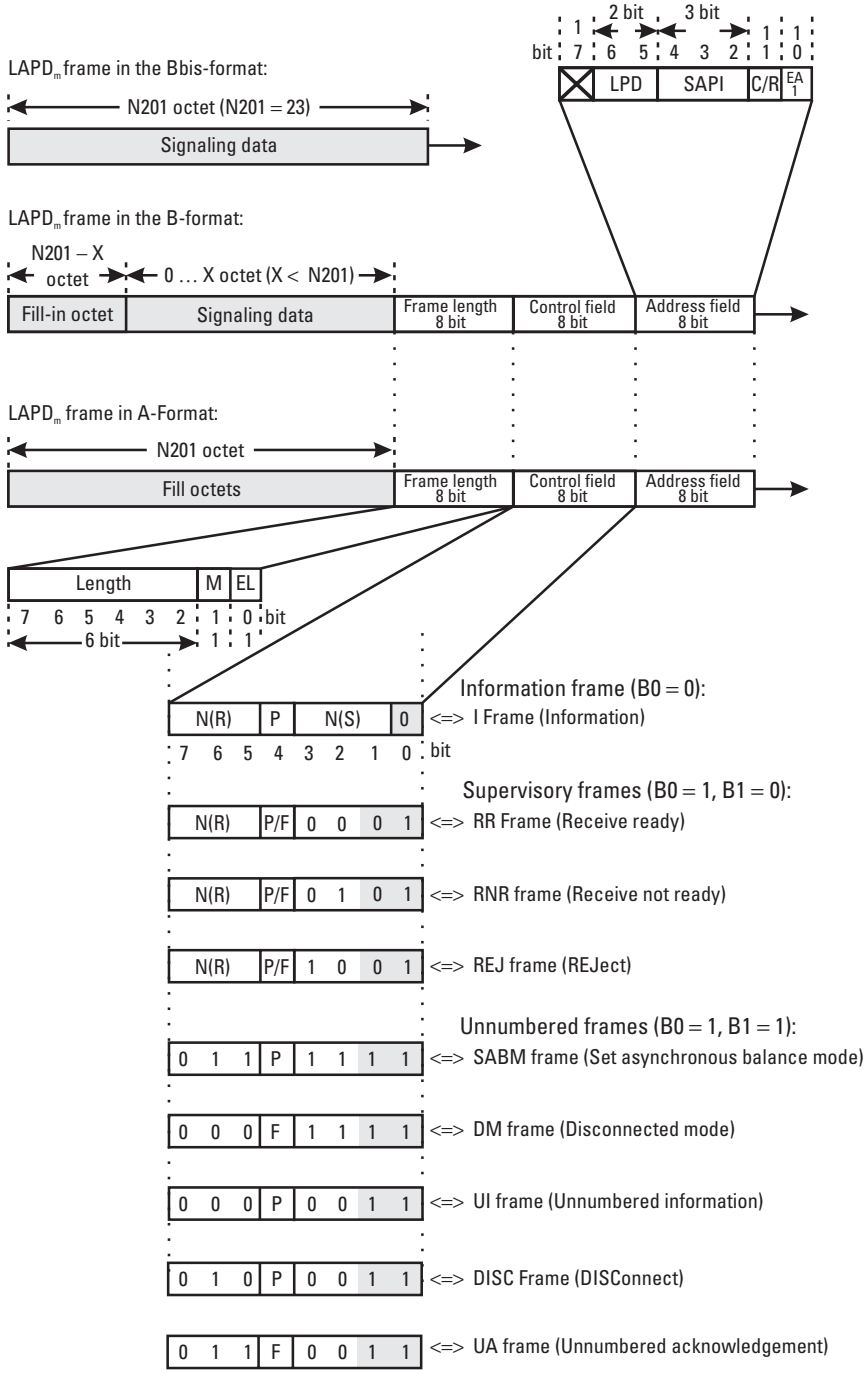

Figure 7.9 Frame format and frame type of $LAPD_m$.

the Abis-interface. Table 7.2 lists the possible values for SAPIs on the Air-interface and their uses. SAPI = 0 is used for all messages that deal with CC, MM, and RR, while SAPI = 3 is used for messages related to supplementary services and the SMS.

Furthermore, the address field of an $LAPD_m$ frame contains the 2-bit-long link protocol discriminator (LPD), which in GSM is, with one exception, always coded with 00_{bin}. The exception is the cell broadcast service (CBS), where LPD = 01_{bin}.

Control Field

The control field of an $LAPD_m$ frame is identical to that of an LAPD frame modulo 8. It defines the frame type and contains, in the case of I frames, the counters for N(S) and N(R); in the case of supervisory frames, it contains only N(R).

The *frame length indicator field* consists of three parts:

- Bit 0, the EL-bit. The EL-bit indicates if the current octet is the last one of the frame length indicator field. When this bit is set to 1, then another length indication octet follows, if set to 0, this octet is the last one. GSM does not allow the frame length indicator field to exceed one octet, and hence, the value of the EL-bit is always zero. GSM may change this restriction, if future applications require a different length.
- Bit 1, the M-bit. If entire messages are longer than the data field of the $LAPD_m$ frames allows, the information has to be partitioned and transmitted in consecutive frames. The M-bit is used in such a situation to indicate that the message was segmented and that further frames belonging to the same messages have to be expected. The M-bit of the last segment is set to zero, as illustrated in Figure 7.10.
- Bits 2–7, the length indicator. This field indicates the actual length of the information field. The value range is from zero to N201.

Table 7.2
Possible Values of SAPI on the Air-Interface

SAPI (Decimal)	Meaning
0	RR, MM, CC
3	SMS, SS

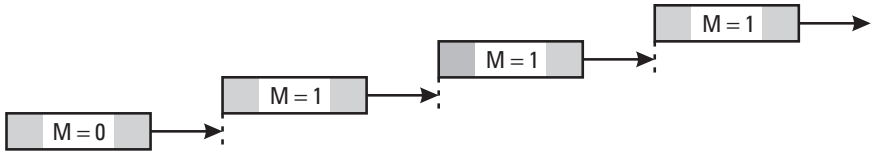

Figure 7.10 Segmentation in $LAPD_m$.

Information Field

For all three frame formats, the information field that carries signaling data consists of N201 octets, where N201 represents a value that is different for the various channel types (see *N201* in the Glossary). How many of the octets—in the case of a B-format—are actually part of Layer 3 depends on the data to be transported. It is important to note that all unused octets in case of the B-format and all octets of the A-format are so-called fill-in octets, which are coded in a precisely defined pattern. This bit pattern is different for uplink and downlink. If, for example, an SDCCH frame contains only 18 bytes of data, the remaining two bytes are occupied with fill-in octets (note that N201 for the SDCCH has a value of 20).

7.5.1.3 Differences Between LAPD and $LAPD_m$

The differences between LAPD and $LAPD_m$ are as follows:

- $LAPD_m$ frames exist in modulo 8 format only. Their control field, therefore, is always 1 octet long. The N(S) and the N(R) are in the range 0 to 7. That theoretically restricts the maximum number of unacknowledged I frames to seven.
- The address field of $LAPD_m$ is only 1 octet long and does not contain a TEI. The reason is that when a channel is already assigned, the connection on the Air-interface is always a point-to-point connection. Several simultaneous users, for example, on a terrestrial point-to-multipoint connection, do not exist, which makes the TEI superfluous.
- $LAPD_m$ frames do not contain an FCS, because channel coding and interleaving of Layer 1 already provide data security.
- $LAPD_m$ frames do not have a flag to indicate the start and end of a frame. That functionality is provided on the Air-interface by Layer 1, in particular by the burst segmentation.
- Unlike in LAPD, SABM frames and UA frames of $LAPD_m$ may even carry Layer 3 data. That saves time during connection setup.

- The maximum lengths of LAPD and $LAPD_m$ frames are very different. While LAPD frames can transport up to 260 octets of signaling data, $LAPD_m$ allows for only 23 octets. If a larger amount of data needs to be transported, segmentation has to be applied.
- $LAPD_m$ frames do not contain a length indicator (Layer 2).
- In LAPD, no fill-in octets are used when the data area is not completely occupied with signaling data.

7.5.1.4 Frame Types of $LAPD_m$

Fewer frame types are defined for the $LAPD_m$ protocol than for LAPD. The XID frame and the FRMR frame are missing in $LAPD_m$. Both frames are used for specific tasks and are not necessary in $LAPD_m$. Table 7.3 lists the frame types of $LAPD_m$ and their specific uses. As for LAPD, it is distinguished whether a frame is used to carry a command, a response, or both. $LAPD_m$ follows the definition of LAPD, that is, the P/F bit and the C/R bits are used the same way for both protocols.

Table 7.3
Frame Types of the Air-Interface

Name	Command Frame?	Answer Frame?	Possible Values of Control Field (Hex)
I-frame group:			
I	Yes	No	(0X), (2X), (4X), (6X), (8X) if even, then I frame
Supervisory-frame group			
RR	Yes	Yes	(1X)
RNR	Yes	Yes	(5X)
REJ	Yes	Yes	(9X)
Unnumbered-frame group			
DISC	Yes	No	(53) because P bit is always 1
UI	Yes	No	(03) because P bit always 0
DM	No	Yes	(0F), (1F)
SABME	Yes	No	(7F) because P bit always 1
UA	No	Yes	(73) because F bit always 1

7.5.2 Layer 3

Figure 7.11 illustrates the Layer 3 format on the Air-interface.

7.5.2.1 Protocol Discriminator

The 4-bit-long protocol discriminator (PD) is used on the Air-interface to classify all messages into groups and allows, within Layer 3, the addressing of various users, just as the message discriminator does on the Abis-interface. Every message is nonambiguously assigned to a PD or service class. A distinction between transparent and nontransparent services is possible at the same time. Supplementary services and the SMS are special, because they do not belong to CC but are still sent with the same PD. Table 7.4 lists all PDs and their service classes.

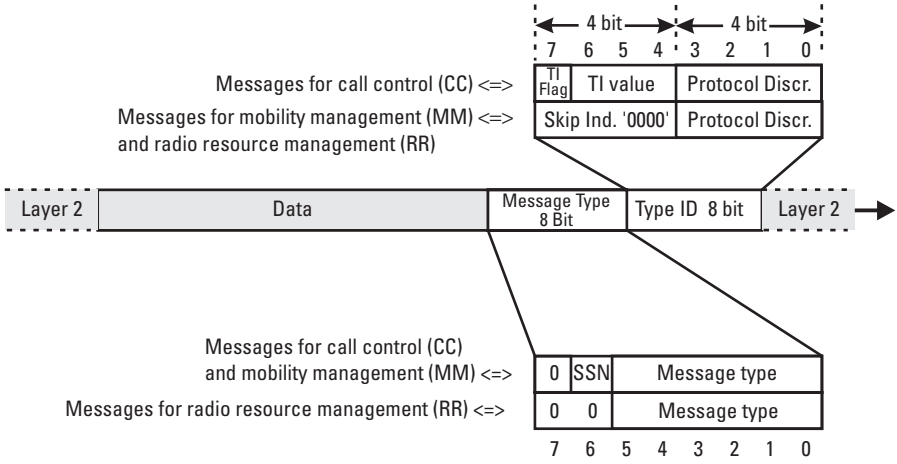

Figure 7.11 The Layer 3 format on the Air-interface.

Table 7.4
Protocol Discriminators on the Air-Interface

PD	Service Class
06	RR (radio resource management)
05	MM (mobility management)
03	CC (call control) SS (supplementary services) SMS (short-message services)

7.5.2.2 Radio Resource Management

Messages in the area of RR are necessary to manage the logical as well as the physical channels on the Air-interface. Depending on the message type, processing of RR messages is performed by the MS, in the BSS, or even in the MSC. Involvement of the BSS distinguishes RR from MM and CC.

7.5.2.3 Mobility Management

MM uses the channels that RR provides, to transparently exchange data between the MS and the NSS. From a hierarchical perspective, the MM lies above the RR, because MM data already are user data. The BSS does not, with a few exceptions, process MM messages. A typical application of MM is location update.

7.5.2.4 Call Control

Like MM, CC uses the connection that RR provides for information exchange. In contrast to MM, which is used only to maintain the mobility of a subscriber, CC is a real application that at the same time provides an interface to ISDN. (The relation between CC and ISDN is discussed in Chapter 10.)

7.5.2.5 Transaction Identifier and Skip Indicator

In CC, the PD is followed by the transaction identifier (TI); in MM and RR, the PD is followed by the skip indicator. The skip indicator in RR and MM messages is a 4-bit-long, fixed coded dummy value with 0000_{bin}. No specific task is assigned to the skip indicator. Messages in which the skip indicator is not 0000_{bin} are ignored by the receiver and indicate a transmission error.

The 4-bit-long TI, on the other hand, can distinguish among several simultaneous transactions of one MS. The format of the TI, shown in Figure 7.11, is separated into the TI flag and the TI value.

The TI flag (bit 7) is used to distinguish between the initiating side and the responding side of a transaction. For the initiating side, the TI flag is set to 0; for the responding side, it has a value of 1. Hence, in a MOC, the TI flags of all CC messages sent from the MS are set to 0. Correspondingly, the TI flags of all CC messages sent from the NSS have a value of 1. In a MTC, the reciprocal applies.

The initiating side also assigns the TI value, which can be in the range of 0 through 6. One TI value is assigned for every transaction, where it is allowed

that the MS and the NSS assign the same TI value to different transactions. The TI flag is used in that case to avoid ambiguity. Several simultaneous transactions are allowed only in the CC protocol, so neither MM nor RR require a TI.

Figure 7.12 illustrates this relation. When the MS is involved in an active call, it places the call on hold and sets up the second call.

7.5.2.6 The Message Type

The value of the protocol discriminator also determines the format of this octet (see Figure 7.11). The first six bits (bits 0 to 5) indicate the message type itself. Section 7.5.2.7 explains all the message types of the Air-interface in more detail. The format of its parameters is shown in Figure 7.13. A distinction is made between mandatory and optional parameters with fixed or variable length, which requires an information element identifier and/or a length indicator.

A special task takes bit number six of the message type. While bits 6 and 7 of the RR are fix-coded with 00_{bin}, bit 6 of MM and CC is held by the send sequence number. No special task is assigned to the send sequence number of MM and CC messages in the downlink direction and is, hence, fix-coded with 0. In the uplink direction, however, the send sequence number of MM and CC messages toggles between a value of 0 and 1. Figure 7.14 provides an example. Note that the send sequence number toggles simultaneously for both CC and MM. The change of the value of the send sequence number is significant for

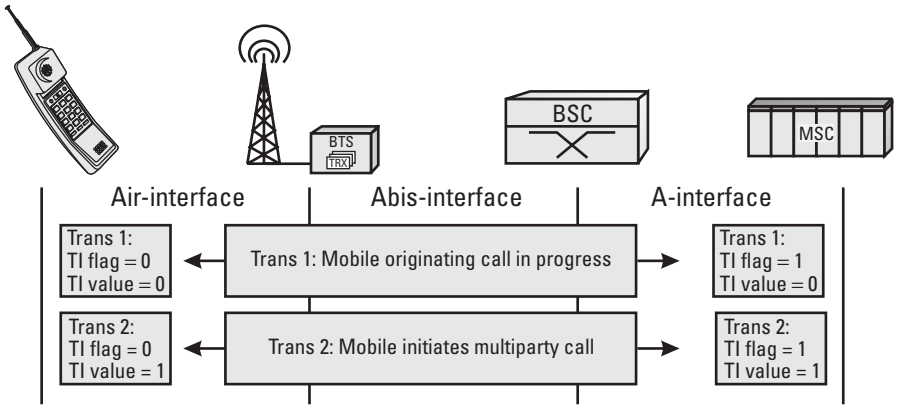

Figure 7.12 Task of the TI in case of several simultaneous CC transactions.

protocol testing, because of two possible values in the uplink direction of MM and CC messages.

7.5.2.7 The Message Type, Bits 0 Through 5

Tables 7.5, 7.6, 7.7, and 7.8 list all the messages that are defined on the Air-interface, together with brief descriptions of their tasks. The messages are ordered according to protocol groups into RR, MM, CC, and supplementary services. Note that two different hexadecimal values for the message type are possible, because of the send sequence number in bit 6 of the message type of MM and CC messages.

The characters in uppercase indicate the abbreviations used in the description.

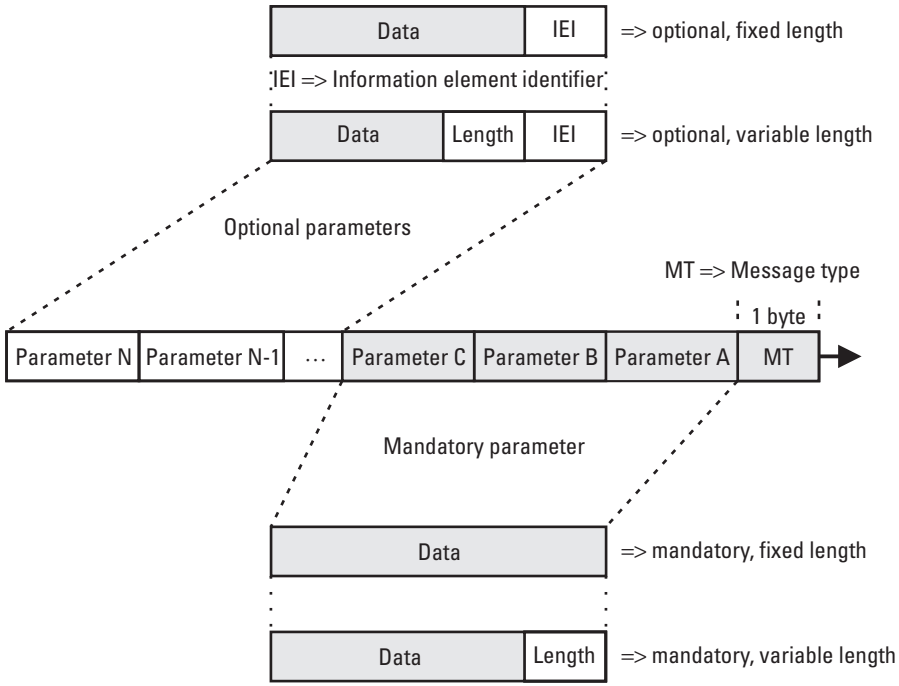

Figure 7.13 Parameter format and Air-interface signaling.

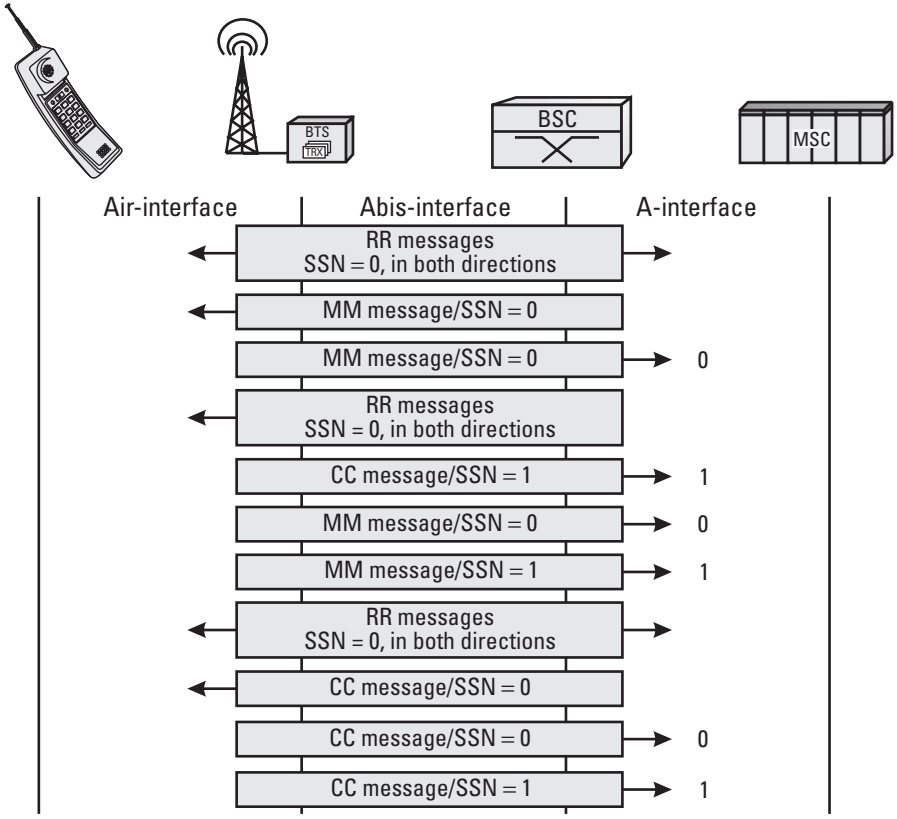

Figure 7.14 Use of the send sequence number.

Table 7.5
Radio Resource Management (Skip Indicator/Protocol Discriminator = 06)

ID (Hex)	Name	Direction	Description
-/-	CHANnel REQuest	MS → BTS	CHAN_REQ is a request of an MS for a channel when in the idle state. Although only 1 byte long this message already contains the reason for the connection request (answer to PAGING, Emergency Call, etc.) and an identifier for the channel type that the MS prefers. The CHAN_REQ has no hexadecimal message type, because the message does not conform to the regular format and is sent via an access burst.

Table 7.5 (continued)

ID (Hex)	Name	Direction	Description
-/-	HaNDover ACCess	MS → BTS	The MS sends consecutive HND_ACC messages on a new traffic channel for every handover (synchronized and nonsynchronized). The only exception is the intra-BTS handover via ASS_CMD. Like the CHAN_REQ, the HND_ACC does not follow the standard format and is sent in an access burst to the BTS. The handover reference is the only information that HND_ACC contains and is assigned with the HND_CMD message to allow for identification of the "correct" MS during BTS access.
02	SYStem INFOrmation 2bis	BTS → MS	The data area of the SYS_INFO 2 is not large enough to allow for distinction of the larger number of channels of DCS 1800, PCS 1900, and also GSM900 with extended band. Hence, SYS_INFO 2bis and 2ter were defined to broadcast, in particular, the frequencies of the neighbor cells, which do not fit into SYS_INFO 2
03	SYStem INFOrmation 2ter	BTS → MS	See SYS_INFO 2bis
05	SYStem INFOrmation 5bis	BTS → MS	The same restrictions for SYS_INFO 2 also apply to SYS_INFO 5, which had to be extended by SYS_INFO 5bis and 5ter to accommodate the greater number of channels of DCS 1800, PCS 1900, and GSM900 with extended band. Hence, SYS_INFO 5bis and 5ter mainly transport the BCCH frequencies of the neighboring cells, which do not fit into SYS_INFO 5. The messages are sent to the MS over the SACCH when an active connection exists.
06	SYStem INFOrmation 5ter	BTS → MS	See SYS_INFO 5bis
0A	PARTial RELease	BTS → MS	When an MS has activated two radio channels at the same time, and CC wants to release one channel, a PART_REL message is sent. For the time being, this is defined only for two halfrate channels.
0D	CHANnel RELease	BTS → MS	The CHAN_REL message is used when a connection is disconnected, to release the radio resources on the air interface. Cause 0 is used for normal clearing; for abnormal clearing, for instance, cause 1 is used.
0F	PARTial RELease COMplete	MS → BTS	With this message, the MS confirms receipt and processing of a PART_REL message.

Table 7.5 (continued)

ID (Hex)	Name	Direction	Description
10	CHANnel MODe MODify	BTS → MS	CHAN_MOD_MOD is sent by the network to the MS, to modify the transmission parameters of Layer 1 (change the transmission rate).
12	RR STATUS	MS ↔ BTS	A RR_STATUS message with an appropriate error cause is sent when one side receives an RR that has an error in Layer 3. These kind of protocol errors happen, for example, in case of bit errors on the air interface.
13	CLASSmark ENQuiry	BTS → MS	The network requests the technical identification (power class, available encryption algorithms A5/X, SMS capability, etc.) from the MS. The network expects a CLASS_CHANGE message as a response.
14	FREQuency REDEFinition	BTS → MS	The FREQ_REDEF message allows the network to change the configuration of an existing connection, e.g., the hopping sequence in frequency hopping.
15	MEASurement REPort	MS → BTS	MEAS_REP transfers the current measurement results of the MS to the BTS (uplink measurements). These measurements contain the sending levels of the serving cell and of the neighboring cells. In the case of an active connection, a MEAS_REP is sent to the BTS every 480 ms via the SACCH. The BTS forwards the MEAS_REP to the BSC, embedded in its own measurement results (MEAS_RES).
16	CLASSmark CHANGE	MS → BTS	The MS sends this message when the classmark changes (e.g., when a handheld phone is connected to a booster in a car) or when a request is made by the network (CLASS_ENQ). It contains the current technical capabilities of the MS.
17	CHANnel MODe MODify ACKnowledge	MS → BTS	The MS confirms with CHAN_MOD_MOD_ACK the change to another transmission mode that was requested with CHAN_MOD_MOD.
18	SYStem INFOrmation 8	BTS → MS	See SYS_INFO 7.
19	SYStem INFOrmation 1	BTS → MS	Contains the access rights and frequencies of a BTS. The Glossary provides an example for a BCCH/SYS_INFO 1.
1A	SYStem INFOrmation 2	BTS → MS	Transmission of neighbor cell frequencies, access rights (e.g., access control class), and network color code (NCC). The Glossary provides an example of BCCH/SYS_INFO 2.

Table 7.5 (continued)

ID (Hex)	Name	Direction	Description
1B	SYStem INFOrmation 3	BTS → MS	Identification of the BTS (cell identity) and the location area and further information about organization of the CCCHs within the BTS. The Glossary provides an example of a BCCH/SYS_INFO 3.
1C	SYStem INFOrmation 4	BTS → MS	SYS_INFO 4 only repeats information of data already sent in the SYS_INFOs 1 - 3.
1D	SYStem INFOrmation 5	BTS → MS	The BTS uses SYS_INFO 5 (via SACCH) to inform the MS, during an active connection, about the BCCH frequencies of the available neighbor cells. This is particularly important after a handover when the MS cannot read the SYS_INFOs 1–4 of the new BTS.
1E	SYStem INFOrmation 6	BTS → MS	During an active connection, the current BTS (serving cell) provides the MS with all the necessary data of the serving cell by means of the SYS_INFO 6 (via SACCH).
1F	SYStem INFOrmation 7	BTS → MS	SYS_INFO 7 and 8 are used only for DCS1800 and PCS1900 to provide the registered MSs with additional information to access the serving cell (cell selection parameters).
21	PAGing REQuest Type 1	BTS → MS	Three different PAG_REQ messages were defined for activation of the MS in the case of an MTC. The difference between the messages lies simply in the number of MSs that can be paged simultaneously with one message (PAG_REQ 1 allows paging of two MSs, PAG_REQ 2 allows paging of three MSs, PAG_REQ 3 allows paging of four MSs). Consequently, the according number of IMSIs/TMSIs are contained in a PAG_REQ. Note that the IMSI is not contained in the PAG_REQ if a TMSI is assigned, even though the PAGING message on the A-interface contains both parameters.
22	PAGing REQuest Type 2	BTS → MS	
24	PAGing REQuest Type 3	BTS → MS	
27	PAGing ReSPonse	MS → BTS	PAG_RSP is the first message sent by the MS on the SDCCH to the BTS in an MTC. PAG_RSP corresponds to the CM_SERV_REQ message of a MOC.
28	HaNDover FAIlure	MS → BTS	After an unsuccessful handover initiated by a HND_CMD, the MS sends a HND_FAI over the still existing connection to the old BTS.
29	ASSignment COMplete	MS → BTS	The MS confirms that it successfully changed to the (new) traffic channel, that is, the one previously assigned by an ASS_CMD message.

Table 7.5 (continued)

ID (Hex)	Name	Direction	Description
2B	HaNDover CoMmanD	BTS → MS	Channel assignment for a handover in which the BTS changes is always performed with HND_CMD; in an intra-BTS handover, the HND_CMD can be used. The message contains a description of the new traffic channel and the handover reference.
2C	HaNDover COMplete	MS → BTS	After successful handover initiated by a HND_CMD, the MS responds to the BTS with a HND_COM.
2D	PHYSical INFOrmation	BTS → MS	PHYS_INFO is the only message actually generated by the BTS. It is used in case of a nonsynchronized handover and is sent to the MS on the new channel *Ny1* times. The content of the PHYS_INFO consists of the TA that the MS has to use initially.
2E	ASSignment CoMmanD	BTS → MS	Assignment of a traffic channel in case of an intracell handover or during call setup.
2F	ASSignment FAIlure	MS → BTS	The MS was not successful in changing to the channel specified in the ASS_CMD message. It has, therefore, changed back to the previously used channel and reports the failed access in a ASS_FAI message.
32	CIPHering MODe COMplete	MS → BTS	The MS confirms that a CIPH_MOD_CMD was received and that it has changed to the cipher mode.
35	CIPHering MODe CoMmanD	BTS → MS	The content of the CIPH_MOD_CMD message originates from the VLR. It is part of the ENCR_CMD message on the Abis-interface. The BTS informs the MS with CIPH_MOD_CMD that all data in both, uplink, and downlink are to be encrypted. The only content is the information as to which encryption algorithm A5/X shall be used.
39	IMMediate ASSignment EXTended	BTS → MS	The task of the IMM_ASS_EXT message is similar to that of the IMM_ASS_CMD message. The difference between the two is that the IMM_ASS_EXT message allows assignment of an SDCCH simultaneously for two MSs. That allows the network to reduce the number of messages. It is particularly helpful when the number of available AGCHs is low.
3A	IMMediate ASSignment REJect	BTS → MS	The BSC may answer a CHAN_REQ message with IMM_ASS_REJ if no SDCCHs are available. In this case, no channel is assigned and the MS is informed about a waiting period, during which it may not send a subsequent CHAN_REQ.

Table 7.5 (continued)

ID (Hex)	Name	Direction	Description
3B	ADDitional ASSignment	BTS → MS	There are some cases in which it may become necessary to assign a second halfrate traffic channel when one halfrate channel is already established, for example, to extend the bandwidth of the current connection for data transfer. In that case, the network sends to the MS an ADD_ASS message describing the new channel.
3F	IMMediate ASSignmnent CoMmanD	BTS → MS	The BSC uses the IMM_ASS_CMD to assign an SDCCH to the MS after a CHAN_REQ message was received. IMM_ASS_CMD is always sent on an AGCH. The message has to be distinguished from ASS_CMD, which is used to assign a traffic channel.

Table 7.6
Mobility Management (Skip Indicator/Protocol Discriminator = 05)

ID (Hex)	Name	Direction	Description
01/41	IMSI DETach INDication	MS → BTS	If IMSI attach/detach is allowed in the PLMN, then every time the MS is switched off the MS sends a IMSI_DET_IND to the MSC/VLR. This allows to more quickly reject an incoming call, or apply secondary call treatment, i.e., without sending PAG_REQ's first.
02	LOCation UPDating ACCept	BTS → MS	The MSC/VLR confirms a successful Location Update with a LOC_UPD_ACC. In some cases the LOC_UPD_ACC is used to assign a new TMSI as well.
04	LOCation UPDating REJect	BTS → MS	If a Location Update is not successful, (e.g., HLR is not reachable, IMSI or TMSI are unknown, etc.), then the MSC/VLR terminates the process with a LOC_UPD_REJ.
08/48	LOCation UPDating REQuest	MS → BTS	The MS sends the LOC_UPD_REQ to the MSC/VLR when it changes the Location Area, when Periodic Location Update is active, and when the MS is switched on again (with active IMSI attach/detach). LOC_UPD_REQ is part of the Location Update procedure.
11	AUTHentica-tion REJect	BTS → MS	The AUTH_REJ message is used to inform the MS that authentication was not successful if the MSC/VLR found that the result for SRES from the MS was incorrect.

Table 7.6 (continued)

ID (Hex)	Name	Direction	Description
12	AUTHentication REQuest	BTS → MS	The MSC/VLR sends an AUTH_REQ message during connection setup, in order to authenticate the MS. The only parameter is RAND.
14/54	AUTHentication ReSPonse	MS → BTS	Answer to AUTH_REQ. It contains the authentication result SRES, which was determined by applying the values of K_i and RAND to the algorithm A3.
18	IDENTity REQest	BTS → MS	Although IDENT_REQ generally allows to request all three identification numbers from the MS, (IMSI, TMSI, and IMEI,) it is typically used by the Equipment Identity Register to request the IMEI only.
19/59	IDENTity ReSPonse	MS → BTS	IDENT_RSP is the answer to IDENT_REQ. The MS provides the network with the requested identification numbers (IMSI, TMSI, IMEI), which were requested in the IDENT_REQ message.
1A	TMSI REALlocation CoMmanD	BTS → MS	For every new connection, the VLR assigns a new TMSI to the MS in order to make tracking and interception of a subscriber more difficult. For this purpose, after the ciphering is active, the TMSI_REAL_CMD message is sent to the MS at any arbitrary position within the scenario.
1B/5B	TMSI REALlocation COMplete	MS → BTS	The MS confirms the receipt of a TMSI with a TMSI_REAL_COM.
21	CM SERVice ACCept	BTS → MS	Is used by the MSC if ciphering is not active or after the establishment of a second simultaneous CC connection. CM_SERV_ACC confirms to the MS that the service request, sent to the MSC in a CM_SERV_REQ message, was processed and accepted.
22	CM SERVice REJect	BTS → MS	The service request in which the MS has sent in a CM_SERV_REQ message is rejected by the MSC. The reason (e.g., overload) is provided.
23/63	CM SERVice ABOrt	MS → BTS	Is sent if a MS wants to terminate a MM connection. The CM_SERV_ABO can only be sent during a very narrow time window, because this message can only be used prior to the fist CC message sent.
24/64	CM SERVice REQuest	MS → BTS	The MS sends a CM_SERV_REQ at the beginning of every mobile originated connection in order to provide its identity (IMSI/TMSI) to the NSS, and to specify the service request in more detail (activation SS, MOC, Emergency Call, and SMS).

Table 7.6 (continued)

ID (Hex)	Name	Direction	Description
28/68	CM REeStab-lishment REQuest	MS → BTS	An option in GSM is to allow for a call reestablishment in case of a dropped connection. In these cases, first a CHAN_REQ has to be sent to the BTS and then it is tried with the CM_RES_REQ to reestablish an RR connection for the still existing and active MM and CC connection.
29	ABORT	BTS → MS	Is sent to the MS in order to release all MM connections. A possible reason is that the mobile equipment was identified as stolen (IMEI check). If this is actually the reason for sending ABORT, then the mobile equipment automatically blocks the Subscriber Identity Module. The SIM can, however, after switching off/on be used again.
31/71	MM STATUS	MS ↔ BTS	If one side receives a message for Mobility Management, which contains a protocol error in Layer 3, then an MM STATUS message with the respective error cause is sent. This kind of protocol error may be caused by bit errors on the Air-interface.

Table 7.7
Call Control (Transaction Identifier/Protocol Discriminator = X3)

ID (Hex)	Name	Direction	Description
01/41	ALERTing	MS ↔ BTS	The MSC sends this message in case of a Mobile Originating Call to the MS. In case of a Mobile Terminating Call, the MS sends an ALERT to the MSC. ALERT corresponds to the Address Complete Message (ACM) of ISUP and is responsible for the generation of a ring back tone at the receiving end. ALERT is always sent to that side of the call, which initiated it. This is important for protocol analysis.
02	CALL PROCeeding	BTS → MS	Is sent by the MSC in case of a Mobile Originating Call, in order to inform the MS that the address information which the MS has sent to the MSC in the SETUP message was received and processed. From the perspective of the MSC, CALL_PROC can be regarded as a confirmation that the ISUP Initial Address Message (IAM) was sent. The consequence for the MS is that the MSC does not need, or is not even able to process additional address information.

Table 7.7 (continued)

ID (Hex)	Name	Direction	Description
03	PROGRESS	BTS → MS	If, for a Mobile Originating Call, interworking or transport of inband signaling should become necessary, then the PROGRESS message is sent instead of ALERT. Examples are calls to automated information services or voice-mail boxes. In this case, the PROGRESS message can be regarded as a substitute for ALERT.
05/45	SETUP	MS ↔ BTS	When initiating a Mobile Originating Call, this message is sent by the MS to the MSC. The most important information are the address information of the called party and the type of connection, which is requested (Bearer Capabilities). In case of a Mobile Terminating Call, the MSC sends a SETUP message to the MS. When CLIP (Calling Line Identification Presentation) is active for the called party and is not restricted by the calling party, then the SETUP message also contains the directory number of the caller. The SETUP message is, furthermore, used to activate the Call Waiting tone (Supplementary Service) at the MS.
07/47	CONnect	MS ↔ BTS	The MSC sends this message during a Mobile Originating Call to the MS, to indicate that the connection was successfully established. The MS receiving the CON message corresponds to the MSC receiving the ISUP Answer Message (ANM). The MS sends a CON message to the MSC in case of a mobile terminanting call, as soon as the called party accepts the call.
08/48	CALL CONFirmed	MS → BTS	After receiving a SETUP message during a Mobile Terminating Call scenario, the MS confirms to the MSC in a CALL_CONF that it is able to establish the requested connection (Bearer Service, halfrate/fullrate, baud rate, etc.).
0E/4E	EMERGency SETUP	MS → BTS	This message is sent by the MS in case of an Emergency Call instead of a regular SETUP to carry address information.
0F/4F	CONnect ACKnowledge	MS ↔ BTS	CON_ACK is acknowledgment for a CON message. A call set up is regarded to be successful only after this message was sent. In particular charging starts typically with the CON_ACK message.

Table 7.7 (continued)

ID (Hex)	Name	Direction	Description
10/50	USER INFOrmation	MS ↔ BTS	It is possible in some cases to directly exchange data between the MS and its peer (e.g., ISDN or other MS). The maximum length of the transported payload is 128 octet, within GSM. For transport between GSM and some outside network, this maximum length may be restricted even further, depending on the capabilities of that other network (between 32 octet and 128 octet).
13/53	MODify REJect	MS ↔ BTS	MOD_REJ is the negative response to a MOD message. If the MS is unable to perform the adaptation which was requested by the peer, then the MS or the MSC respectively answers with a MOD_REJ. The reject cause is included in the message.
17/57	MODify	MS ↔ BTS	In some cases, it may become necessary to change the transmission parameters of an existing connection. This applies in particular, when a change from speech to data is made (Bearer Services 61 and 81). The MOD message carries out this task.
18/58	HOLD	MS → BTS	The HOLD message is used to put a call on hold when the user of a MS, while engaged in an active call, receives a second incoming call or wants to set up another call (Multiparty). Then the HOLD message is sent to the MSC. Hold is also the name of the related Supplementary Service.
19	HOLD ACKnowledge	BTS → MS	Acknowledgment by the MSC that a call was placed in the hold state after a HOLD message was received.
1A	HOLD REJect	BTS → MS	The MSC was unable to place a call into hold state. Therefore, the HOLD message is answered with a HOLD_REJ. The reason for this rejection is given in the cause value.
1C/5C	RETRIEVE	MS → BTS	The MS sends this message in order to reactivate a connection which was previously placed on hold.
1D	RETRIEVE ACKnowledge	BTS → MS	The MSC confirms that it has received and processed the RETRIEVE message. The call which was placed on hold is now active again.
1E	RETRIEVE REJect	BTS → MS	It is not possible to switch back to a call that was put on hold. The RETRIEVE request gets a negative response.

Table 7.7 (continued)

ID (Hex)	Name	Direction	Description
1F/5F	MODify COMplete	MS ↔ BTS	MOD_COM is the acknowledgment of a MOD message. Depending on the direction, MOD_COM is sent at different points in a scenario. The MSC sends MOD_COM only after the requested adaptation has been performed. The MSC sends this message already after receiving and accepting the MOD message.
25/65	DISConnect	MS ↔ BTS	Is used either by the MSC or the MS, to terminate an existing CC connection. The DISC message always contains a cause value, which indicates the reason why the connection was disconnected. When the call is terminated regularly, the cause value "16" is sent, which stands for 'normal clear'. Another value in case of problems is e.g., cause 47 = Resources unavailable. Please be advised that when analyzing trace files, even in case of errors the DISC message may carry a normal clear. This is the case when the problem was not detected by call control.
2A/6A	RELease COMplete	MS ↔ BTS	REL_COM is the answer to a REL message and the acknowledgment that the CC resources have been released. REL_COM is always sent by that side, which had previously sent the DISC message. Like for REL, also for REL_COM there exists an ISUP message with the same name.
2D/6D	RELease	MS ↔ BTS	Because of the fact that signaling in GSM is related to ISDN, there are some similarities in the CC protocol between the two. The REL message corresponds directly to an ISUP message with the same name, which in the case of ISDN is responsible for terminating a connection. The same functionality provides this message in GSM, namely to release the CC resources. The relationship is illustrated in Chapter 12, "Scenarios".
31/71	STOP DTMF	MS → BTS	It is possible to use DTMF signaling with a MS. For this purpose, a START_DTMF message is sent to the MSC when the user presses a button on the keypad. This tells the MSC to generate the respective DTMF sound and send it inband to the peer entity (ISDN, PSTN) When the user releases the button, a STOP_DTMF message is sent to the MSC which triggers the MSC to stop sending the respective tone.

Table 7.7 (continued)

ID (Hex)	Name	Direction	Description
32	STOP DTMF ACKnowledge	BTS → MS	Acknowledgment by the MSC that a STOP_DTMF message was received and sending of the DTMF tone was stopped.
34/74	STATUS ENQuiry	MS ↔ BTS	Both MS and MSC may use STATUS_ENQ to inquire about the current state of Call Control in the peer entity. The peer has to answer the STATUS_ENQ with a STATUS message otherwise the connection is torn down.
35/75	START DTMF	MS → BTS	The MS uses START_DTMF to send ASCII coded DTMF tones to the MSC. The only content of a START_DTMF message is the ASCII value of the respective button, which was pressed at the MS. This is for example 31hex when the '1' button was pressed. A START DTMF message can only be sent in a traffic channel during an active connection. Please note that it is not possible to transmit an analog DTMF tone between the MS and the MSC, only the START_DTMF message. The tone, which can be heard at the MS at the same time is generated in the MS. The Glossary provides a detailed description on the transmission of DTMF tones.
36	START DTMF ACKnowledge	BTS → MS	START_DTMF_ACK is the acknowledgment of the MSC that a START_DTMF message was received. When the MSC sends the START_DTMF_ACK, it simultaneously sends an analog DTMF tone which is sent inband in a traffic channel towards the PSTN/ISDN. The duration of the tone is determined by when a STOP_DTMF message is received .
37	START DTMF REJect	BTS → MS	When the MSC is unable to process the START_DTMF, then it sends a START_DTMF_REJ message to the MS. The respective reason is included in the cause value.
39/79	CONGESTion CONTROL	MS ↔ BTS	This message may be used by both sides, in order to activate flow control for data which is transported within USER_INFO messages.
3D/7D	STATUS	MS ↔ BTS	A STATUS message can be sent if protocol errors in the area of Call Control are detected or if a STATUS_ENQ has to be answered. Such an error situation can occur, in particular, when misinterpretations of CC messages occur, because of bit errors (refer also to MM_STATUS and RR_STATUS).

Table 7.7 (continued)

ID (Hex)	Name	Direction	Description
3E/7E	NOTIFY	MS ↔ BTS	The NOTIFY message is used in case of an active connection to inform the peer entity about a incident in the area of Call Control. Example: When a GSM subscriber is placed on Hold because the other party intends to accept or establish another call, then the MSC sends a NOTIFY message to that MS.

Table 7.8
Supplementary Services (Transaction Identifier/Protocol Discriminator = XB)

ID (Hex)	Name	Direction	Description
2A/6A	RELease COMplete	MS ↔ BTS	Although already presented for the Call Control, the REL_COM message shall be separately presented for Supplementary Services. If a connection was established because of a Supplementary Services request, then this connection is released by sending a REL_COM message. [GSM 04.10, GSM 04.80]
3A/7A	FACILITY	MS ↔ BTS	The FACILITY message may be used by both the MS as well as the NSS. The content of this message is transparent data for Supplementary Services. Please note that almost all CC messages contain an optional information element, the 'Facility', with which SS information can be transported without requiring a FACILITY-message. [GSM 04.10, GSM 04.80]
3B/7B	REGISTER	MS ↔ BTS	The REGISTER message is needed for the activation or inquiry of call-independent supplementary services. Example: the activation of Call Forwarding. In this case, sending of a REGISTER message implies that a new Transaction Identifier is assigned and the dialog between MS and the network is established. [GSM 04.10, GSM 04.80]