GSM

The GSM System for Mobile Communications

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and a counter is incremented and decremented according to the validity of each block. A link failure is reported to the upper layers when the counter (whose initial value *RADIO_LINK_TIMEOUT* is set by the operator) reaches zero.

Next comes the frame acknowledgement and repetition function, which supports a very high performance in terms of removing remaining errors. None of the three protocols studied here makes use of forward error correction capabilities (such features are usually considered to be in the physical layer). All three use HDLC-like mechanisms for backward error correction, with a choice between two modes:

- the non-acknowledged mode, in which frames are transmitted once, whatever the outcome at the receiver end;
- the acknowledged mode, ensuring correction of erroneous frames by repetition.

The two modes coexist in all three protocols. One may wonder what is the use of the non-acknowledged mode, if better error performance is available using the acknowledged mode. But the choice is not completely black-and-white. For example, for the recurrent measurement messages sent by the mobile station over the radio and Abis interfaces, the non-acknowledged mode is more adequate than the acknowledged one. Not only does a loss not cause any great damage, but furthermore, it is better for the receiver to get a new (and up-to-date) measurement report in this case rather than to receive a repeated (and obsolete) message. So measurement reports are actually transmitted using the non-acknowledged mode on the radio and Abis interfaces. A few other messages are also sent unacknowledged, such as the answer to a handover access (e.g., the RIL3-RR PHYSICAL INFORMATION messages) and the general information sent by the network to mobile stations on the SACCH (e.g., the RIL3-RR SYSTEM INFORMATION TYPE 5 AND 6 messages—all these messages come from procedures cited in Chapter 6), not to mention all the messages sent on a point-to-multipoint channel (BCCH or PAGCH). Apart from these messages, the vast majority of messages sent on dedicated channels are sent in acknowledged mode.

Acknowledgement and repetition is based on a cyclic frame numbering, which enables the recipient to detect possible repetitions and/or losses of frames, and to acknowledge specific frames. In LAPD and LAPDm, the acknowledgement is done by the receiver transmitting the number of the next expected frame to the sender, in an indicator

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RADIO RESOURCE MANAGEMENT

As a telecommunication system, GSM enables its users to communicate through transmission paths, of various characteristics, as explained in the previous chapters. However these transmission paths are not reserved once for all between any two pairs of users. They are set up on demand, and only for the time necessary for a given communication. This requires exchanges of information, not only between the users and the network they are in direct contact with, but also between machines within the network. This and the two next chapters are devoted to the description of these information exchanges, which enable distant participants, users and machines, to act together to provide the communication services for which the networks are designed.

This technological field is known as signalling, and under this name, its reputation has not yet grown as wide as other fields such as modulation, signal processing, and other transmission techniques. Many people consider it simply as a branch of software engineering, though it is in fact at the centre of the design of complex systems, where tasks can be executed only through the co-operation of distinct machines. This is the case of telecommunications, where machines are by essence distinct and distant. The study of GSM signalling is therefore of prime importance to understand how the system operates, and the reader should not be surprised that half of the book is devoted to the signalling interchanges.

Signalling is often the juxtaposition of many simple and more or less inter-dependent procedures, and its complexity stems mainly from the number and the diversity of small issues. We have already seen in

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Chapter 2, concerning the architecture, that the basic methodology to tackle such issues is "divide and conquer". Pervasive in the specifications of GSM signalling is a split in three functional domains: Radio Resource Management, Mobility Management and Communication Management. The management of the calls is the upper plane in this organisation, and deals with the establishment and the release of end-to-end transmission paths, through the GSM domain and by interworking with external networks, to support user to user communications. Communication Management, as a functional plane, relies on the Mobility Management functions for dealing with the mobility of the users and with security-related functions. The management of the radio resources groups functions specific to the radio interface.

A major difference between a radio mobile telecommunication network and a network with fixed links is the management of the access resources. In a fixed system, a dedicated communication medium exists continuously between the user terminal and the infrastructure, ready to be used when a call need to be established. On the contrary, in a cellular system like GSM, a dedicated channel over the radio interface is provided to the mobile stations only on demand and for the duration of the call, under the control of the infrastructure. This calls for functions which bear no equivalent in ISDN for instance. Even if 64 kbit/s channels are allocated dynamically in the case of an ISDN multi-terminal installation, this resource management is rather limited compared to the one in a full GSM cell. Moreover, in ISDN, a signalling channel is always ready for use by any terminal. The matter is quite different in GSM, where the signalling capabilities offered to a mobile station in idle mode, that is to say when not allocated a radio channel to its private usage, are limited to the absolute minimum. The consequence is that a host of new procedures are needed.

Besides dynamic channel allocation, another feature of GSM (or cellular systems in general) compared with fixed networks is the **handover**. The problem consists in providing a dedicated channel from mobile station to MSC at every moment during a call, despite the movements of the user. This calls for a complex measurement and decision process to trigger the transfer of the communication at the right moment and toward the right cell. In a cellular system, the handover process is very important, since it impacts significantly the quality of the communications as perceived by the users, as well as the spectral efficiency.

This chapter will be devoted to these topics, that is to say to the functions required to co-ordinate the mobile stations and the infrastructure so as to provide the suitable transmission means over the radio interface, whatever the telecommunication service requires, and

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whatever the user's movements. These functions form a well defined area, which we presented in Chapter 2 as the **RR** (Radio Resource management) functional plane. They are spread among four entities in the canonical GSM architecture: the mobile station (of course!), the two base station sub-system components (BTS and BSC), and a small part in the MSC. All the higher layer functions, described in Chapters 7 and 8, are basically managed directly between mobile station and MSC, the base station sub-system (BSS) acting for these functions as a single complex transmission system. The spread of the radio resource management functions implies the existence of signalling procedures between the involved infrastructure machines; this is the purpose of the signalling protocols on the A (BSC-MSC) and Abis (BSC-BTS) interfaces, which will therefore be described in this chapter.

The chapter is basically composed of two parts. After preliminary architecture considerations needed to introduce some specific concepts, the major requirements which drove the design of the RR protocols will be looked at. Then, after a section to present the protocol architecture, the various procedures needed to fulfil these requirements will be developed.

Preliminary Architecture Considerations

A section in the middle of this chapter will be devoted to the architecture and the protocols in the Radio Resource management domain. However, some basic notions are necessary for the understanding of the first part of the chapter. It concerns mainly the notion of anchor MSC.

The major roles are played in this chapter by the components of the BSS, the BTS and the BSC. The MSC intervenes a little, to deal with handovers between cells managed by different BSCs. Some handovers may even transfer the mobile station from a cell within one MSC area to a cell in another MSC area, thus involving *two* MSCs. The roles of the two MSCs are different. In no case does the MSC in charge of the communication relinquish its control to the new MSC. This MSC is called the **anchor MSC** for the connection. This is an important design choice of GSM, with numerous consequences on the procedures. Several arguments justify this choice; a compelling one is the charging problem, since toll ticketing is much simpler when one MSC follows a call from its beginning to its end.

A consequence of this architectural choice is that after an inter-MSC handover, two MSCs (and at most two) may be involved in the connection. The transmission chain between the mobile station and the interworking point with external networks is then composed of a BTS, a

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REJECT message, containing a time indication during which the mobile station is forbidden to make any more attempts on the RACH (the *WAIT INDICATION* parameter). If the overload situation does not concern the RACH, the value of the *WAIT INDICATION* can be null, otherwise it is a useful mechanism to help reduce RACH load (see page 370).

The PAGCH is an important potential bottleneck of the system. In order to improve its efficiency, both initial assignment indications and channel request rejection indications can be grouped together to form messages. There are two assignments in an RIL3-RR IMMEDIATE ASSIGNMENT EXTENDED message, and up to four rejections in an RIL3-RR IMMEDIATE ASSIGNMENT REJECT message. Though this point is unclear in the *Specifications*, the original intention was for the BTS to perform the grouping on the basis of the individual indications provided by the BSC. The BSC has the possibility to provide the BTS with immediate assignment indications which are not ready-to-send messages (using the RSM IMMEDIATE ASSIGN COMMAND message). The BTS must then build the corresponding RIL3-RR messages The fact is that the BSC *can* also perform the grouping and build the messages, and can provide ready-to-send messages to the BTS (this is, by the way, the only possibility for assignment rejection messages). However, nothing really precludes the BTS to un-build these messages and to build others grouping the requests differently. The same debate exists for the paging indications.

In no case does the BSC schedule the transmission of the assignment indications: this is much easier for the BTS. The counterpart is that, despite grouping, congestion may happen. This is resolved simply by the BTS, which drops messages which are in excess of the achievable throughput. While this resolves the BTS congestion problem, for the BSC it results in TACHs allocated but not "assigned". To avoid a worsening of the congestion situation through this effect, the BTS can indicate the non-sending of a message with an RSM DELETE INDICATION message. A second effect of the message is to indicate the overload to the BSC.

6.3.1.4. The Initial Message

Once it has received an initial assignment indication, the addressed mobile station modifies its reception and transmission configuration to adapt it to the frequency and time characteristics of the new channel. In phase 1, this new channel can be a TACH/8 or a TACH/F, always in "signalling only" mode (see page 321). The transmission level is set to a value broadcast on the BCCH (or to the maximum transmission level of the mobile station, whichever the smaller), and the transmission starts with the timing advance value specified by the BSC.

The first thing the mobile station does on the new channel is to transmit a link layer SABM frame for SAPI 0, i.e., the frame used to establish in acknowledged mode the link layer connection for signalling messages.

In standard HDLC protocols, an SABM frame does not carry any information other than the one necessary for the link layer level. In GSM, the SABM frame sent within the initial access procedure contains a signalling message, the "initial message". The reasons for departing from standard usage are twofold. The first reason is efficiency, though this was

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There is usually but one choice for this "initial message". One case of collision may arise, when, after having sent an RIL3-RR CHANNEL REQUEST message, the mobile station receives a paging indication and then the answer to its RIL3-RR CHANNEL REQUEST. What should the initial message be in such a case? Should it be consistent with the reason for sending the original RIL3-RR CHANNEL REQUEST message, or should it be the RIL3-RR PAGING RESPONSE message? It would seem fair to choose the RIL3-RR PAGING RESPONSE message if for instance the request from the mobile station concerned periodic location updating, but no priority scheme is defined in the *Specifications*, and the whole matter is left open for mobile station manufacturers.

Once an "initial message" has been received by the BTS (and sent back without any modification inside the UA frame), it is passed to the BSC in an RSM ESTABLISH INDICATION message. At this point, the mobile station classmark is stored for further use (e.g., to choose the power control loop parameters), and the BSC then sets up an SCCP connection towards the MSC (see Chapter 5). This is done through an SCCP CONNECTION REQUEST message, on which the initial message may optionally be piggybacked. Only then does the MSC become aware of the contact with the mobile station. The initial message, whether piggybacked or sent after the SCCP connection establishment, is carried in a BSSMAP COMPLETE LAYER 3 INFORMATION message, independently from its protocol (RR or MM). It contains enough information for the MSC to trigger required actions in the upper layers (MM, CC, ...), but this comes out of the scope of the access procedure.

When the access procedure ends, the RR-session is fully established with a complete signalling path between the mobile station and the MSC. With the establishment of the SCCP connection, the MSC takes control of the decisions concerning the transmission characteristics of the RR-session, and the BSS is at the ready whilst monitoring the transmission and performing handover decisions.

6.3.1.5. The Mobile Station Classmark

Mobile stations differ by many characteristics, such as their maximum transmission power and the services they may support. It is important for the infrastructure to be aware of some of these characteristics when the mobile station is engaged in a connection. Because the equipment of the user may be changed without warning the operator (subscription is linked to the SIM, not to the mobile equipment), this indication must be given at the beginning of each new connection. This is the purpose of the mobile station classmark. The full contents of the classmark are shown in table 6.6.

There exists in fact, for efficiency reasons, a subset of the full classmark, called "mobile station classmark type 1" in the *Specifications* (the full classmark being referred to as "mobile station classmark type 2"), destined to be sent in the RIL3-MM LOCATION UPDATING REQUEST message, so that this message fits in a single block (segmenting is not

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