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Introduction to GSM Networks

Figure 1.1 is a schematic overview of the main components in a GSM network. The various interface labels are the formal names given to these interfaces. More details about these interfaces are found in GSM TS 03.02 [26].

The GSM network consists mainly of the following functional parts:

- *MSC* – the mobile service switching centre (MSC) is the core switching entity in the network. The MSC is connected to the radio access network (RAN); the RAN is formed by the BSCs and BTSs within the Public Land Mobile Network (PLMN). Users of the GSM network are registered with an MSC; all calls to and from the user are controlled by the MSC. A GSM network has one or more MSCs, geographically distributed.
- *VLR* – the visitor location register (VLR) contains subscriber data for subscribers registered in an MSC. Every MSC contains a VLR. Although MSC and VLR are individually addressable, they are always contained in one integrated node.
- *GMSC* – the gateway MSC (GMSC) is the switching entity that controls mobile terminating calls. When a call is established towards a GSM subscriber, a GMSC contacts the HLR of that subscriber, to obtain the address of the MSC where that subscriber is currently registered. That MSC address is used to route the call to that subscriber.
- *HLR* – the home location register (HLR) is the database that contains a subscription record for each subscriber of the network. A GSM subscriber is normally associated with one particular HLR. The HLR is responsible for the sending of subscription data to the VLR (during registration) or GMSC (during mobile terminating call handling).
- *CN* – the core network (CN) consists of, amongst other things, MSC(s), GMSC(s) and HLR(s). These entities are the main components for call handling and subscriber management. Other main entities in the CN are the equipment identification register (EIR) and authentication centre (AUC). CAMEL has no interaction with the EIR and AUC; hence EIR and AUC are not further discussed.
- *BSS* – the base station system (BSS) is composed of one or more base station controllers (BSC) and one or more base transceiver stations (BTS). The BTS contains one or more transceivers (TRX). The TRX is responsible for radio signal transmission and reception. BTS and BSC are connected through the Abis interface. The BSS is connected to the MSC through the A interface.
- *MS* – the mobile station (MS) is the GSM handset. The structure of the MS will be described in more detail in a next section.

A GSM network is a *public land mobile network* (PLMN). Other types of PLMN are the time division multiple access (TDMA) network or code division multiple access (CDMA) network. GSM uses the following sub-division of the PLMN:

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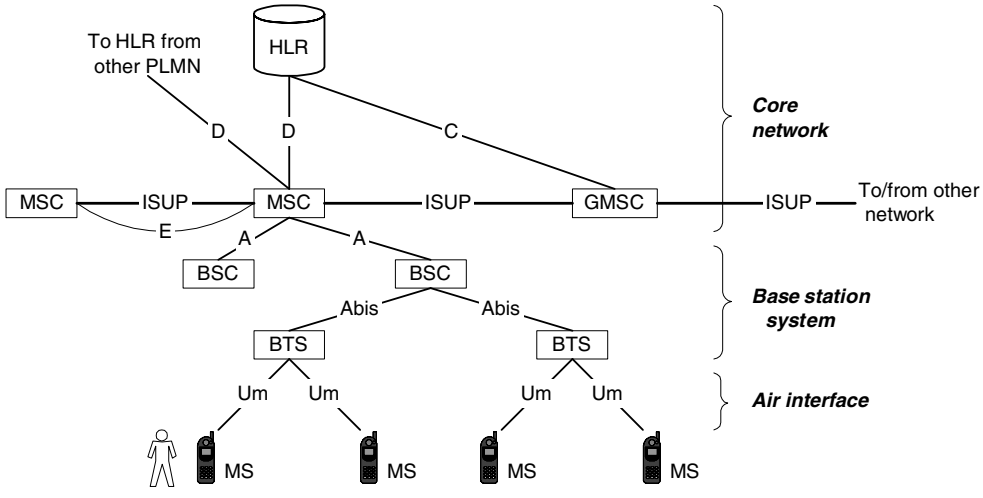

Figure 1.1 GSM network architecture

- *Home PLMN (HPLMN)* – the HPLMN is the GSM network that a GSM user is a subscriber of. That implies that GSM user's subscription data resides in the HLR in that PLMN. The HLR may transfer the subscription data to a VLR (during registration in a PLMN) or a GMSC (during mobile terminating call handling). The HPLMN may also contain various service nodes, such as a short message service centre (SMSC), service control point (SCP), etc.
- *Visited PLMN (VPLMN)* – the VPLMN is the GSM network where a subscriber is currently registered. The subscriber may be registered in her HPLMN or in another PLMN. In the latter case, the subscriber is *outbound roaming* (from HPLMN's perspective) and *inbound roaming* (from VPLMN's perspective). When the subscriber is currently registered in her HPLMN, then the HPLMN is at the same time VPLMN.[1]
- *Interrogating PLMN (IPLMN)* – the IPLMN is the PLMN containing the GMSC that handles mobile terminating (MT) calls. MT calls are always handled by a GMSC in the PLMN, regardless of the origin of the call. For most operators, MT call handling is done by a GMSC in the HPLMN; in that case, the HPLMN is at the same time IPLMN. This implies that calls destined for a GSM subscriber are always routed to the HPLMN of that GSM subscriber. Once the call has arrived in the HPLMN, the HPLMN acts as IPLMN. MT call handling will be described in more detail in subsequent sections. When basic optimal routing (BOR) is applied, the IPLMN is not the same PLMN as the HPLMN.

The user of a GSM network is referred to as the *served subscriber*; the MSC that is serving that subscriber is known as the *serving MSC*. Examples are:

- *mobile originated call* – the MSC that is handling the call is the *serving MSC* for this call; the calling subscriber is the *served subscriber*;
- *mobile terminated call* – the GMSC that is handling the call is the *serving GMSC* for this call; the called subscriber is the *served subscriber*.

[1] The CAMEL service requirement, GSM TS 02.78 [12] uses this strict definition. The term VPLMN is, however, commonly used to denote any network other than the HPLMN.

1.1 Signalling in GSM

The various entities in the GSM network are connected to one another through signalling networks. Signalling is used for example, for subscriber mobility, subscriber registration, call establishment, etc. The connections to the various entities are known as 'reference points'. Examples include:

- *A interface* – the connection between MSC and BSC;
- *Abis interface* – the connection between BSC and BTS;
- *D interface* – the connection between MSC and HLR;
- *Um interface* – the radio connection between MS and BTS.

Various signalling protocols are used over the reference points. Some of these protocols for GSM are the following:

- *mobile application part (MAP)* – MAP is used for call control, subscriber registration, short message service, etc.; MAP is used over many of the GSM network interfaces;
- *base station system application part (BSSAP)* – BSSAP is used over the A interface;
- *direct transfer application part (DTAP)* – DTAP is used between MS and MSC; DTAP is carried over the Abis and the A interface. DTAP is specified in GSM TS 04.08 [49];
- *ISDN user part (ISUP)* – ISUP is the protocol for establishing and releasing circuit switched calls. ISUP is also used in landline Integrated Services Digital Network (ISDN). A *circuit* is the data channel that is established between two users in the network. Within ISDN, the data channel is generally a 64 kbit/s channel. The circuit is used for the transfer of the encoded speech or other data. ISUP is specified in ITU-T Q.763 [137].

When it comes to call establishment, GSM makes a distinction between *signalling* and *payload*. Signalling refers to the exchange of information for call set up; payload refers to the data that is transferred within a call, i.e. voice, video, fax etc. For a mobile terminated GSM call, the signalling consists of exchange of MAP messages between GMSC, HLR and visited MSC (VMSC). The payload is transferred by the ISUP connection between GMSC and VMSC. It is a continual aim to optimize the payload transfer through the network, as payload transfer has a direct cost aspect associated with it. Some network services are designed to optimize the payload transfer. One example is optimal routing.

1.2 GSM Mobility

Roaming with GSM is made possible through the separation of *switching capability* and *subscription data*. A GSM subscriber has her subscription data, including CAMEL data, permanently registered in the HLR in her HPLMN. The GSM operator is responsible for provisioning this data in the HLR. The MSC and GMSC in a PLMN, on the other hand, are not specific for one subscriber group. The switching capability of the MSC in a PLMN may be used by that PLMN's own subscribers, but also by *inbound roaming* subscribers; see Figure 1.2.

In Figure 1.2, the GSM user who is a subscriber of PLMN-A roams to PLMN-B. The HLR in PLMN-A transfers the user's subscription data to the MSC in PLMN-B. The subscriber's subscription data remains in the MSC/VLR as long as she is served by a BSS that is connected to that MSC. Even when the user switches her MS off and then on again, the subscription data remains in the MSC. After an extended period of the MS being switched off, the subscription data will be purged from the MSC. When the subscriber switches her MS on again, the subscriber has to re-register with the MSC, which entails the MSC asking the HLR in the HPLMN to re-send the subscription data for that subscriber.

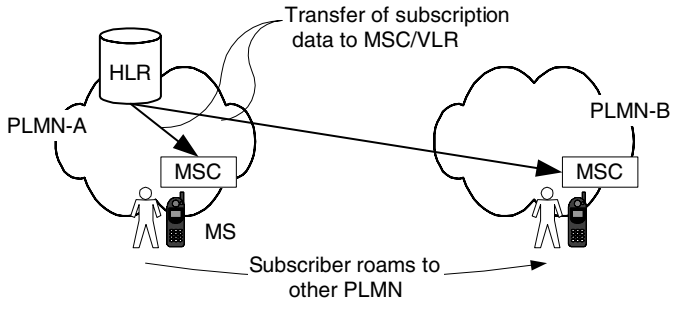

Figure 1.2 Transfer of GSM subscription data for a roaming subscriber

When the subscriber moves from one MSC service area (MSC-1) to another MSC service area (MSC-2), the HLR will instruct MSC-1 to purge the subscription data of this subscriber and will send the subscription data to MSC-2.

1.3 Mobile Station

The MS, i.e. the GSM handset, is logically built up from the following components:

- *mobile equipment (ME)* – this is the GSM terminal, excluding the SIM card;
- *subscriber identification module (SIM)* – this is the chip embedded in the SIM card that identifies a subscriber of a GSM network; the SIM is embedded in the SIM card. When the SIM card is inserted in the ME, the subscriber may register with a GSM network. The ME is now effectively personalized for this GSM subscriber; see Figure 1.3. The characteristics of the SIM are specified in GSM TS 11.11. The SIM card contains information such as IMSI, advice of charge parameters, operator-specific emergency number, etc. For the UMTS network an enhanced SIM is specified, the universal subscriber identity module (USIM); refer 3GPP TS 31.102.

1.4 Identifiers in the GSM Network

GSM uses several identifiers for the routing of calls, identifying subscribers (e.g. for charging), locating the HLR, identifying equipment, etc. Some of these identifiers play an important role for CAMEL.

1.4.1 International Mobile Subscriber Identity

The international mobile subscriber identity (IMSI) is embedded on the SIM card and is used to identify a subscriber. The IMSI is also contained in the subscription data in the HLR. The IMSI is used for identifying a subscriber for various processes in the GSM network. Some of these are:

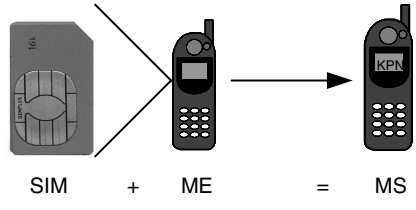

Figure 1.3 Components of the mobile station

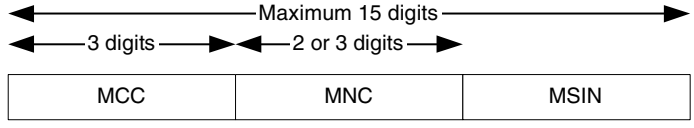

Figure 1.4 Structure of the IMSI

- *location update* – when attaching to a network, the MS reports the IMSI to the MSC, which uses the IMSI to derive the global title (GT) of the HLR associated with the subscriber;
- *terminating call* – when the GSM network handles a call to a GSM subscriber, the HLR uses the IMSI to identify the subscriber in the MSC/VLR, to start a process for delivering the call to that subscriber in that MSC/VLR.
- *roaming charging* – a VPLMN uses the IMSI to send billing records to the HPLMN of a subscriber.

Figure 1.4 shows the format of the IMSI.

- *mobile country code (MCC)* – the MCC identifies the country for mobile networks. The MCC is not used for call establishment. The usage of MCC is defined in ITU-T E.212 [129]. The MCC values are allocated and published by the ITU-T.
- *mobile network code (MNC)* – the MNC identifies the mobile network within a mobile country (as identified by MCC). MCC and MNC together identify a PLMN. Refer to ITU-T E.212 [129] for MNC usage. The MNC may be two or three digits in length. Common practice is that, within a country (as identified by MCC), all MNCs are either two or three digits.
- *mobile subscriber identification number (MSIN)* – the MSIN is the subscriber identifier within a PLMN.

The IMSI is reported to the SCP during CAMEL service invocation. The IMSI may be needed, for example, when identifying a country; countries in North America have equal country code (country code = 1), but different MCC (e.g. Canada = 303; Mexico = 334).

1.4.2 Mobile Station Integrated Services Digital Network Number (MSISDN Number)

The MSISDN is used to identify the subscriber when, among other things, establishing a call to that subscriber or sending an SMS to that subscriber. Hence, the MSISDN is used for routing purposes. Figure 1.5 shows the structure of the MSISDN.

- *country code (CC)* – the CC identifies the country or group of countries of the subscriber;
- *national destination code (NDC)* – each PLMN in a country has one or more NDCs allocated to it; the NDC may be used to route a call to the appropriate network;
- *subscriber number (SN)* – the SN identifies the subscriber within the number plan of a PLMN.

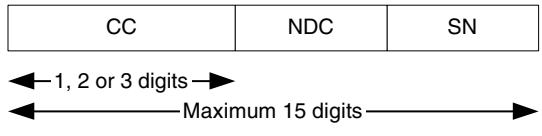

Figure 1.5 Structure of the MSISDN

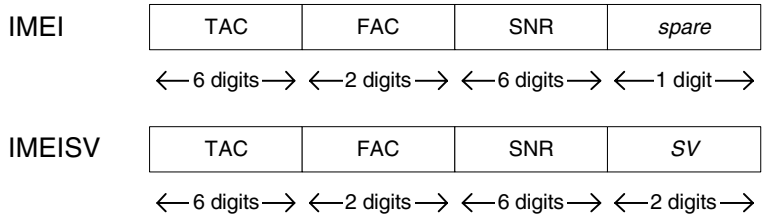

Figure 1.6 Structure of IMEI and IMEISV

The MSISDN is not stored on the subscriber's SIM card and is normally not available in the MS.[2] The MSISDN is provisioned in the HLR, as part of the subscriber's profile, and is sent to MSC during registration. The MSISDN is also reported to SCP when a CAMEL service is invoked. One subscriber may have multiple MSISDNs. These MSISDNs are provisioned in the HLR. At any one moment, only a single MSISDN is available in the MSC/VLR for the subscriber.

1.4.3 International Mobile Equipment Identifier

The international mobile equipment identifier (IMEI) is used to identify the ME [or user equipment (UE) in UMTS network]. Each ME has a unique IMEI. The IMEI is hard-coded in the ME and cannot be modified. Figure 1.6 shows the structure of the IMEI. The IMEI is not used for routing or subscriber identification.

Refer to GSM TS 03.03 [27] for the type approval code (TAC), final assembly code (FAC) and serial number (SNR). The software version (SV) may be included in the IMEI ('IMEISV') to indicate the version of software embedded in the ME. The IMEI is always encoded as an eight-octet string. As from CAMEL Phase 4, the IMEI(SV) may be reported to the SCP.

1.4.4 Mobile Station Roaming Number

The mobile station roaming number (MSRN) is used in the GSM network for routing a call to a MS. The need for the MSRN stems from the fact that the MSISDN identifies a subscriber, but not the current location of that subscriber in a telecommunications network. The MSRN is allocated to a subscriber during MT call handling and is released when the call to that subscriber is established. Each MSC in a PLMN has a (limited) range of MSRNs allocated to it. An MSRN may be allocated to any subscriber registered in that MSC. The MSRN has the form of an E.164 number and can be used by the GMSC for establishing a call to a GSM subscriber. An MSRN is part of a GSM operator's number plan. The MSRN indicates the GSM network a subscriber is registered in, but not the GSM network the subscriber belongs to. Figure 1.7 shows how the MSRN is used for call routing. The MSRN is not meant for call initiation. GSM operators may configure their MSC such that subscribers cannot dial numbers that fall within the MSRN range of that operator.

1.5 Basic Services

All activities that may be done in the GSM network, such as establishing a voice call, establishing a data call, sending a short message, etc., are classified as *basic services*. In order for a subscriber to use a GSM basic service, she must have a subscription to that service.[3] The handling of a basic

[2] GSM subscribers may program their MSISDN into the phone; this has, however, no significance for the network.

[3] Exceptions are Tele Service 12 (emergency call establishment) and Tele Service 23 (Cell Broadcast). Subscribers do not need a subscription to these Tele Services to use them.

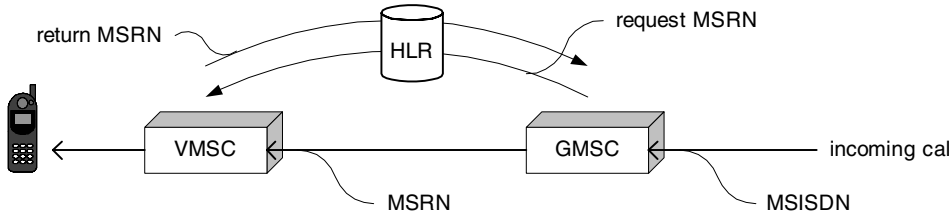

Figure 1.7 Usage of MSRN during call establishment to a GSM subscriber

service is fully standardized. Hence, a subscriber may use a basic service in any GSM network she roams to, provided that that basic service is supported in that network. The HLR will send a list of subscribed basic services to the MSC/VLR, during registration. When a GSM subscriber initiates a call, the MS supplies the serving MSC with a set of parameters describing the circuit-switched connection that is requested. These parameters are the bearer capability (BC), low-layer compatibility (LLC) and high-layer compatibility (HLC), as will be described below. The MSC uses the BC, LLC and HLC to derive the basic service for this call. The rules for deriving the basic service from LLC, HLC and BC are specified in GSM TS 09.07 [55]. The MSC then checks whether the subscriber has a subscription to the requested basic service, i.e. whether the subscription data in the VLR contains that basic service. If the service is not subscribed to, then the MSC disallows the call. The basic service is not transported over ISUP.

When a CAMEL service is invoked, the MSC reports the requested basic service to the SCP. The SCP may use the indication of the requested basic service for call service processing. Examples include:

- video calls may be charged at a higher rate than speech calls;
- for data calls and fax calls, the CAMEL service shall not play any announcements or tones.

Basic services are divided into two groups: tele services and bearer services.

1.5.1 Tele Services

Table 1.1 provides an overview of the available tele services (TS); see also GSM TS 02.03 [3].

1.5.2 Bearer Services

Table 1.2 provides an overview of the available bearer services (BS). The two bearer service groups are sub-divided into a variety of bearer services with different characteristics. Refer to GSM TS 02.02 [2].

1.5.3 Circuit Bearer Description

Bearer capability, low-layer compatibility and high-layer compatibility are descriptors of a circuit-switched (CS) connection. When a GSM subscriber initiates a call, the BC, LLC and HLC are transported from MS to MSC over DTAP. The MSC includes the parameters in the ISUP signal to the destination. These parameters are also reported to the SCP during CAMEL service invocation. That enables a CAMEL service to adapt the service logic processing to the type of call. Figure 1.8 shows the relation between LLC, HLC and BC on the DTAP and the corresponding parameters on ISUP.

Table 1.1 Tele services

Tele service	Description	Comment
11	Telephony	This TS represents the normal speech call
12	Emergency calls	The emergency call uses the characteristics of telephony (TS11), but may be established without subscription and bypasses various checks in the MS and in the MSC
21	Short message MT	This TS relates to receiving an SMS. This TS is not sent to the MSC/VLR. When an SMS is sent to the subscriber, the HLR checks whether the destination subscriber has a subscription to TS 21
22	Short message MO	This TS relates to the sending of an SMS
23	Cell broadcast	This TS relates to the capability of an SMS that is sent as a broadcast SMS
61	Alternate speech and fax group 3	This TS relates to the capability to establish a speech and fax (group 3) call
62	Automatic fax group 3	This TS relates to the capability to establish a fax (group 3) call
91	Voice group call	This TS relates to the capability to participate in a group call as specified in GSM TS 03.68 [35]
92	Voice broadcast	This TS relates to the capability to receive a voice broadcast as specified in GSM TS 03.68 [35]

Table 1.2 Bearer services

Tele service	Description	Comment
20	Asynchronous data bearer services	May be used for asynchronous services from 300 bit/s to 64 kbit/s.
30	Synchronous data bearer services	May be used for synchronous services from 1.2 to 64 kbit/s. This BS may be used, amongst other things, for multimedia services such as video telephony.[4]

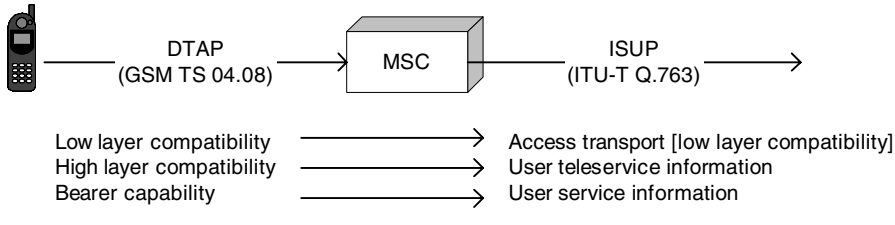

Figure 1.8 Transfer of LLC, HLC and BC through DTAP and ISUP

- *Low-layer compatibility* – the LLC is transported transparently between the calling entity and called entity; it may be used by the respective entities to adapt codecs for interworking purposes. LLC describes mainly characteristics related to the data transfer.

[4] 3GPP Rel-7 may include a dedicated bearer service for video telephony.

- *High-layer compatibility* – the HLC is also transported transparently between the calling entity and called entity; it is used to describe the requested service, such as telephony, Fax, video telephony, etc.
- *Bearer capability* – the BC describes the characteristics of the 64 kbit/s circuit requested for the call.

1.6 Supplementary Services

Supplementary services (SS) in GSM are a means of enriching the user experience. An SS may, for example, forward a call in the case of no reply from the called party, bar certain outgoing or incoming calls, show the number of the calling party to the called party, etc. In order to use an SS, a GSM user needs a subscription to that SS. The subscription to supplementary services is contained in the HLR and is sent to the MSC/VLR during registration. The supplementary services are fully standardized. A GSM subscriber can therefore use her supplementary services in any GSM network, provided that the network supports these supplementary services, and have the same user experience.

Table 1.3 GSM supplementary services

SS group	Supplementary services	GSM TS
Line identification	Calling line identification presentation (CLIP)	02.81 [13]
	Calling line identification restriction (CLIR)	
	Connected line presentation (COLP)	
	Connected line restriction (COLR)	
Name identification	Calling name presentation (CNAP)	02.96 [24]
Call forwarding	Call forwarding – unconditional (CFU)	02.82 [14],
	Call forwarding – busy (CFB)	
	Call forwarding – no reply (CFNRY)	
	Call forwarding – not reachable (CFNRC)	
	Call deflection (CD)	02.72 [11]
Call offering	Explicit call transfer (ECT)	02.91 [22]
Call completion	Call waiting (CW)	02.83 [15],
	Call hold (CH)	
	Call completion to busy subscriber (CCBS)	02.93 [23],
	Multi-call (MC)	22.135 [69][a]
Multi-party	Multi-party call (MPTY)	02.84 [16]
Community of interest	Closed user group (CUG)	02.85 [17]
Charging	Advice of charge – information (AOCI)	02.86 [18]
	Advice of charge – charge (AOCC)	
Additional information transfer	User-to-user signalling – service 1 (UUS1)	02.87 [19]
	User-to-user signalling – service 2 (UUS2)	
	User-to-user signalling – service 3 (UUS3)	
Call barring	Barring of all outgoing calls (BAOC)	02.88 [20]
	Barring of outgoing international calls (BOIC)	
	Barring of outgoing international calls except to the home country (BOIC-exHc)	
	Barring of all incoming calls (BAIC)	
	Barring of all incoming calls when roaming (BICROAM)	
Call priority	enhanced multi-level precedence and pre-emption (eMLPP)	02.67 [10]

[a] For the multi-call service, there is no GSM TS available, but only a 3GPP TS (22.135).

Supplementary services may be provisioned for an individual basic service or for a group of basic services, e.g. a subscriber may have barring of all outgoing calls for all tele services and all bearer services, except SMS (tele service group 20). Such a subscriber is barred from establishing outgoing calls (except emergency calls), but may still send short messages. Some supplementary services may be activated or deactivated by the user. Examples include call forwarding and call barring. An operator may decide to bar certain subscribers or subscriber groups from modifying their supplementary services.

Table 1.3 shows the Supplementary Services. They are combined in service groups. Subscriptions are per individual Supplementary Service. The right-most column indicates the GSM technical specifications (TS) that specify the service requirement for the respective Supplementary Service(s).

The chapters on CAMEL Phases 1–4 describe the interaction between CAMEL and the various supplementary services. Not all GSM networks support all supplementary services. Many of the supplementary services in GSM have equivalent supplementary services in ISDN. The ISDN supplementary services are described in ITU-T recommendations.

GSM TS 02.03 [3] describes how the supplementary services may be activated, deactivated and invoked.