within a wireless network.

Gateway MSC

The **gateway MSC** (GMSC) is an MSC that interfaces the wireless mobile network to other telecommunications networks. Although a cellular network might have numerous MSCs to facilitate coverage of a large geographical area, not all of these switching centers need to be connected to other wireline networks or other PLMNs. Usually this connection is made at one particular MSC and this MSC is now known as a gateway MSC or GMSC. To support its function as a gateway, the GMSC will contain an interrogation function for obtaining location information from the HLR of a subscriber. The GMSC will also have the ability to reroute a call to an MS using the information provided by the HLR. Charging and accounting functions are typically implemented in the GMSC.

Interworking Units

Interworking units (IWUs) are required to provide an interface to various data networks. These nodes are used to connect the base station controller and hence the radio base stations to various data services networks. This is necessitated by the fact that the MSC is a circuit-switched device and inappropriate for the transmission of data packets. Presently, for both TDMA and CDMA systems, these interworking units have evolved into specific functional nodes such as gateway GPRS support nodes (GGSNs) and **packet core network** (PNC) nodes, respectively. These IWUs will be discussed in greater detail in Chapter 7.

Data Transmission Interworking Unit An early interworking unit, the data transmission IWU (DTI), was used to allow the subscriber to alternate between speech and data during the same call. The main functions performed by the DTI were protocol conversion and the rate adaptation necessary for fax and data calls through a modem.

SMS Gateways and Interworking Units To provide **short message service** (SMS) (i.e., the sending of a text message consisting of up to 160 alphanumeric characters either to or from a mobile), two network elements are required in GSM networks: the short message service gateway MSC (SMS-GMSC) and the short message service interworking MSC (SMS-IWMSC). This first device is capable of receiving a short message from an SMS center (SC), interrogating an HLR to obtain routing information and message waiting data, and finally delivering the short message to the MSC of the receiving mobile. The second device is capable of receiving a mobile-originated short message from the MSC or an alert message from the HLR and delivering these messages to the subscriber's SMS center. Multimedia message service or MMS uses a different means of providing data transmission through the wireless network than SMS does. Again, more detail about SMS and MMS operations will be forthcoming in Chapter 7.

Network Management System

All modern telecommunication networks have some form of network management built into the system. This overarching management tool provides for overall network surveillance and support to the operation and maintenance of the entire network. A wireless service provider will usually have a **network operations center** (NOC) devoted to the use of this network management system (NMS) to provide 24/7 coverage of the system. Different equipment manufacturers have different names for these management systems; however, they all tend to have the same functionality. They provide fault management in the form of network surveillance, performance management, trouble management, configuration management, and security management.

Usually, the NMS has subnetwork management platforms that provide management of the circuit, packet, and radio networks. These subnetwork management platforms also provide configuration, fault, performance, and security management of their respective subsystems.

Other Nodes

Other nodes that may be connected to the switching system but are not really part of the telecommunications network itself are the SMS or service center (SC), the billing gateway (BGW), and the service order gateway (SOG). The service center acts like a store and forward center for short messages, the billing gateway collects billing information, and the service order gateway provides subscription management functions.

Service Center

The service center is used to facilitate the operation of short message service. It performs two functions: a mobile-originated short message is transferred from the cellular network to the SC for storage until the message can be transferred to its MS destination, or the SC stores a mobile-terminated short message from some other short message entity (SME) that might or might not be a MS until it can be accepted by the intended MS.

Billing Gateway

The billing gateway (BGW) collects billing information from various wireless network elements (principally, the MSC and GMSC). The common term used for the information collected by the BGW is call data records (CDRs). As these call records are collected from the network elements they become files used by a customer administrative system to generate billing information for the system's subscribers. Information about monthly access fees, home usage and roaming usage charges, data and special services usage charges, and so on, are all used to generate a monthly bill for each subscriber.

Service Order Gateway

The **service order gateway** (SOG) is used to connect a customer administrative system to the switching system. This system is used to input new subscriber data to the HLR or to update current subscriber data already contained in the HLR. The SOG also allows access to the AUC and the EIR for equipment administration. When a customer initially signs a service contract with a cellular service provider, the information about the contract is entered into the customer administrative system. The administrative system sends customer service orders to the SOG. The SOG interprets the service orders and delivers the appropriate information to the correct network elements in the form of network service orders.

3.2 HARDWARE AND SOFTWARE VIEWS OF THE CELLULAR NETWORK

At this point in our discussion of the various hardware elements that are used to realize a cellular system will be instructive to examine a possible implementation of a typical 2G/2.5G/2.5G+/3G wireless syste How the components are actually physically laid out and connected to provide coverage to a particular a will be discussed. How the network elements are viewed by system software is slightly different howe This view will also be presented and contrasted with the hardware point of view. See Figure 3–8 for illustration of a possible hardware layout used to cover a specific geographic area.

Figure 3–8 depicts a fairly large geographic area with a potential subscriber base of approxima 100,000 that is served by a cellular network consisting of two mobile switching centers and a total of base station controllers. The reader is urged to try and relate the demographic and geographic features his or her own hometown location to this example. For the sake of clarity, all the radio base stations (ce for only one BSC are shown. All the details of the individual cells are not included at this time.

Hardware View of a Cellular Network

The area on the left side of the diagram is served by MSC-1 and thus will be known as the service area MSC-1. The right side of the diagram is served by MSC-2 and is thus labeled as the service area of MSC MSC-1 interfaces with three BSCs (BSC-1A, BSC-1B, and BSC-1C) that are used to cover the three ar that the MSC-1 service area has been subdivided into. Each of these BSCs has several to many RBSs s viced by it depending upon the population density and nature of the various areas (urban, suburba business district, industrial, etc.). In some of the areas there may be both microcells and macrocells where other locations will just have macrocells. In the service area of MSC-2, there are three more BSCs (BSC 2A, BSC-2B, and BSC-2C).

The RBSs might be named to reflect their connection to a particular BSC (i.e., RBS-2A1, RBS-2A2, an so on for RBSs connected to BSC-2A). In this diagram, the GMSC provides the gateway connection to th PSTN for MSC-1 and MSC-2, and MSC-1 has the switching system databases colocated with it. PCM link

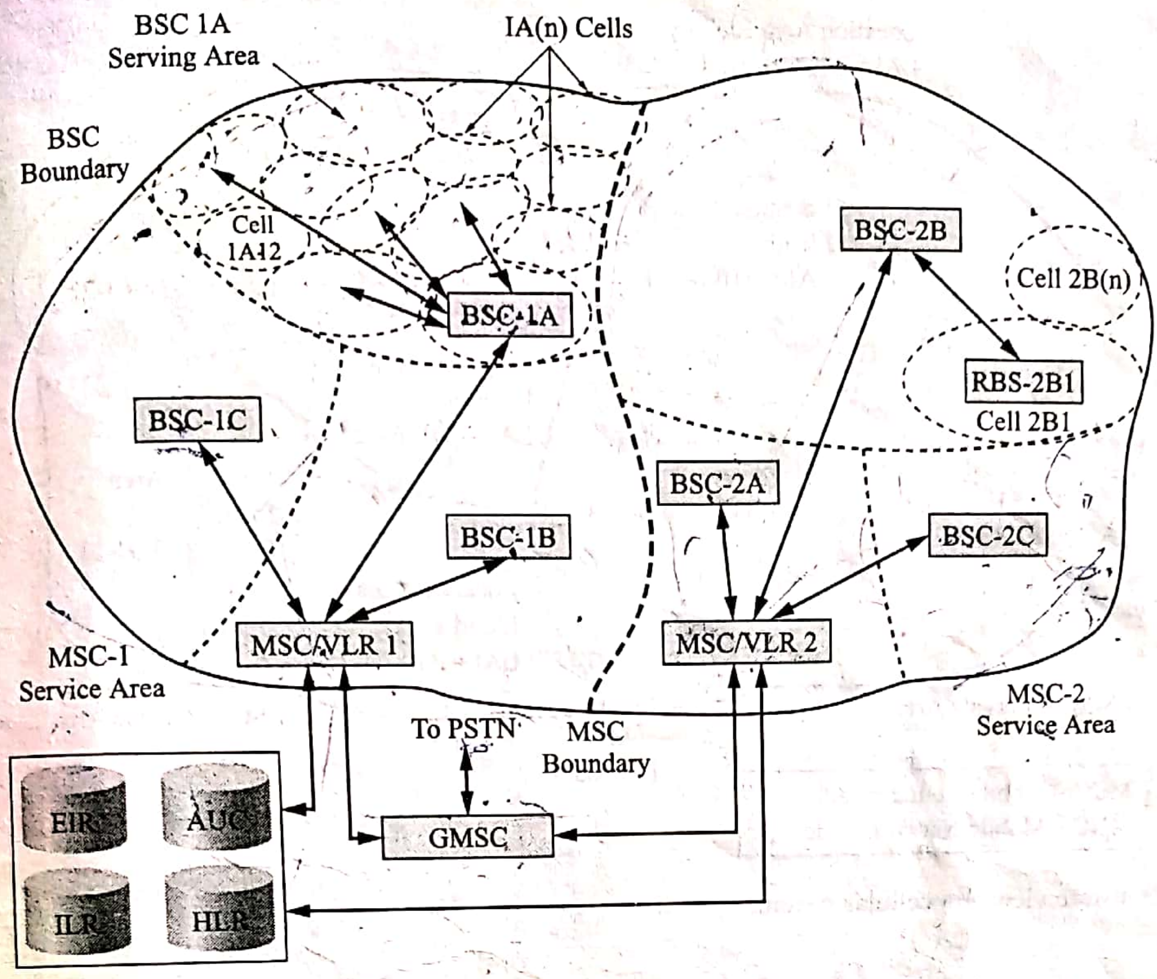


Figure 3–8 Hardware view of a cellular system.

exist between each RBS and its BSC, between each BSC and its MSC/VLR, and between the MSC/VLRs. These PCM links might be leased from the local telephone company or they may be implemented using microwave digital radio links installed by the service provider or a combination of both facilities. The gateway MSC is most likely linked to the PSTN by some form of high-capacity T-carrier or fiber span. Actual statistics about cell site locations and antenna statistics of cellular and PCS systems are available from the FCC's Web site. This information is contained in the universal licensing system database that may be found at http://wireless.fcc.gov/uls/.

Software View of a Cellular Network

The operations performed within the cellular network to complete calls, keep track of a mobile's location, and maintain radio links through handoff, but to name a few, are all directed by the network elements under program or software control. The cellular network therefore takes on a slightly different appearance to the system software. Physical objects and areas take on logical names to distinguish them from each other and to allow the software the ability to perform the required operations. Figure 3–9 shows the same geographic area as Figure 3–8; however, this time the cellular network is shown from a software viewpoint.

As shown in Figure 3–9, the network is defined by location area identity (LAI) numbers and cell global identity (CGI) numbers. The CGI numbers locate a particular cell whereas the LAI numbers define an area for paging. Because a mobile may have moved since its last location updating message (that would include the LAI number), an incoming call to the mobile will result in a page to every cell within the location area. If a mobile moves into another location area, it is required to automatically update its location with the VLR for the new location area.

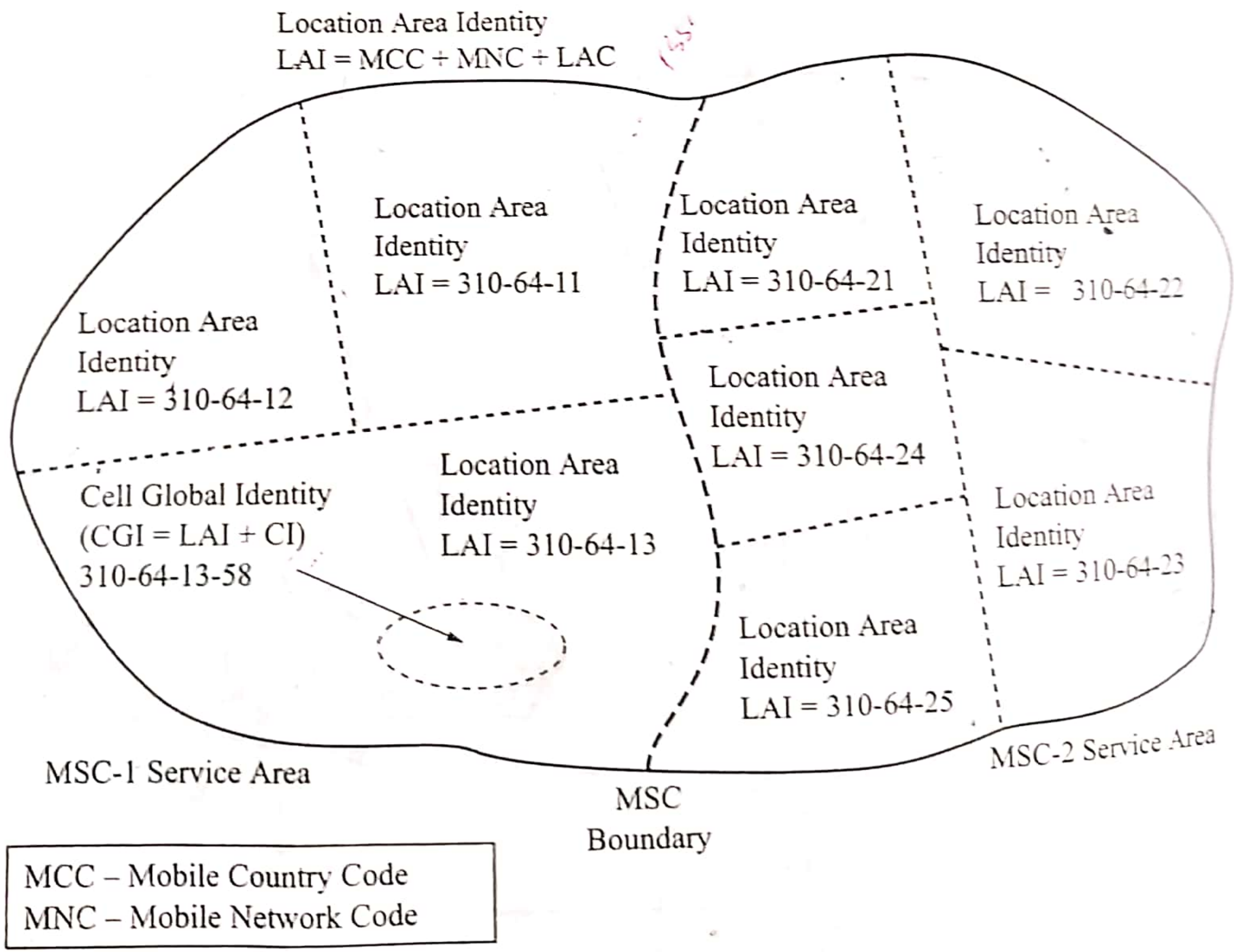


Figure 3–9 Software view of a cellular system.

3.4 CELLULAR COMPONENT IDENTIFICATION

To switch a voice call from the PSTN to a mobile subscriber the correct cellular network elements must b involved in the operation. It is therefore necessary to address these elements correctly or the operation w not be completed properly. The International Telecommunications Union (ITU), acting in its capacity as global standards organization, has adopted several standards and recommendations to deal with these issues. Recommendation E.164 is known as the international public telecommunication numbering plan This recommendation, adopted in 1997, details the numbers to be used for assigning PSTN telephone numbers on a global basis. This same recommendation is followed when assigning numbers to cellular tele-phones and provides a dialable number with which one can connect with the mobile through a wireless network. Furthermore, Recommendation E.212 deals with the numbering schemes for mobile terminals on a global basis. As stated before, the transmission of messages between cellular network elements used to facilitate cellular switching and control operations is accomplished through the use of SS7, in the same fashion as the PSTN. Therefore, network switching elements or processing nodes are associated wit addresses assigned to SS7 signaling points. These signaling point addresses are generated by the translation of E.164 and E.212 information into mobile global titles (Recommendation E.214) during the processing of operations by the cellular system elements.

This section will examine some of the basic numbering schemes used in wireless mobile networks for the different network elements that make up the system. Further details about specific systems will be offered in upcoming chapters.

Subscriber Device Identification

The mobile subscriber device (SD) can have several different system identification numbers associated with it. The identification information used depends upon the type of cellular technology (TDMA, GSM, or CDMA) employed by the network it is being used in and the scope of the network (e.g., national or international). The next few sections will expand upon this topic.

Mobile station International subscriber Directory Number

Mobile Station ISDN Identification Number

The mobile-station ISDN (MSISDN) number is a dialable number that is used to reach a mobile telephone. There are slight variations in the MSISDN number depending upon whether one is in North America or in other parts of the world. Figure 3–11 provides a graphic of how these MSISDN numbers are formed.

As shown, in North America an MSISDN number consists of the following:

$$MSISDN = CC + NPA + SN$$

(country or geographical area

Where, CC = Country Code, NPA = Number Planning Area, and SN = Subscriber Number

Subscriber no

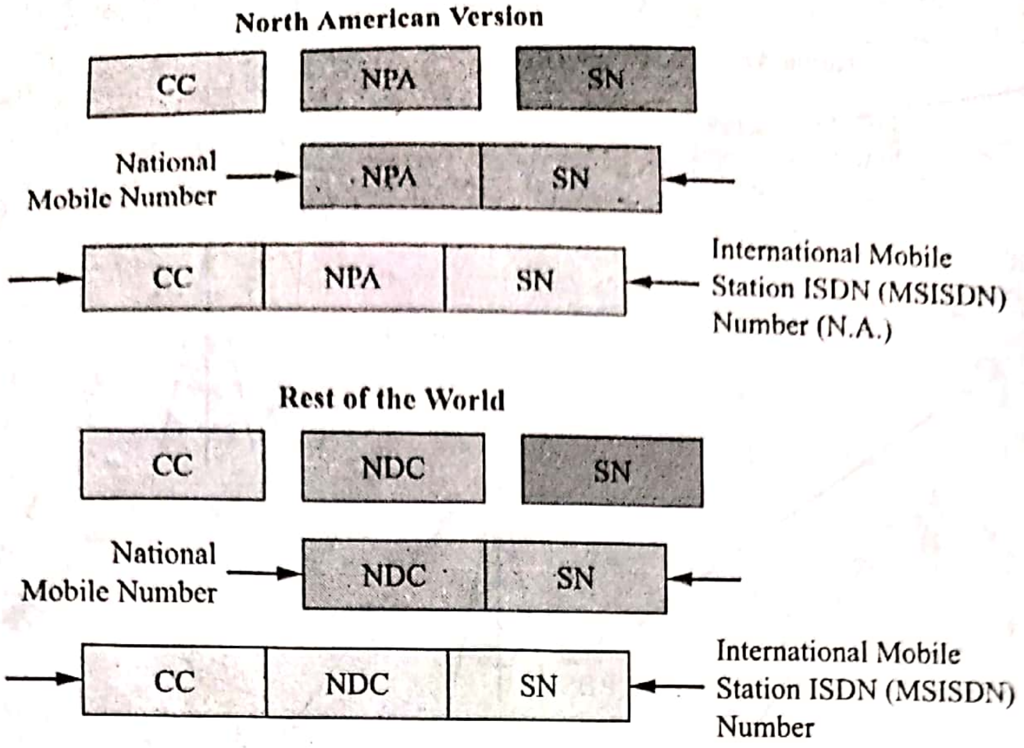


Figure 3–11 Formation of the MSISDN number.

Example 3–2

A cellular telephone subscriber signs up for service in Springfield, MA, USA. What is the su MSISDN?

Solution: Since the country code for the USA is +1 and the area code for Western Massachusetts i MSISDN will take the form

area code SN

MSISDN = +1-413-732-XXXX

country code - area code - National Destination NU planning area +SN

Country code - National Destination +

In the rest of the world an MSISDN number consists of the following:

MSISDN = CC + NDC + SN ⇒ station subscriber number ISDN number

0821 Mysore. +91 MCC

Where, NDC = National Destination Code. The NDC is similar to the NPA but can also identify tl network (fixed, wireless, etc.) being called.

International Mobile Subscriber Identity

For international public land mobile networks an international mobile subscriber identity (IMSI) is to each subscriber. Figure 3–12 indicates how the IMSI is formed.

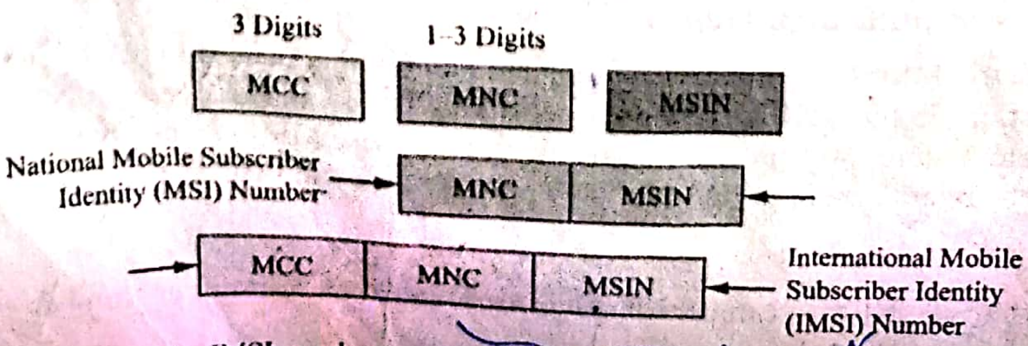


Figure 3–12 Formation of the IMSI number.

NMSI 15 digits

As shown, the IMSI number consists of the following:

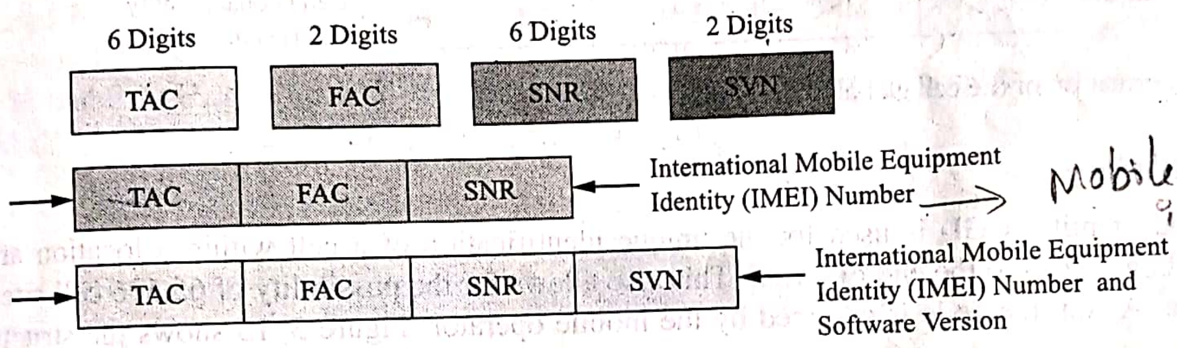
IMSI = MCC + MNC + MSIN

Where, MCC = Mobile Country Code (see Recommendation E.212), MNC = Mobile Network Code, and MSIN = Mobile Subscriber Identification Number. For a GSM network the IMSI number is stored in the SIM (subscriber identity module) card that is inserted into the mobile telephone and provided to the subscriber by the service provider.

There is also a temporary mobile subscriber identity (TMSI) number that may be used instead of the IMSI. This TMSI number is used to provide security over the air interface and therefore only has local significance within an MSC/VLR area.

International Mobile Equipment Identity

For international mobile networks, an international mobile equipment identity (IMEI) number is defined and is used to uniquely identify a MS as a piece of equipment to be used within the network. Figure 3–13 indicates the structure of the IMEI number.



Mobile identity num
it is in the phone
back of batt

Figure 3–13 Formation of the IMEI number.

The IMEI can be modified to include information about the software version of the subscriber device operating system or application software within the identity number.

Cellular System Component Addressing

The rest of the cellular network hardware components that make up the switching system or the base station system have either signaling point (SP) addresses or some type of logical name assigned to them to distinguish them from similar components within the network. Some of the addresses are predetermined by the ITU Recommendations E.164 and E.212 and some are translated into new addresses that conform to Recommendation E.214. The logical names of devices are assigned by the system operator.

Additionally, physical areas of network coverage are also defined and given logical identification names and numbers to provide for the mobility management functions of the system or to define billing areas for regional or national service plans.

Location Area Identity

The location area identity (LAI) is used for paging an MS during an incoming (mobile terminating) call and for location updating of mobile subscribers. Figure 3–14 shows the structure of an LAI number.

As shown, the LAI consists of the following:

LAI = MCC + MNC + LAC

Where, again, MCC = Mobile Country Code, MNC = Mobile Network Code, and LAC = Location Area Code, which is 16 bits in length and therefore allows the network operator 65,536 different possible areas or codes within a network. The code is assigned by the mobile operator.

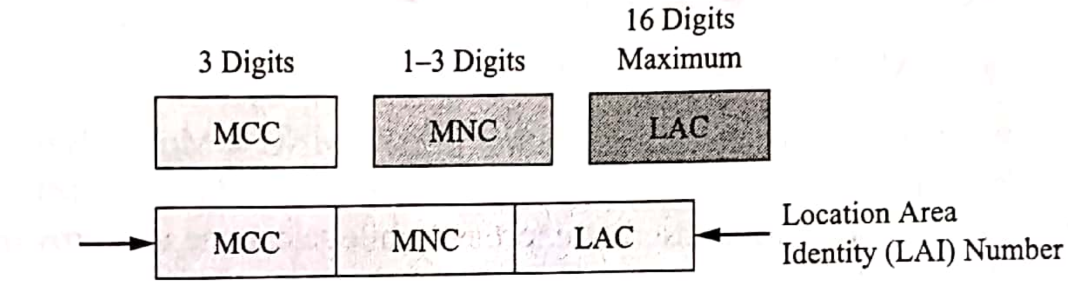


Figure 3–14 Formation of the location area identity number.

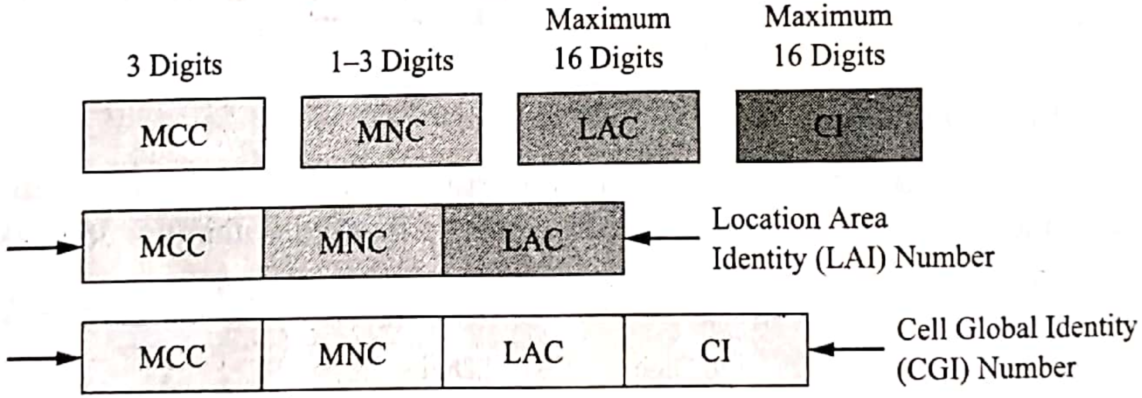


Figure 3–15 Formation of the cell global identity number.

Cell Global Identity

The cell global identity (CGI) is used for the unique identification of a cell within a location area. I formed by adding 16 bits to the end of a LAI. This also allows for the possibility of 65,536 cell sites wi a location area. Again, the code is assigned by the mobile operator. Figure 3–15 shows the structure CGI number.

Radio Base Station Identity Code

A radio base station identity code (BSIC) is used by the mobile operator to identify RBSs within the less network. This code allows an MS to distinguish between different neighboring base stations. The usually consists of a 3-bit network color code and a 3-bit base station color code.

3.5 CALL ESTABLISHMENT

The topic of **call establishment** was first introduced in Chapter 2 during an overview of the first-generation analog AMPS system. At that time, the reader was introduced to the many handshaking functions that were performed between the MS and the BS and between the BS and the MSC to complete call setup and hand-off functions. Now that more detail about the network elements and databases of digital wireless cellular systems has been introduced, it would again be instructive to take a look at some of the basic wireless

Mobile-Terminated Call

The mobile-terminated call consists of the steps shown in Figure 3–17. Step #1: Any incoming call t mobile system from the PSTN is first routed to the network's gateway mobile switching center (GMSC Step #2: When the wireless mobile system detects an incoming call at the GMSC, the mobile system m first determine where the mobile is located at that particular moment in time. To determine the mobil location, the GMSC will examine the mobile station's MDISDN to find out which home location regi (HLR) the mobile subscriber is registered in. Using SS7 (SCCP), the MSISDN is forwarded to the H with a request for routing information to facilitate the setup of the call. Step #3: The HLR looks up w MSC/VLR is presently serving the MS and the HLR sends a message to the appropriate MSC/V requesting an MS roaming number (MSRN), so that the call may be routed. This operation is required b this information is not stored by the HLR; therefore, a temporary MSRN must be obtained from the app priate MSC/VLR. Step #4: An idle MSRN is allocated by the MSC/VLR and the MSISDN numbe linked to it. The MSRN is sent back to the HLR. Step #5: The MSRN is sent to the GMSC by the H Step #6: Using the MSRN, the GMSC routes the call to the MSC/VLR. Step #7: When the ser MSC/VLR receives the call, it uses the MSRN number to retrieve the mobile's MSISDN. At this point

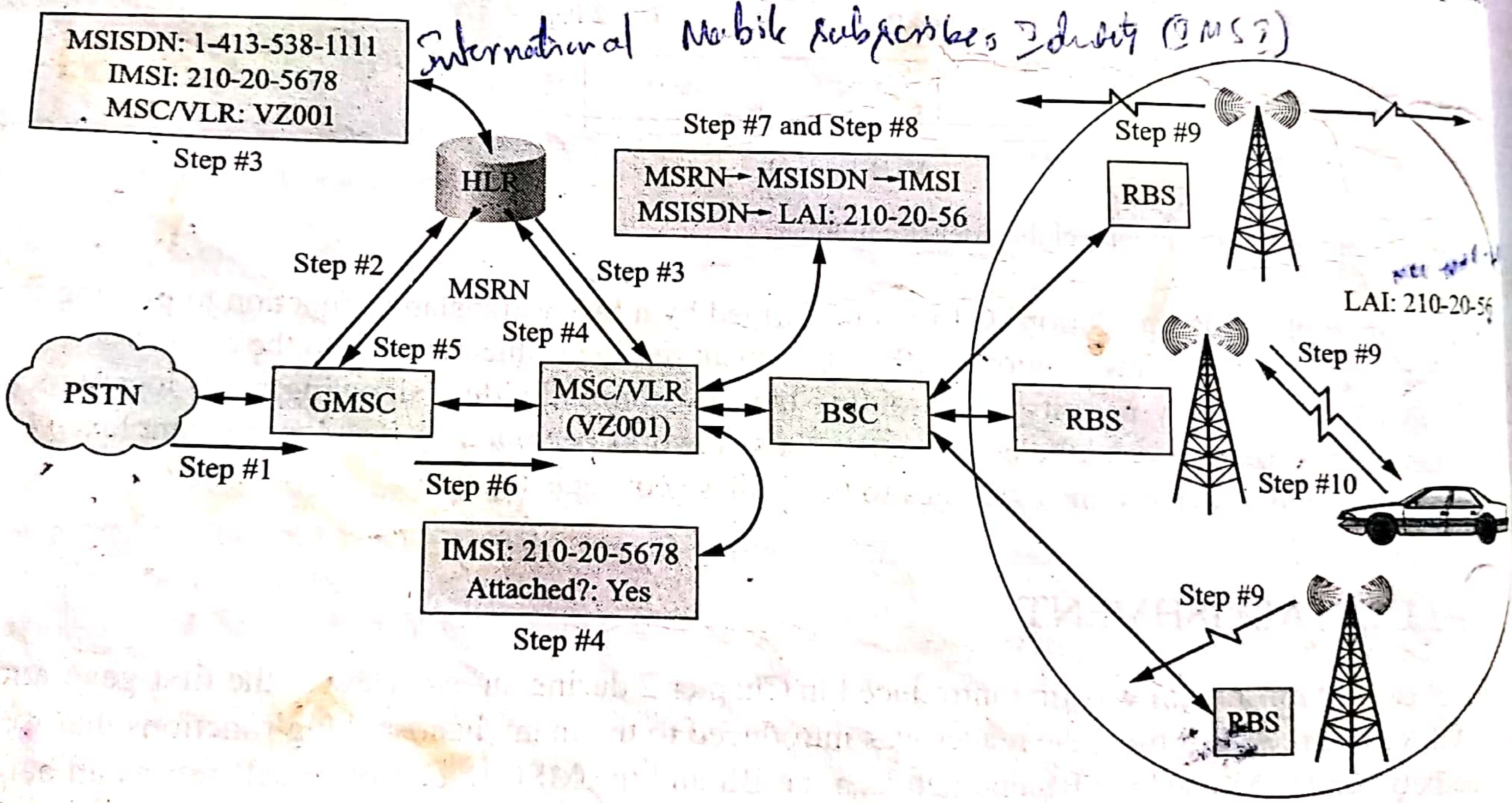


Figure 3–17 Mobile-terminated call operations.

temporary MSRN number is released. Step #8: Using the mobile's MSISDN, the MSC/VLR determines th location area where the mobile is located. Step #9: The MS is paged in all the cells that make up this loca tion area. Step #10: When the MS responds to the paging message, authentication is performed anc encryption enabled. If the authentication and encryption functions are confirmed, the call is connected from the MSC to the BSC to the RBS where a traffic channel has been selected for the air interface.

Mobile-Originated Call

A mobile-originated call consists of the steps shown in Figure 3–18. Step #1: The originating mobile subscriber call starts with a request by the mobile for a signaling channel using a common control channel. If possible, the system assigns a signaling channel to the mobile. Step #2: Using its assigned signaling channel, the MS indicates that it wants service from the system. The VLR sets the status of the mobile to "busy." Step #3: Authentication and encryption are performed. Step #4: The mobile specifies what type of service it wants (assume a voice call) and the number of the party to be called. The MSC/VLR acknowledges the request with a response. Step #5: A link is set up between the MSC and the BSC and a traffic channel is seized. The acquisition of the traffic channel requires several steps: the MSC requests the BSC to assign a traffic channel, the BSC checks to see if there is an idle channel available, if a channel is idle the BSC sends a message to the RBS to activate the channel, the RBS sends a message back to the BSC indicating that the channel has been activated, the MS responds on the assigned traffic channel, the BSC sends a message back to the MSC to indicate that the channel is ready, and finally the MSC/VLR sets up the connection to the PSTN. Step #6: An alerting message is sent to the mobile to indicate that the called party is being sent a ringing tone. The ringing tone generated in the PSTN exchange that is serving the called party is transmitted through the MSC back to the mobile. When the called party answers, the network sends a Connect message to the mobile to indicate that the call has been accepted. The mobile returns a Connect Accepted message that completes the call setup process.

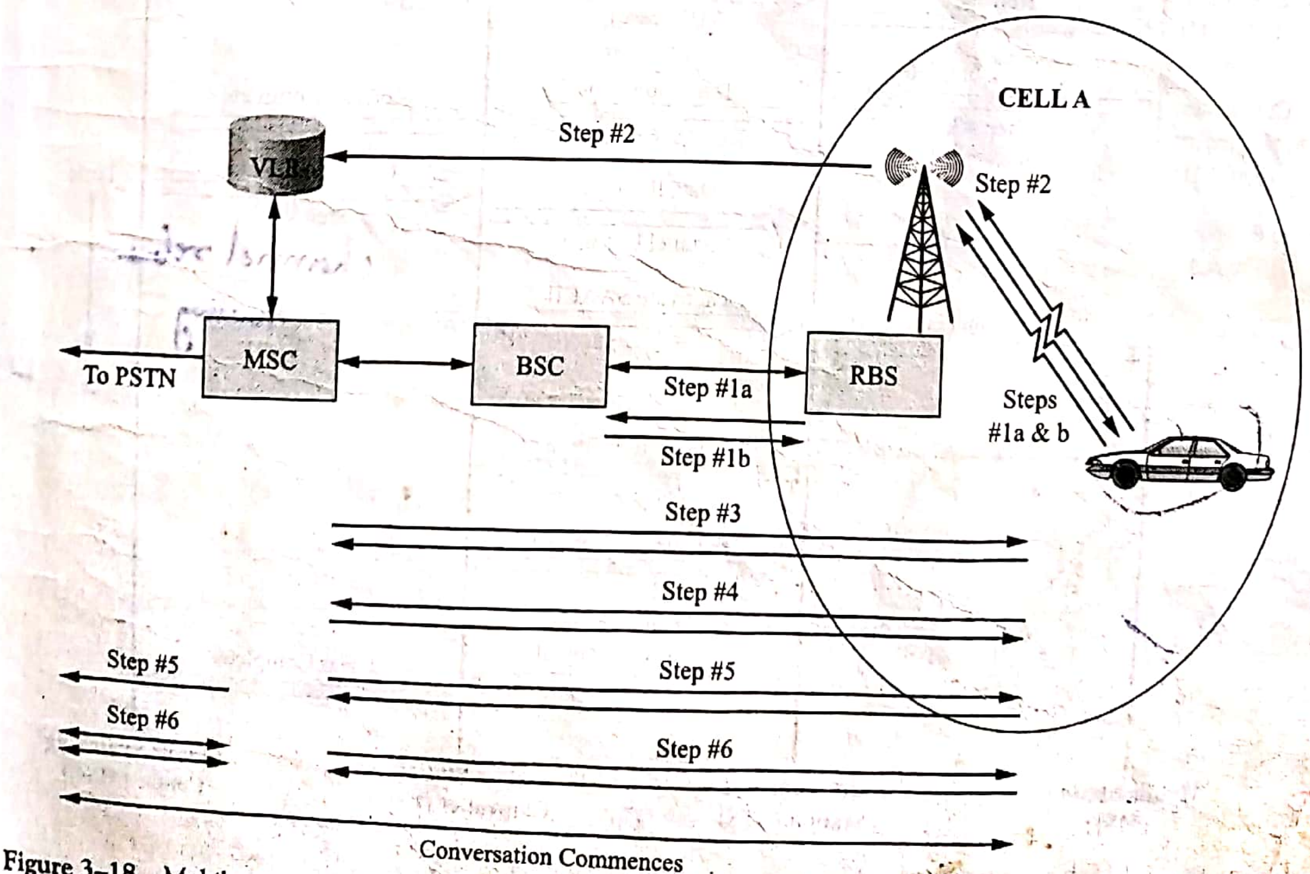
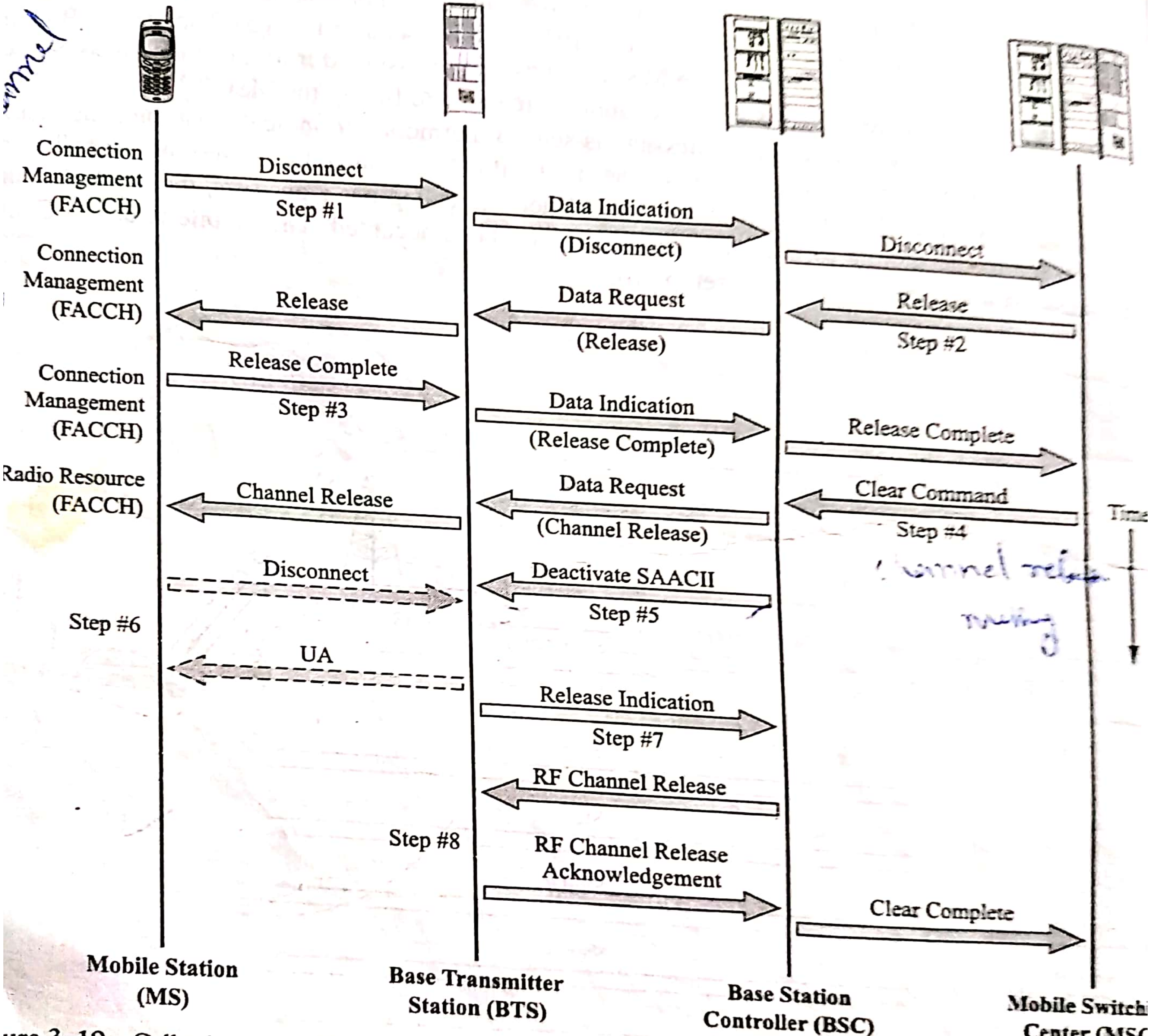


Figure 3–18 Mobile-originated call operations.

Call Release

Call release initiated by the mobile consists of the steps shown in Figure 3–19. Step #1: The mobile sends a Disconnect message to the RBS, the message is passed on to the BSC where it is sent through a signaling link to the MSC. Step #2: The MSC sends a Release message to the MS. Step #3: The MS sends a Release Complete message back to the MSC as an acknowledgement that the operation is complete. Step #4: The network initiates a channel release by sending a Clear Command message from the MSC to the BSC. The BSC sends the Channel Release message to the mobile through the RBS. Step #5: At this point, the BSC sends a Deactivate message to the RBS telling it to stop sending periodic messages to the mobile on a control channel. Step #6: When the mobile gets the Channel Release message, it disconnects the traffic channel and sends the LAPDm disconnect frame. The RBS sends an LAPDm acknowledgement frame back to the mobile. Step #7: A Release Indication message is sent from the RBS to the BSC. Step #8: The BSC sends an *RF* Channel Release message to the RBS that is acknowledged as shown, as soon as the RBS stops transmitting on the traffic channel. After a short period (regulated by a BSC system timer) a Clear Complete message is sent to the MSC from the BSC.



ure 3–19 Call release operations.

wireless mobile network and the overall system-level functions that occur.

QUESTIONS AND PROBLEMS

1. Which two elements of a wireless cellular system perform the "air interface" function?
2. What is the function of the transcoder controller?
3. What is the function of the visitor location register?
4. What is the function of the home location register?
5. What is the function of the mobile switching center?
6. What wireless cellular network element or elements provide security functions for the system?
7. What does a cell global identity number correspond to?
8. The LAI is used for what purpose?
9. What is the function of a radio network controller?
10. Name the two core networks associated with 3G cellular networks.
11. What is the difference between an MSISDN number and an IMSI number?
12. What is the purpose of a global title?
13. What is a mobile global title?
14. What is global title translation?
15. Using the Internet, determine the mobile country code for Mexico.
16. Explain the function of a mobile station roaming number.
17. During a mobile-originated call, when is authentication and encryption performed?
18. What is the first step performed by the mobile during a call release operation?
19. What is the last step performed during a call release operation?
20. What wireless cellular network elements are involved in a mobile-originated call?