# Global System for Mobile Communication (GSM)

## Definition

Global system for mobile communication (GSM) is a globally accepted standard for digital cellular communication. GSM is the name of a standardization group established in 1982 to create a common European mobile telephone standard that would formulate specifications for a pan-European mobile cellular radio system operating at 900 MHz. It is estimated that many countries outside of Europe will join the GSM partnership.

## Overview

This tutorial provides an introduction to basic GSM concepts, specifications, networks, and services. A short history of network evolution is provided in order set the context for understanding GSM.

## Topics

1. Introduction: The Evolution of Mobile Telephone Systems
2. GSM
3. The GSM Network
4. GSM Network Areas
5. GSM Specifications
6. GSM Subscriber Services

Self-Test

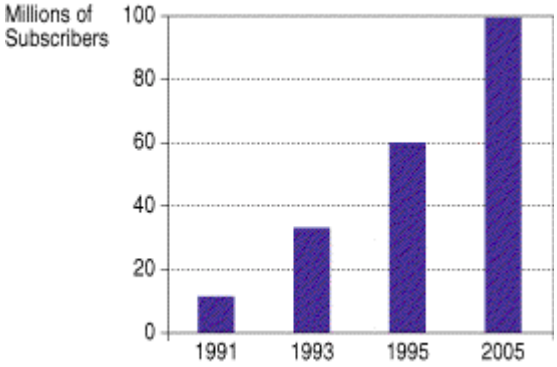
Correct Answers

Acronym Guide

# 1. Introduction: The Evolution of Mobile Telephone Systems

Cellular is one of the fastest growing and most demanding telecommunications applications. Today, it represents a continuously increasing percentage of all new telephone subscriptions around the world. Currently there are more than 45 million cellular subscribers worldwide, and nearly 50 percent of those subscribers are located in the United States. It is forecasted that cellular systems using a digital technology will become the universal method of telecommunications. By the year 2005, forecasters predict that there will be more than 100 million cellular subscribers worldwide. It has even been estimated that some countries may have more mobile phones than fixed phones by the year 2000 (see *Figure 1*).

**Figure 1. Cellular Subscriber Growth Worldwide**




The concept of cellular service is the use of low-power transmitters where frequencies can be reused within a geographic area. The idea of cell-based mobile radio service was formulated in the United States at Bell Labs in the early 1970s. However, the Nordic countries were the first to introduce cellular services for commercial use with the introduction of the Nordic Mobile Telephone (NMT) in 1981.

Cellular systems began in the United States with the release of the advanced mobile phone service (AMPS) system in 1983. The AMPS standard was adopted by Asia, Latin America, and Oceanic countries, creating the largest potential market in the world for cellular.

In the early 1980s, most mobile telephone systems were analog rather than digital, like today's newer systems. One challenge facing analog systems was the inability to handle the growing capacity needs in a cost-efficient manner. As a result, digital technology was welcomed. The advantages of digital systems over analog systems include ease of signaling, lower levels of interference, integration of transmission and switching, and increased ability to meet capacity demands. *Table 1* charts the worldwide development of mobile telephone systems.

**Table 1. The Development of Mobile Telephone Systems**

| Year | Mobile System |
|---|---|
| 1981 | Nordic Mobile Telephone (NMT) 450 |
| 1983 | American Mobile Phone System (AMPS) |
| 1985 | Total Access Communication System (TACS) |
| 1986 | Nordic Mobile Telephony (NMT) 900 |
| 1991 | American Digital Cellular (ADC) |
| 1991 | Global System for Mobile Communication (GSM) |
| 1992 | Digital Cellular System (DCS) 1800 |
| 1994 | Personal Digital Cellular (PDC) |
| 1995 | PCS 1900—Canada |
| 1996 | PCS—United States |

# 2. GSM

Throughout the evolution of cellular telecommunications, various systems have been developed without the benefit of standardized specifications. This presented many problems directly related to compatibility, especially with the development of digital radio technology. The GSM standard is intended to address these problems.

From 1982 to 1985 discussions were held to decide between building an analog or digital system. After multiple field tests, a digital system was adopted for GSM. The next task was to decide between a narrow or broadband solution. In May 1987, the narrowband time division multiple access (TDMA) solution was chosen. A summary of GSM milestones is given in *Table 2*.

**Table 2. GSM Milestones**

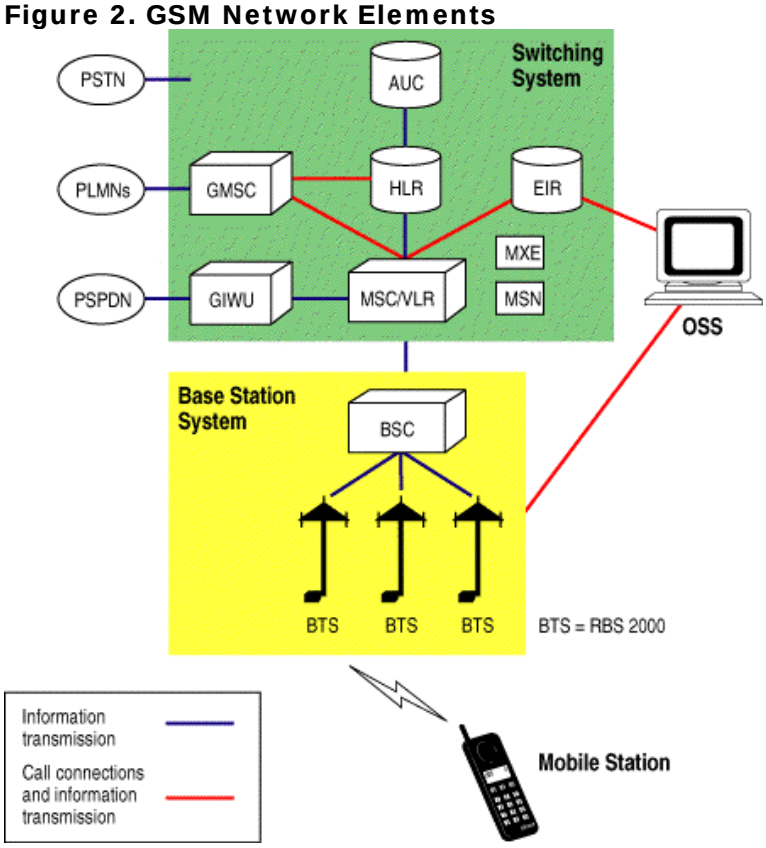
| Year | Milestone |
|---|---|
| 1982 | GSM formed |
| 1986 | field test |
| 1987 | TDMA chosen as access method |
| 1988 | memorandum of understanding signed |

| | |
|---|---|
| 1989 | validation of GSM system |
| 1990 | preoperation system |
| 1991 | commercial system start-up |
| 1992 | coverage of larger cities/airports |
| 1993 | coverage of main roads |
| 1995 | coverage of rural areas |

# 3. The GSM Network

GSM provides recommendations, not requirements. The GSM specifications define the functions and interface requirements in detail but do not address the hardware. The reason for this is to limit the designers as little as possible but still to make it possible for the operators to buy equipment from different suppliers. The GSM network is divided into three major systems: the switching system (SS), the base station system (BSS), and the operation and support system (OSS). The basic GSM network elements are shown in *Figure 2*.

**Figure 2. GSM Network Elements**



## The Switching System

The switching system (SS) is responsible for performing call processing and subscriber-related functions. The switching system includes the following functional units:

- **home location register (HLR)**—The HLR is a database used for storage and management of subscriptions. The HLR is considered the most important database, as it stores permanent data about subscribers, including a subscriber's service profile, location information, and activity status. When an individual buys a subscription from one of the PCS operators, he or she is registered in the HLR of that operator.

- **mobile services switching center (MSC)**—The MSC performs the telephony switching functions of the system. It controls calls to and from other telephone and data systems. It also performs such functions as toll ticketing, network interfacing, common channel signaling, and others.

- **visitor location register (VLR)**—The VLR is a database that contains temporary information about subscribers that is needed by the MSC in order to service visiting subscribers. The VLR is always integrated with the MSC. When a mobile station roams into a new MSC area, the VLR connected to that MSC will request data about the mobile station from the HLR. Later, if the mobile station makes a call, the VLR will have the information needed for call setup without having to interrogate the HLR each time.

- **authentication center (AUC)**—A unit called the AUC provides authentication and encryption parameters that verify the user's identity and ensure the confidentiality of each call. The AUC protects network operators from different types of fraud found in today's cellular world.

- **equipment identity register (EIR)**—The EIR is a database that contains information about the identity of mobile equipment that prevents calls from stolen, unauthorized, or defective mobile stations. The AUC and EIR are implemented as stand-alone nodes or as a combined AUC/EIR node.

## The Base Station System (BSS)

All radio-related functions are performed in the BSS, which consists of base station controllers (BSCs) and the base transceiver stations (BTSs).

- **BSC**—The BSC provides all the control functions and physical links between the MSC and BTS. It is a high-capacity switch that provides functions such as handover, cell configuration data, and control of radio frequency (RF) power levels in base transceiver stations. A number of BSCs are served by an MSC.

- **BTS**—The BTS handles the radio interface to the mobile station. The BTS is the radio equipment (transceivers and antennas) needed to service each cell in the network. A group of BTSs are controlled by a BSC.

## The Operation and Support System

The operations and maintenance center (OMC) is connected to all equipment in the switching system and to the BSC. The implementation of OMC is called the operation and support system (OSS). The OSS is the functional entity from which the network operator monitors and controls the system. The purpose of OSS is to offer the customer cost-effective support for centralized, regional, and local operational and maintenance activities that are required for a GSM network. An important function of OSS is to provide a network overview and support the maintenance activities of different operation and maintenance organizations.

## Additional Functional Elements

Other functional elements shown in *Figure 2* are as follows:

- **message center (MXE)**—The MXE is a node that provides integrated voice, fax, and data messaging. Specifically, the MXE handles short message service, cell broadcast, voice mail, fax mail, e-mail, and notification.

- **mobile service node (MSN)**—The MSN is the node that handles the mobile intelligent network (IN) services.

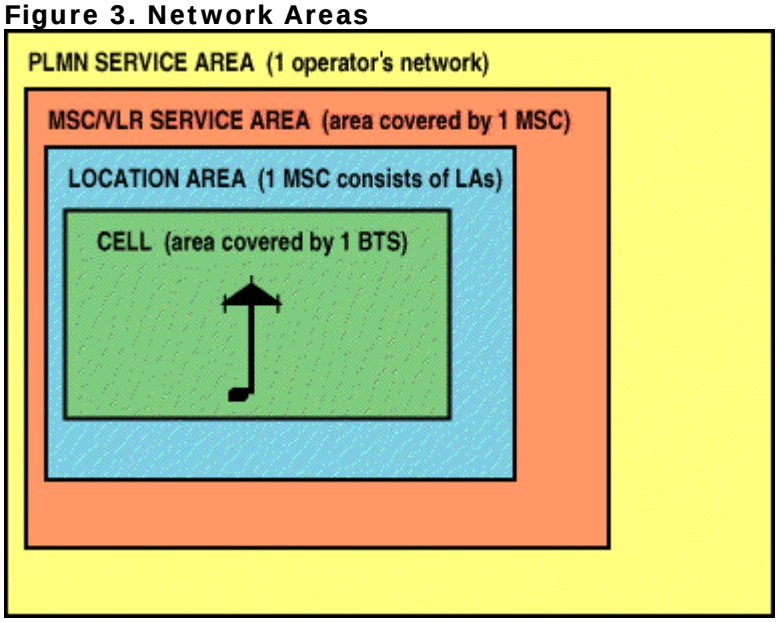
- **gateway mobile services switching center (GMSC)**—A gateway is a node used to interconnect two networks. The gateway is often implemented in an MSC. The MSC is then referred to as the GMSC.

- **GSM interworking unit (GIWU)**—The GIWU consists of both hardware and software that provides an interface to various networks for data communications. Through the GIWU, users can alternate between speech and data during the same call. The GIWU hardware equipment is physically located at the MSC/VLR.

# 4. GSM Network Areas

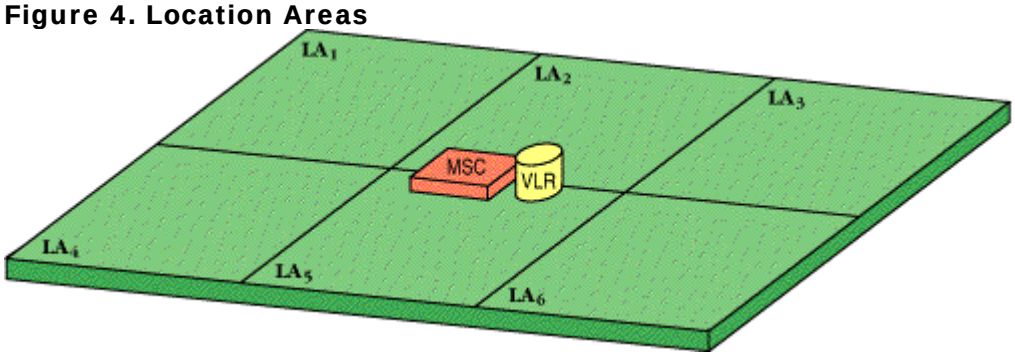
The GSM network is made up of geographic areas. As shown in *Figure 3*, these areas include cells, location areas (LAs), MSC/VLR service areas, and public land mobile network (PLMN) areas.

**Figure 3. Network Areas**



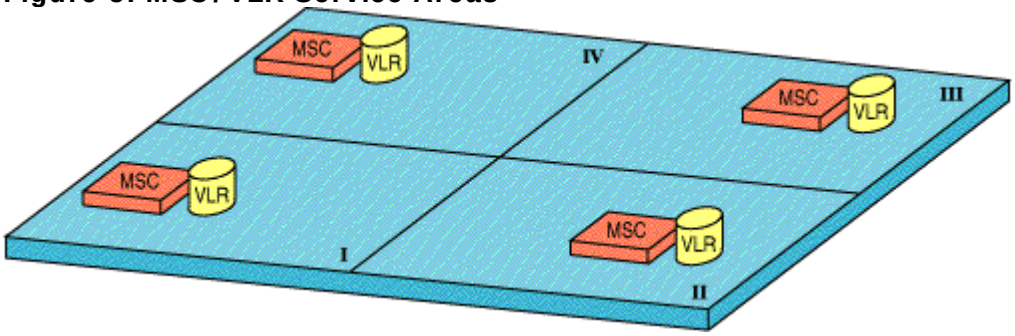

The cell is the area given radio coverage by one base transceiver station. The GSM network identifies each cell via the cell global identity (CGI) number assigned to each cell. The location area is a group of cells. It is the area in which the subscriber is paged. Each LA is served by one or more base station controllers, yet only by a single MSC (see *Figure 4*). Each LA is assigned a location area identity (LAI) number.

**Figure 4. Location Areas**



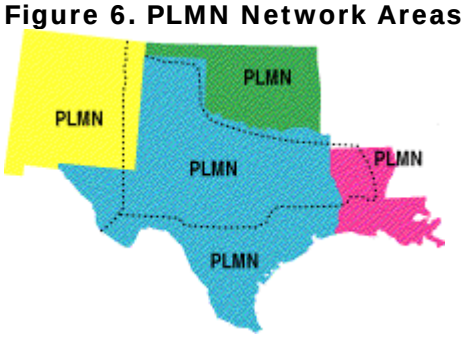

An MSC/VLR service area represents the part of the GSM network that is covered by one MSC and which is reachable, as it is registered in the VLR of the MSC (see *Figure 5*).

**Figure 5. MSC/VLR Service Areas**




The PLMN service area is an area served by one network operator (see *Figure 6*).

**Figure 6. PLMN Network Areas**




# 5. GSM Specifications

Before looking at the GSM specifications, it is important to understand the following basic terms:

- **bandwidth**—the range of a channel's limits; the broader the bandwidth, the faster data can be sent
- **bits per second (bps)**—a single on-off pulse of data; eight bits are equivalent to one byte
- **frequency**—the number of cycles per unit of time; frequency is measured in hertz (Hz)
- **kilo (k)**—kilo is the designation for 1,000; the abbreviation kbps represents 1,000 bits per second
- **megahertz (MHz)**—1,000,000 hertz (cycles per second)
- **milliseconds (ms)**—one-thousandth of a second
- **watt (W)**—a measure of power of a transmitter

Specifications for different personal communication services (PCS) systems vary among the different PCS networks. Listed below is a description of the specifications and characteristics for GSM.

- **frequency band**—The frequency range specified for GSM is 1,850 to 1,990 MHz (mobile station to base station).

- **duplex distance**—The duplex distance is 80 MHz. Duplex distance is the distance between the uplink and downlink frequencies. A channel has two frequencies, 80 MHz apart.

- **channel separation**—The separation between adjacent carrier frequencies. In GSM, this is 200 kHz.

- **modulation**—Modulation is the process of sending a signal by changing the characteristics of a carrier frequency. This is done in GSM via Gaussian minimum shift keying (GMSK).

- **transmission rate**—GSM is a digital system with an over-the-air bit rate of 270 kbps.

- **access method**—GSM utilizes the time division multiple access (TDMA) concept. TDMA is a technique in which several different calls may share the same carrier. Each call is assigned a particular time slot.

- **speech coder**—GSM uses linear predictive coding (LPC). The purpose of LPC is to reduce the bit rate. The LPC provides parameters for a filter that mimics the vocal tract. The signal passes through this filter, leaving behind a residual signal. Speech is encoded at 13 kbps.

# 6. GSM Subscriber Services

There are two basic types of services offered through GSM: telephony (also referred to as teleservices) and data (also referred to as bearer services). Telephony services are mainly voice services that provide subscribers with the complete capability (including necessary terminal equipment) to communicate with other subscribers. Data services provide the capacity necessary to transmit appropriate data signals between two access points creating an interface to the network. In addition to normal telephony and emergency calling, the following subscriber services are supported by GSM:

- **dual-tone multifrequency (DTMF)**—DTMF is a tone signaling scheme often used for various control purposes via the telephone network, such as remote control of an answering machine. GSM supports full-originating DTMF.

- **facsimile group III**—GSM supports CCITT Group 3 facsimile. As standard fax machines are designed to be connected to a telephone using analog signals, a special fax converter connected to the exchange is used in the GSM system. This enables a GSM–connected fax to communicate with any analog fax in the network.

- **short message services**—A convenient facility of the GSM network is the short message service. A message consisting of a maximum of 160 alphanumeric characters can be sent to or from a mobile station. This service can be viewed as an advanced form of alphanumeric paging with a number of advantages. If the subscriber's mobile unit is powered off or has left the coverage area, the message is stored and offered back to the subscriber when the mobile is powered on or has reentered the coverage area of the network. This function ensures that the message will be received.

- **cell broadcast**—A variation of the short message service is the cell broadcast facility. A message of a maximum of 93 characters can be broadcast to all mobile subscribers in a certain geographic area. Typical applications include traffic congestion warnings and reports on accidents.

- **voice mail**—This service is actually an answering machine within the network, which is controlled by the subscriber. Calls can be forwarded to the subscriber's voice-mail box and the subscriber checks for messages via a personal security code.

- **fax mail**—With this service, the subscriber can receive fax messages at any fax machine. The messages are stored in a service center from which they can be retrieved by the subscriber via a personal security code to the desired fax number.

## Supplementary Services

GSM supports a comprehensive set of supplementary services that can complement and support both telephony and data services. Supplementary services are defined by GSM and are characterized as revenue-generating features. A partial listing of supplementary services follows.

- **call forwarding**—This service gives the subscriber the ability to forward incoming calls to another number if the called mobile unit is not reachable, if it is busy, if there is no reply, or if call forwarding is allowed unconditionally.

- **barring of outgoing calls**—This service makes it possible for a mobile subscriber to prevent all outgoing calls.

- **barring of incoming calls**—This function allows the subscriber to prevent incoming calls. The following two conditions for incoming call barring exist: baring of all incoming calls and barring of incoming calls when roaming outside the home PLMN.

- **advice of charge (AoC)**—The AoC service provides the mobile subscriber with an estimate of the call charges. There are two types of AoC information: one that provides the subscriber with an estimate of the bill and one that can be used for immediate charging purposes. AoC for data calls is provided on the basis of time measurements.

- **call hold**—This service enables the subscriber to interrupt an ongoing call and then subsequently reestablish the call. The call hold service is only applicable to normal telephony.

- **call waiting**—This service enables the mobile subscriber to be notified of an incoming call during a conversation. The subscriber can answer, reject, or ignore the incoming call. Call waiting is applicable to all GSM telecommunications services using a circuit-switched connection.

- **multiparty service**—The multiparty service enables a mobile subscriber to establish a multiparty conversation—that is, a simultaneous conversation between three and six subscribers. This service is only applicable to normal telephony.

- **calling line identification presentation/restriction**—These services supply the called party with the integrated services digital network (ISDN) number of the calling party. The restriction service enables the calling party to restrict the presentation. The restriction overrides the presentation.

- **closed user groups (CUGs)**—CUGs are generally comparable to a PBX. They are a group of subscribers who are capable of only calling themselves and certain numbers.

# Self-Test

1. Right now, GSM is the accepted cellular standard in _____.

    a. Europe

    b. South America

c. North America

d. Southeast Asia

e. all of the above

2. Which area of the world first deployed cellular services for commercial use?

a. Scandinavia

b. Central America

c. Western Africa

d. Central Asia

e. Eastern Europe

3. Modulation refers to _____.

a. the distance between the uplink and downlink frequencies

b. the separation between adjacent carrier frequencies

c. the process of changing the characteristics of a carrier frequency

d. the number of cycles per unit of time

4. Which of the following are not telephony services supported by GSM?

a. dual-tone multifrequency

b. voice mail

c. fax mail

d. call waiting

5. What is the basic service unit of cellular telephony?

a. location area

b. cell

c. PLMN service area

d. MSC/VLR service area

6. The first cellular systems were _____.

a. analog

b. digital

7. The location area is the area in which a subscriber can be paged.

a. true

b. false

8. The idea of cell-based mobile radio service was formulated in the Nordic countries in the early 1970s.

a. true

b. false

9. GSM provides requirements for analog cellular service.

a. true

b. false

10. The home location register (HLR) is a database used for storing and managing subscriptions.

a. true

b. false

11. The authentication center (AUC) provides authentication and encryption parameters that verify the user's identity and ensure the confidentiality of each call.

a. true

b. false

12. The message center (MXE) is the node that provides intelligent network services.

a. true

b. false

13. The PLMN service area is an area served by one network operator.

    a. true

    b. false

14. GSM utilizes the code division multiple access (CDMA) concept, rather than time division multiple access (TDMA).

    a. true

    b. false

# Correct Answers

1. Right now, GSM is the accepted cellular standard in _____.

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    See Topic 1.

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# Acronym Guide

**ADC**
American Digital Cellular

**AMPS**
advanced mobile phone service

**AoC**
advice of charge

**AUC**
authentication center

**bps**
bits per second

**BSC**
base station controller

**BSS**
base station system

**BTS**
base transceiver station

**CGI**
cell global identity

**CUG**
closed user group

**DCS**
digital cellular system

**DTMF**
dual-tone multifrequency

**EIR**
equipment identity register

**GIWU**
GSM interworking unit

**GMSC**
gateway mobile services switching center

**GMSK**
Gaussian minimum shift keying

**GSM**
global system for mobile communication

**HLR**
home location register

**Hz**
hertz

**ISDN**
integrated services digital network

**k**
kilo

**kbps**
kilobits per second

**LA**
location area

**LAI**
location-area identity

**LPC**
linear predictive coding

**MHz**
megahertz

**MSC**
mobile services switching center

**MSN**
mobile service node

**MXE**
message center

**NMT**
Nordic Mobile Telephone

**OMC**
operations and maintenance center

**OSS**
operation and support system

**PCS**
personal communications services

**PDC**
personal digital cellular

**PLMN**
public land mobile network

**SS**
switching system

**TACS**
total access communication system

**TDMA**
time division multiple access

**VLR**
visitor location register