

# OA&M for the GSM Network

Yi-Bing Lin, National Chiao Tung University

## Abstract

This article provides a road map to understand the GSM operation, administration, and maintenance (OA&M) management. We describe how the telecommunication management network (TMN) concept is applied to the GSM OA&M. The home location registration and call recording management are used as examples to illustrate how GSM OA&M functions can be implemented under the TMN platform.

**G**lobal System for Mobile Communications (GSM) is a wireless digital signaling network standard designed by standardization committees from the major European telecommunications operators and manufacturers. The GSM standard provides a common set of compatible services and capabilities to all mobile users worldwide. Different aspects of GSM have been introduced in the literature [1, 2]. This article provides an overview to the operations, administration, and maintenance (OA&M) aspects of GSM.

Figure 1 illustrates the GSM network architecture. The network consists of:

- Databases such as home location register (HLR), visitor location register (VLR), equipment identity register (EIR), and authentication center (AuC)
- Switches such as mobile switching centers (MSCs) and gateway MSCs (GMSCs)
- The radio system or base station system (BSS), including base station controllers (BSCs), base transceiver stations (BTSs), and mobile stations (Mss)

The details of the GSM architecture can be found in [1-3].

GSM, like other telecommunication systems, requires OA&M functions. These functions are not specific to GSM. To be compatible with other telecommunication systems, GSM follows the standard telecommunication management network (TMN) concept [4] developed by the International Telecommunications Union — Telecommunications Standardization Sector (ITU-T). The general TMN concept will be briefly described. Then we focus on the GSM-specific features implemented on top of the TMN platform.

## The TMN Concept

The TMN architecture is illustrated in Fig. 2. Some of the TMN components are introduced in this section. The reader is referred to [5] for complete TMN model treatment:

*Operations System* — With the operations system function (OSF), the operations system (OS) is responsible for overall TMN management. The OSFs can be billing, accounting, management of mobile equipment, HLR measurement, and so on.

*Network Element* — The network elements (NEs) in GSM are HLR, VLR, MSC, EIR, AuC, BSC, and BTS. The

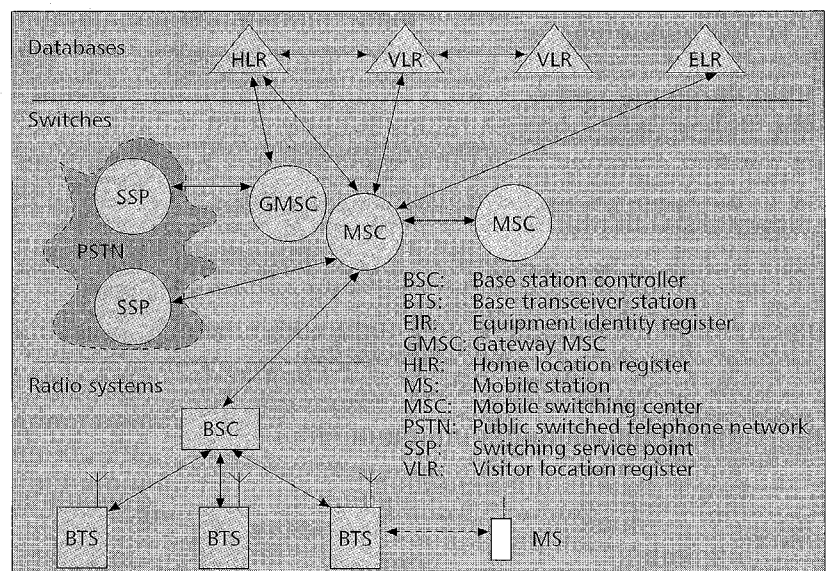


Figure 1. The GSM architecture.

NEs are monitored or controlled by the OS. The network element functions (NEFs) in the NE represent the telecommunications and support functions to be managed by the OS.

**Data Communication Network** — The OSs, NEs, and other TMN elements communicate through the data communication network (DCN) by using the data communication function (DCF). The DCN technology can be wide area network (WAN), local area network (LAN), or others.

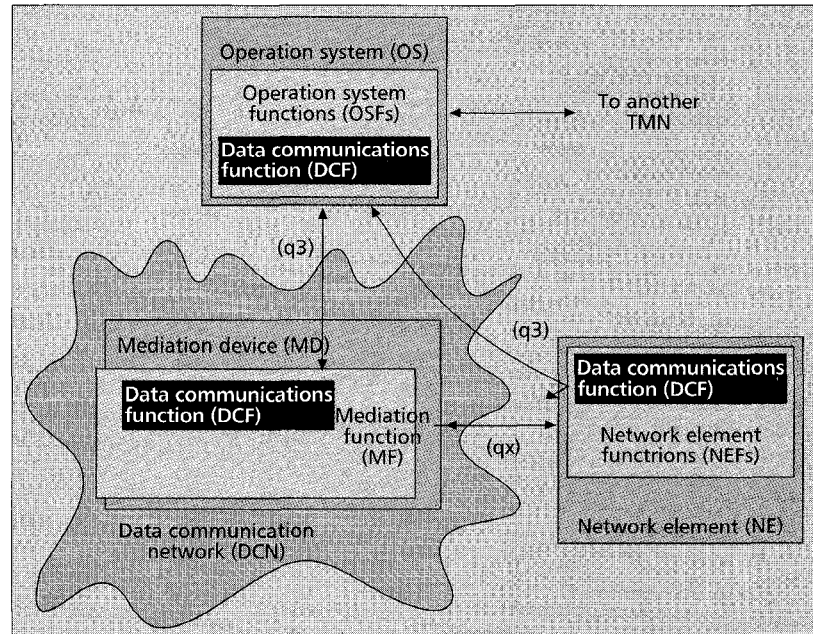
**Mediation Device** — The mediation device (MD) adapts the OS to the specific NEs. It uses the mediation function (MF) to route or pass information between standardized interfaces. For example, the BTSs are connected to the management network through their BSC (Fig. 3). Thus, the BSC acts as the MD for the BTSs under its control.

The relationship between components of TMN functions are defined by using the *reference points*. The  $q_3$  point connects an OSF to an MF or an NEF. The  $q_x$  points connect an MF to an NEF.

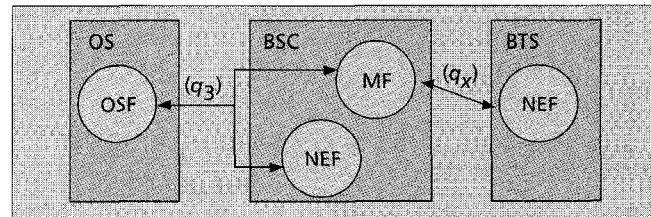
### High-Level Managed Object Class Containment

In GSM TMN, some common management functions (see i in Fig. 4) are used to support other specific functions such as *hlrFunction* and *vlrFunction* (see a–h in Fig. 4). All these functions are derived from the *managedElement* class defined in [6] (see j in Fig. 4). The *managedElement* class is derived from the *plmnNetwork* class defined in [4] (see k in Fig. 4), and the *plmnNetwork* class is derived from the *network* class defined in [6] (see l in Fig. 4). The *common management functions* for GSM are classified into three categories.

**Forwarding of Event Notifications** — GSM managed object classes (in an NE) emit event notifications (to the OS) following the *Event Report Systems Management Function* [7]. The object class Event Forwarding Discriminator (EFD) in the NE manages the forwarding of event notifications (to be elaborated in the next section).



■ Figure 2. A simplified TMN architecture.



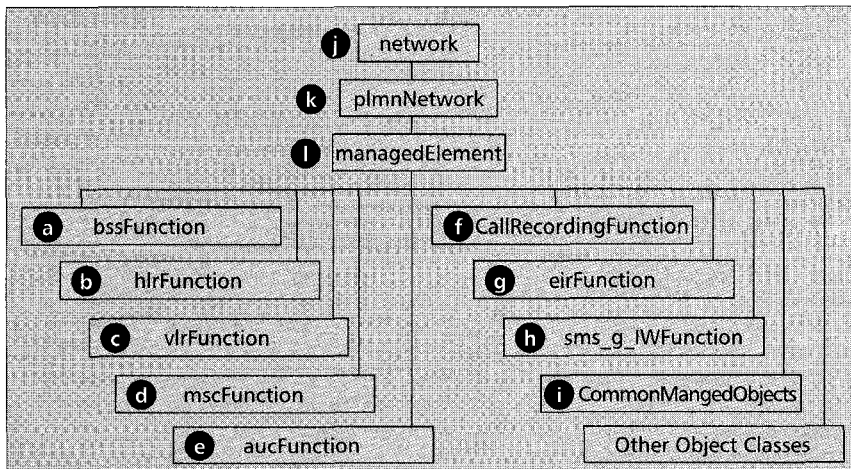
■ Figure 3. The TMN connection for the GSM base station system.

**Information Logging** — Information generated by the NE may be stored in a record filestore in the NE. The information can subsequently be retrieved by the NE or the OS. The GSM NE follows the standard *Log Control Systems Management Function* [8] to allow the OS to control the logging of selective event notifications.

**Bulk Data Transfer between the OS and NE** — The data transfer between the OS and NE uses the common management information service element (CMISE) control of file transfer access and management (FTAM) [9]. The data transfer is controlled by the OS.

The specific GSM network management functions (Fig. 4) include

- *bssFunction* [10, 11] for BSS management (the function resides in the BSC in Fig. 1)
- *hlrFunction* [10, 12] for HLR management (the function resides in the HLR in Fig. 1)
- *vlrFunction* [11, 13] for VLR management (the function resides in the VLR in Fig. 1)
- *mscFunction* [10, 13] for MSC management (the function resides in the MSC and the GMSC in Fig. 1)
- *eirFunction* [10, 12] for EIR management (the function resides in the EIR in Fig. 1)
- *callRecordingFunction* [13] for call recording management (the function resides in all GSM components illustrated in Fig. 1)



■ Figure 4. GSM managed object class containment.

## Acronyms

AoC	Advice of charge
AuC	Authentication center
BSC	Base station controller
BSS	Base station system
BTS	Base transceiver station
CMISE	Common management information service element
DCN	Data communication network
DCF	Data communication function
EFD	Event forwarding discriminator
EIR	Equipment identity register
FTAM	File transfer access and management
GMSC	Gateway mobile switching center
GSM	Global System for Mobile Communications
HLR	Home location register
IMSI	International mobile subscriber identity
MAP	Mobile application part
MD	Mediation device
MF	Mediation function
MS	Mobile station
MSC	Mobile switching center
NE	Network element
NEF	Network element function
OA&M	Operations, administrations, and maintenance
OS	Operations system
OSF	Operations system function
PSTN	Public switched telephone network
SDR	Special drawing right
SS7	Signaling System Number 7
SSP	Switching service point
TAP	Transfer account procedure
TMN	Telecommunication management network
VLR	Visitor location register

- *aucFunction* [10, 12] for AuC management (the function resides in the AuC)
  - *sms\_G\_IW\_Function* [10] for short message service management (the function resides in the GMSC in Fig. 1)
- This article will use *callRecordingFunction* and *hlrFunction* as examples to illustrate the GSM network management concept. The sidebar lists all abbreviations used in this article.

## Call Recording Functions

In GSM operation, the billing of mobile subscribers, and statistics of service usage and roaming traffic must be monitored by the OS [13]. This information is provided by NEs such as the MSCs, BSSs, and location registers (VLR/HLR), and is managed by the *tariff and charging administration* defined in [14].

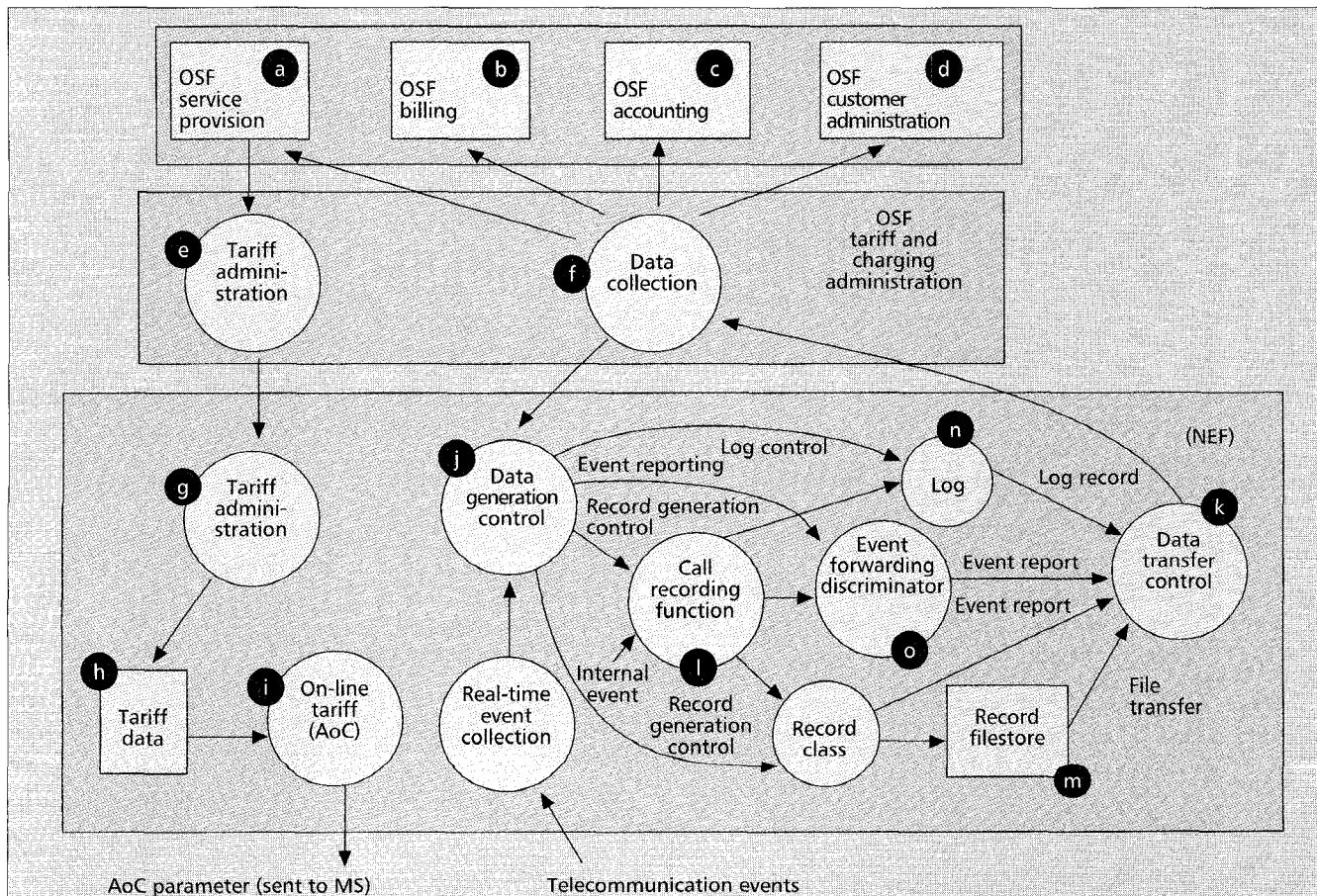
The administration includes the following services.

*Service Provision* — (a in Fig. 5) — This OSF introduces new or modified services to the GSM network. The modifications to the existing services may be partly based on the service usage statistics provided by the NEs (e.g., MSC).

*Billing* — (b in Fig. 5) — Based on the data collected from the NEs, this OSF determines the charge for the services.

*Accounting* — (c in Fig. 5) — GSM accounting consists of two parts:

- *Inter-PLMN accounting* is required for roaming traffic management, which is settled by means of the transfer account



■ Figure 5. Tariff and charging administration.

procedure (TAP) [15]. TAP records are regularly exchanged between a GSM network and other networks. For a visitor from another GSM network, the mobile-originated call charges are calculated and converted to an agreed-on accounting currency such as special drawing rights (SDRs) before they are stored in the TAP. The mobile-terminated calls for the visitor may or may not be charged, but the rerouting charges must be considered. The GSM network may receive the TAPs of its customers roaming in other networks. These TAPs will be processed by the billing OSF.

- *Fixed-network accounting* manages call traffic (between mobile stations and fixed networks) and signaling traffic (e.g., for location updates). The charges for the above traffic are based on the call records provided by the NEs (such as MSCs).

*Customer Administration* — (d in Fig. 5) — This OSF handles customer queries such as billing complaints.

An important aspect of the tariff and charging administration OS is that normal operation of the system should not be interrupted when it is modified. This goal is achieved by creating a duplicate copy of the OSF using the “tsCopyTariffSystem” action defined in [16].

#### Tariff Administration

The tariff administration function in the OSF (e in Fig. 5) provides tariff administration information to the NEs (specifically, the MSCs). The information is then passed from the MSC to the MS (g, h, and i in Fig. 5) to support the advice of charge (AoC) described in [16, 17].

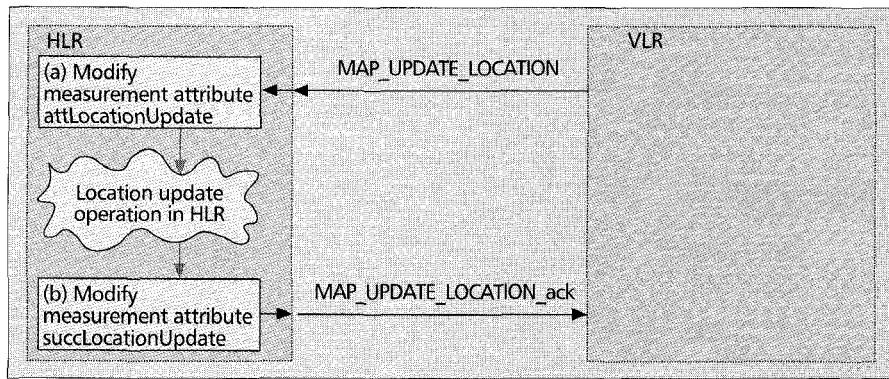
The OSF uses the *tariff class management functions* to assign a *tariff class* with service, distance, and time-based tariff-dependent charging parameters. These dependencies are elaborated below.

- The service charging dependencies are defined based on the customized AoC. The AoC service definition may consist of one or more service types (basic and/or supplementary), radio channel types, connection type (call origination or termination), and so on.
- Distance dependencies are defined based on origins, destinations, and charging zones.
- The time-based tariff dependencies are based on tariff periods (holiday/workday, off-peak/peak, and so on).

#### Data Collection

The data collection functions in the OSF (f in Fig. 5) provides specifications of the collected data to the NEs through *data generation control* (including record generation, event reporting, and log controls; j in Fig. 5) in the NEF, and collects the data from these NEs through the *data transfer control* (k in Fig. 5) in the NEF. In the NEF, the *call recording function* (l in Fig. 5) generates potential call and event records based on the internal telecommunication events of the NE. The record generation control determines where the records are sent. There are three possibilities:

- The records may be forwarded to the record filestore (m in Fig. 5) and then transferred to the OSF



■ Figure 6. Measurement attribute modifications in location update.

via FTAM in real time. One or more class types (billing, accounting, and so on) are defined for the transferred records.

- The records may be saved in a log file (n in Fig. 5), and later accessed by the OSF using the log control [8].
- The records may also be passed to the EFDs controlled by the event reporting function [17] for short-term event reporting (o in Fig. 5).

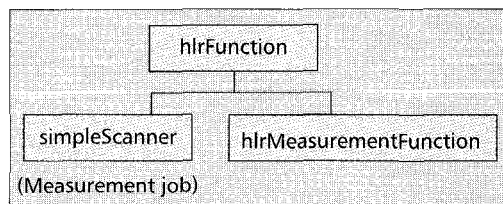
### Performance Measurement and Management

The performance of the GSM network should be evaluated based on the data provided by the NEs. The data include the user/signaling traffic levels, network configuration verification, resource access measurements, quality of service, and so on [10].

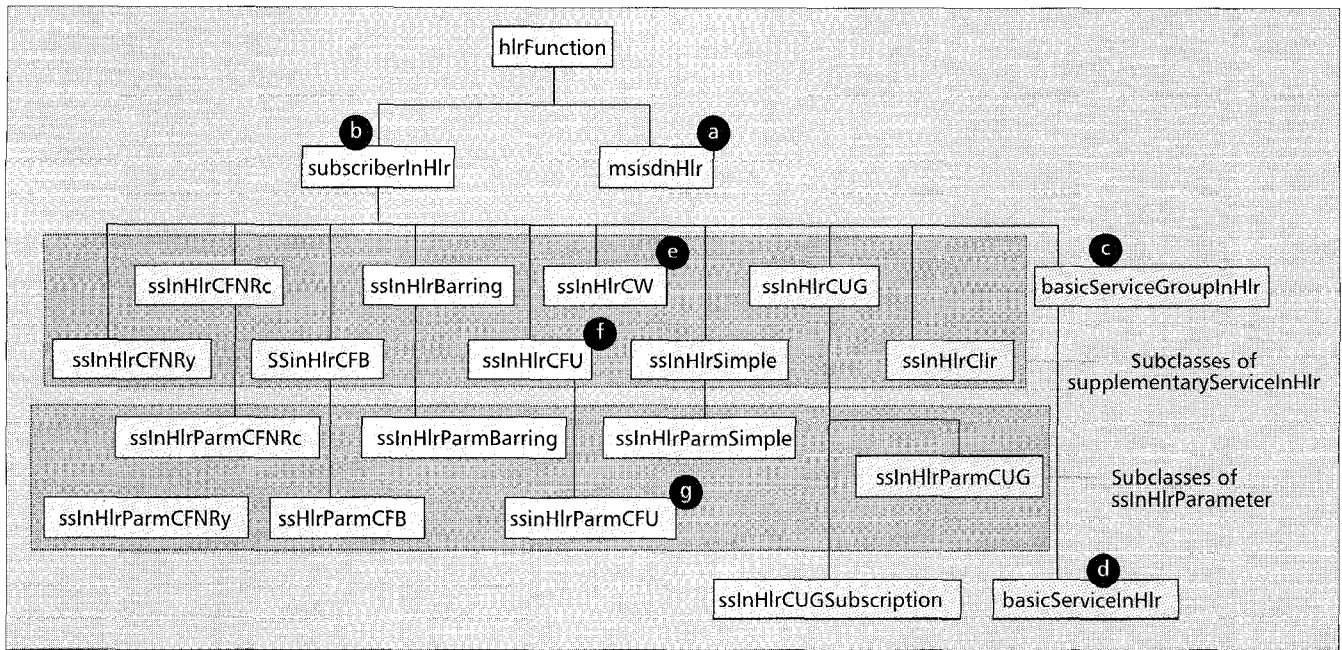
The measurement task is achieved by administrating the *measurement jobs*. A measurement job is created, modified, displayed, suspended, resumed, and deleted in the OS. This job is scheduled in a period to accumulate the measurement data for inspection. The measurement job instructs the *measurement function* objects in the NEs to collect the data. In measurement management, the data exchanges between the OS and NEs follows a mechanism similar to that illustrated in Fig. 5.

Consider the location update measurements of HLR as an example (Fig. 6). In this example, the VLR sends a GSM MAP message MAP\_UPDATE\_LOCATION (i.e., an SS7 message) [3] to the HLR. The HLR updates the location information as well as two measurement attributes, and sends the GSM MAP message MAP\_UPDATE\_LOCATION\_ack back to the VLR. The measurement job created in the OS is implemented as a “simpleScanner” object defined in [18]. Both the HLR measurement job (the “simpleScanner”) and the *hlrMeasurementFunction* (Fig. 7) is derived from the *hlrFunction* class (which is derived from the *managedElement* class in Fig. 4). The simpleScanner object has the following attributes.

*Measurement Types* — In our example (Fig. 6), the measurement types are *attLocationUpdate* (the number of the attempted location updates) and *succLocationUpdate* (the number of successful location updates). Both attributes are single-integer values. The *attLocationUpdate* value is incremented by one (a in Fig. 6) when the MAP\_UPDATE\_LOCATION service indication [3] is received. The *succLocationUpdate* value is incremented by one (b in Fig. 6) when the MAP\_UPDATE\_LOCATION service response is received without the “user error” parameter value.



■ Figure 7. HLR measurement object class containment.



■ Figure 8. HLR subscriber administration object class containment

*Measured Network Resources* — In Fig. 6, the network resource is the HLR.

*Measurement Function* — The simpleScanner specifies one or more measurement functions in the NEs to collect the desired data. In our example, this attribute is hlrMeasurementFunction in the HLR (Fig. 7). The measurement functions must be created before the simpleScanner is instantiated.

In our example, the hlrMeasurementFunction has a conditional package called locationUpdatePackage. This package consists of two attributes, attLocationUpdate and succLocationUpdate (these two attributes are the measurement types of the simpleScanner).

*Measurement Schedule* — This attribute specifies the start time and stop time of the active measurement period. The measurement should be started within 90 days after the measurement job is created.

*Granularity Period* — This attribute specifies the frequency (or, more accurately, the interval) of sending measured data from the NE (HLR in Fig. 7) to the OS. The granularity period should be longer than 5 min, and cannot be changed during the lifetime of the simpleScanner. If this attribute is not specified (i.e., it has the value 0), the measured data are gathered by request of the OS.

*Scan Report* — At the end of every granularity period, a scan report is sent from the NE to the OS. The report includes the timestamp (when the report is sent to the OS) and the measurements (in Fig. 7, the numbers of the attempted and successful location updates) collected by all the measurement functions defined in the simpleScanner.

Other performance management and measurement functions include the functions for BSC, BTS, MSC, GMSC, VLR, and EIR. The details can be found in [10].

### Subscriber and Service Data Management

The GSM subscriber and service data management [12] defines the management for NEs such as AuC, HLR, VLR, and EIR. Under this management, the managed data in different NEFs may depend on each other. For example,

to create a subscriber profile in the HLR, the subscriber data should already exist in the AuC. If not, the creation in the HLR fails. We will use the HLR as an example to illustrate the GSM subscriber and service data management. Figure 8 shows the HLR subscriber administration object class hierarchy. Basically, the mobile station ISDN numbers (MSISDNs) and the subscribers represented by the international mobile subscriber identities (IMSI) are managed in the HLR.

Blocks of available MSISDNs are provided in an HLR. The information of the MSISDN is stored in msisdnHlr (a in Fig. 8). An MSISDN may be connected to a subscriber (IMSI), and can be disconnected when the IMSI is removed from the service. An MSISDN can be associated with several basic services; an association is established between the msisdnHlr object and the basicServiceInHlr objects (d in Fig. 8).

When a customer subscribes to the GSM services, a subscriber profile and thus the subscriberInHlr object (b in Fig. 8) is created in the HLR, and an IMSI is assigned to the customer. One or more MSISDNs are allocated to the IMSI (the association is made between the msisdnHlr objects and the subscriberInHlr object). For every basic service the customer subscribes, a basicServiceInHlr object and the relevant basicServiceGroupInHlr object (c and d in Fig. 8) are created. Similarly, for every supplementary service (e.g., call waiting or call forwarding), a supplementaryServiceInHlr object (e.g., sslnHlrCW or sslnHlrCFU; e and f in Fig. 8) is created. Some supplementary services are specified with parameters, in which case the supplementaryServiceInHlr object will contain the sslnHlrParameter object. For example, the sslnHlrCFU object contains the sslnHlrParmCFU (g in Fig. 8) with attributes such as forwardedToNumber. The subscriber data may be modified (e.g., when a basic or a supplementary service is withdrawn or a new service added). When a subscriber is deleted from the HLR, the corresponding subscriberInHlr object and all its contained objects are removed. The attribute of the corresponding msisdnHlr is modified (the MSISDN is no longer associated with the IMSI).

Other subscriber and service data management functions include the functions for AuC, VLR, and EIR. The details can be found in [12].

## Conclusions

This article provided an overview of GSM O&AM management following the TMN concept. We specifically discussed call recording and HLR management. Complete descriptions (e.g., network security [19], network configuration [20], etc.) of GSM O&AM management can be found in the 12 series of GSM technical specifications. An excellent introduction to and history of the GSM TMN are given in [21, 22]. The details of the mobility databases (such as VLR and HLR) can be found in [23, 24].

One of the major challenges in GSM O&AM is feature interaction with user mobility. New telecommunications service features may interact with GSM user mobility procedures, and the standard O&AM functions will need to be significantly modified to support these services.

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## Biography

YI-BING LIN [SM] received his B.S.E.E. degree from National Chiao Tung University in 1983, and his Ph.D. degree in computer science from the University of Washington in 1990. From 1990 to 1995, he was with the Applied Research Area at Bell Communications Research (Bellcore), Morristown, New Jersey. In 1995, he was appointed full professor of the Department of Computer Science and Information Engineering, National Chiao Tung University. His current research interests include design and analysis of personal communications services networks, mobile computing, distributed simulation, and performance modeling. His e-mail address is [liny@csie.nctu.edu.tw](mailto:liny@csie.nctu.edu.tw). plain