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June 2000
Vol. 7 No. 3

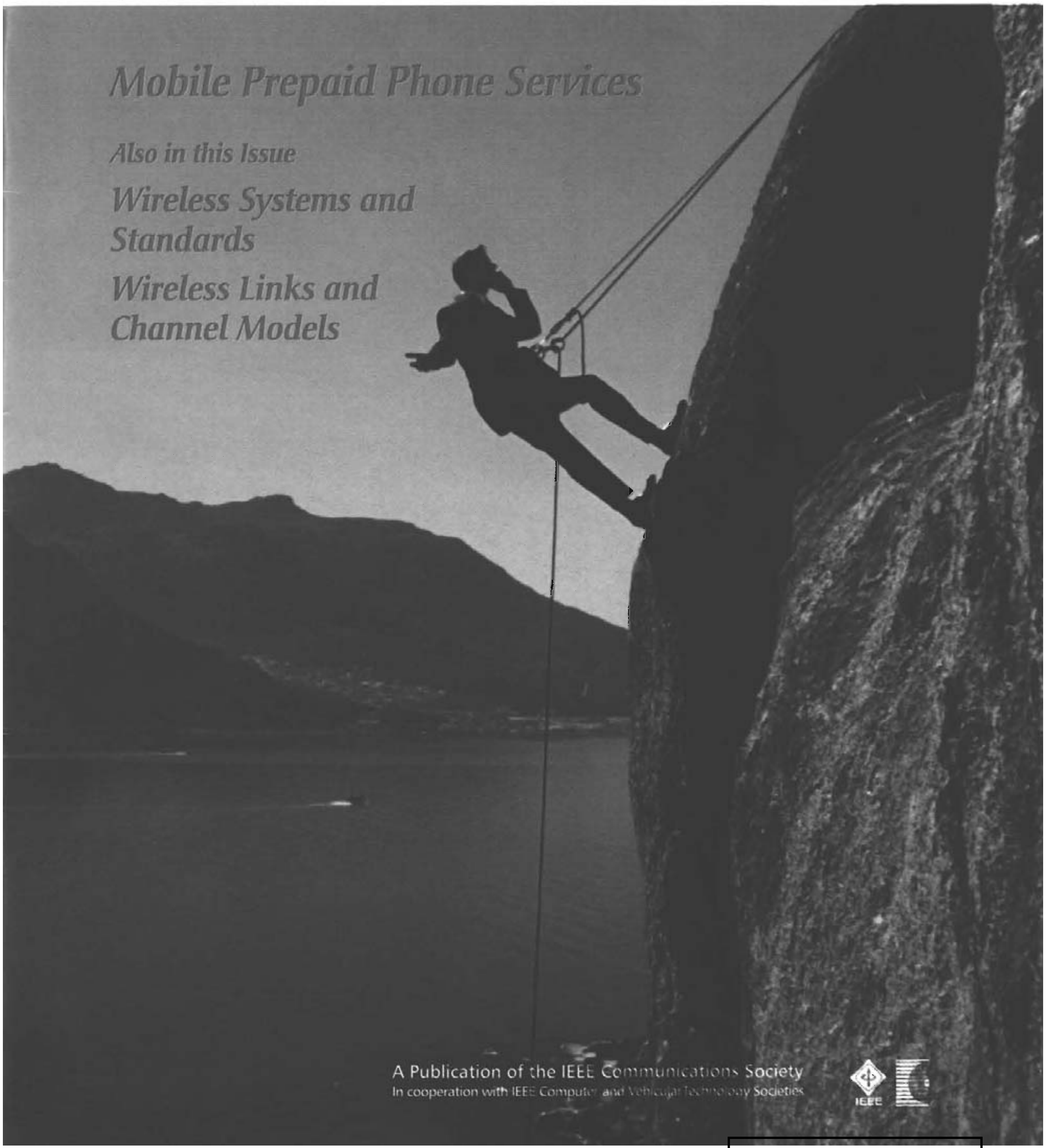
THE MAGAZINE OF WIRELESS COMMUNICATIONS AND NETWORKING

Mobile Prepaid Phone Services

Also in this Issue

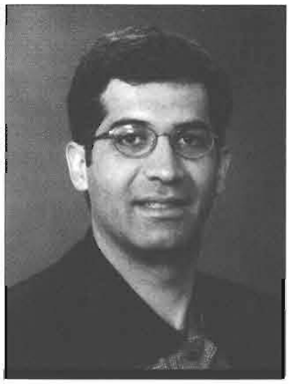
Wireless Systems and Standards

Wireless Links and Channel Models



A Publication of the IEEE Communications Society
In cooperation with IEEE Computer and Vehicular Technology Societies

EDITOR'S NOTE



MAHMOUD NAGHSHINEH

This issue of *IEEE Personal Communications* contains several articles in the areas of mobile and wireless services, wireless systems and standards, and issues related to wireless links and channel models.

The first article, by Y. Lin, H. Rao, and M. Chang, offers an overview of mobile prepaid services and how such services can be provided in a wireless network. It covers a number of example scenarios as well as issues such as billing and subscriber call management with respect to prepaid services. Moreover, this article discusses the network elements and architectural components for prepaid services. Finally, the authors provide a comparison between different prepaid solutions based on scalability, fraud risk, system management issues, and service features.

Our second article is a tutorial on GSM short message services (SMS). This article is authored by G. Peersman, S. Cvetkovic, P. Griffiths, and H.Spaer, and presents a discussion on SMS integration with existing messaging services and its relation to TCP/IP. This tutorial starts with a brief overview of GSM network building blocks, and then puts emphasis on the SMS network and protocol architecture within the GSM framework. Next, an overview of the most widely used messaging protocols is provided, and finally, a summary of current and future issues in this area is presented.

Our next article is authored by D. Koulakiotis and A. Aghvami, and reviews data detection techniques for direct sequence code-division multiple access (DS-CDMA) mobile systems. The authors start by provid-

IEEE Personal Communications — The Magazine of Wireless Communications and Networking (ISSN 1070-9916) is published bimonthly by The Institute of Electrical and Electronics Engineers, Inc. Headquarters address: IEEE, 3 Park Avenue, 17th Floor, New York, NY 10016-5997; tel: 212-705-8900; fax: 212-705-8999; e-mail: c.kemelmacher@comsoc.org. Responsibility for the contents rests upon authors of signed articles and not the IEEE or its members. Unless otherwise specified, the IEEE neither endorses nor sanctions any positions or actions espoused in *IEEE Personal Communications.*

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Editorial correspondence: Manuscripts for consideration may be submitted to the Editor-in-Chief: Mahmoud Naghshineh, IBM Watson Research Center, 30 Saw Mill River Road, Hawthorne, NY 10532. Electronic submissions may be sent in postscript to: mahmoud@watson.ibm.com.

Postmaster: Send address changes to *IEEE Personal Communications*, IEEE, 445 Hoes Lane, Piscataway, NJ 08855-1331; or email to address.change@ieee.org. Printed in USA. Periodicals postage paid at New York, NY and at additional mailing offices. Canadian GST #125634188.

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Abstract

This tutorial presents an overview of the Global System for Mobile Communications Short Message Service from the viewpoint of implementing new telematic services. SMS offers the users of GSM networks the ability to exchange alphanumeric messages up to the limit of 160 characters. The tutorial is motivated by an acute absence of research publications in this field. The information gathered in the tutorial was required considering the increasing potential SMS offers for integration with existing messaging services and its ability to offer a successful replacement for the Transmission Control and Internet Protocols as far as low-bandwidth-demanding applications are concerned. Initially, the tutorial gives a brief overview of the building blocks of GSM networks — the mobile station, base station, and network subsystem — and then emphasizes the SMS network and protocol architecture. The most widely used protocols for message submission are then introduced (text-based, SMS2000, ETSI 0705, TAP) and compared in terms of features provided and flexibility to handle extended alphabets or two-way messaging. Finally the tutorial outlines a summary of current and future issues for further development and research in the light of novel features for submission protocols and telematic services.

The Global System for Mobile Communications Short Message Service

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Since the first Global System for Mobile Communications (GSM) network started operation in 1991, more than 100 countries have adopted the standard. Over 20 million subscribers of GSM networks are now offered worldwide coverage, outstanding voice quality over a whole range of operating conditions, and a variety of value-added services. These services include voice mail, call handling facilities, call line identification, and Short Message Service (SMS).

With SMS, users are able to exchange alphanumeric messages (up to 160 characters) with other users of digital cellular networks, almost anywhere in the world, within seconds of submission. Even if the service was originally conceived as a paging mechanism for notifying the users of voicemail messages, SMS is now increasingly used as a messaging service. The messages are typically created on mobile phone keypads, which is somewhat awkward. Fortunately, there are other ways to access the message centers, as discussed in this article.

Numerous applications are already available and make short message reception and submission possible using a computer. Gateway architectures are also being widely implemented and connect company's e-mail or voicemail systems to the SMS.

The practical implementation of SMS and the different protocols for message submission are addressed in this article. The future of SMS and a brief review of the fields currently being studied will conclude this article.

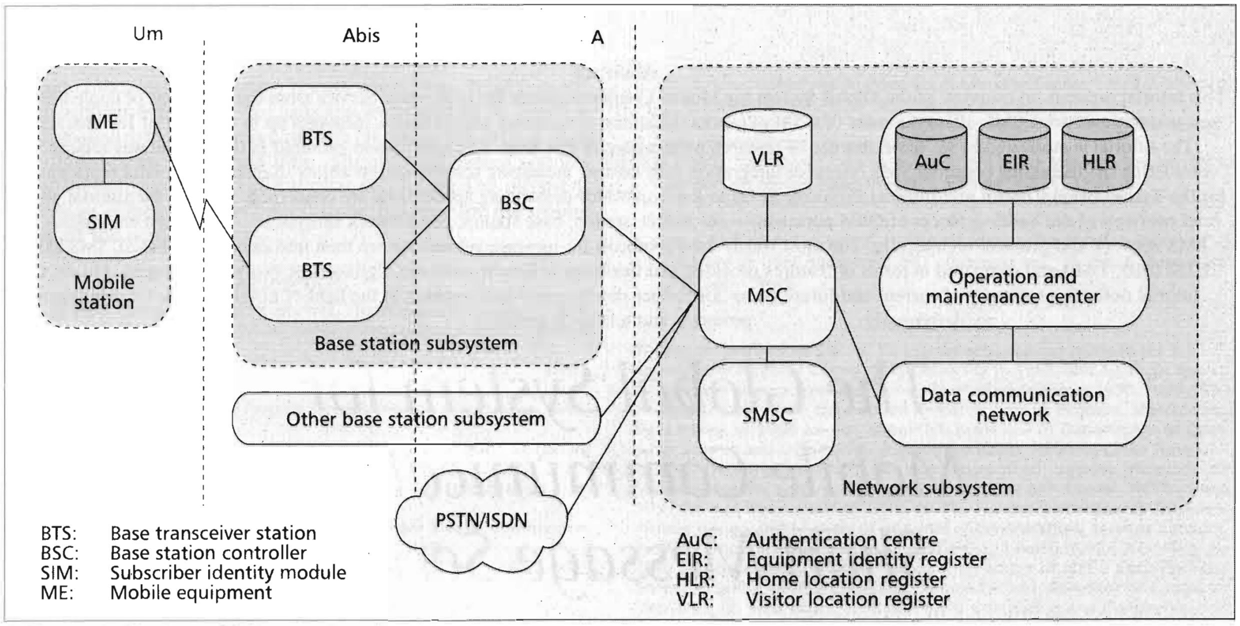
The Short Message Service

Developed as part of the GSM Phase 2 specification, the Short Message Service, or SMS as it is more commonly known, is based on the capability of a digital cellular terminal to send and/or receive alphanumeric messages. The short messages can be up to 140 bytes in length, and are delivered within a few seconds where GSM coverage is available. More than a common paging service, the delivery of the message is guaranteed even when the cellular terminal is unavailable (e.g., when it is switched off or outside the coverage area). The network will hold the message and deliver it shortly after the cellular terminal announces its presence on the network.

The fact that SMS (through GSM) supports international roaming with very low latency makes it particularly suitable for applications such as paging, e-mail, and voice mail notification, and messaging services for multiple users. However, the facilities offered to users and the charges for these facilities still mainly depend on the level of service provided by the network operator.

There are two types of SMS available: cell broadcast [1] and point-to-point [2]. In cell broadcast, a message is transmitted to all the active handsets or mobile stations (MSs) present in a cell that have the capability of receiving short messages and have subscribed to this particular information service. This service is only one-way, and no confirmation of receipt will be sent. It can send up to 93 7-bit character or 82 8-bit characters, typically used to transmit messages about traffic conditions, weather forecast, stock market, and so on.

In point-to-point service, messages can be sent from one mobile to another or from a PC to a mobile and vice versa. These messages are maintained and transmitted by an SMS Center (SMSC). The SMSC is an electronic form of ordinary mail postal service that stores and then forwards the messages when they can be delivered. Each GSM network must support one or more SMSCs to sort and route the messages. Each SMSC checks, organizes, and sends the message to the opera-



■ **Figure 1.** *The basic GSM network architecture.*

tor. It also receives and passes on any confirmation messages to any GSM mobile on any network. However, in practice, there are no agreements to allow SMS to travel between networks.

There are several ways in which a short message can be submitted, depending on the interfaces supported by the GSM network SMSC. Users can call a central paging bureau (i.e., an operator), or directly create the message on the keypad of their handset. Typing the messages is made easier when using a personal digital assistant (PDA) or a laptop connected to the handset. A few SMSC equipment manufacturers and companies have also developed their own protocols for short message submission. Consequently, more and more GSM networks now offer access to their SMSC using these protocols over a variety of hardware interfaces: modem dialup, X25, and even the Internet.

GSM Network Architecture

The layout of a generic GSM network with its several functional entities is shown in Fig. 1 [3]. The architecture can be divided in three main components:

- The subscriber holds the MS, namely the GSM terminal
- The base station subsystem controls the radio link with the MS
- The network subsystem performs the switching of calls and other management tasks such as authentication.

The Mobile Station

The MS and base station subsystem communicate across the Um interface, also known as the air interface or radio link. The base station subsystem communicates with the network subsystem across the A interface. The MS consists of the physical terminal and contains the radio transceiver, the display and digital signal processors, and the Subscriber Identity Module (SIM). The SIM provides the user with the ability to access their subscribed services regardless of the location and the terminal used. The insertion of the SIM in any GSM cellular phone allows the user to access a network, make and receive phone calls, and use all the subscribed services.

The International Mobile Equipment Identity (IMEI) uniquely identifies the mobile terminal according to the International Mobile Subscriber Identity (IMSI) contained in the SIM. Because the IMEI and IMSI are independent, personal mobility is possible. The SIM can be protected against unauthorized use by a personal identity number (PIN).

The Base Station Subsystem

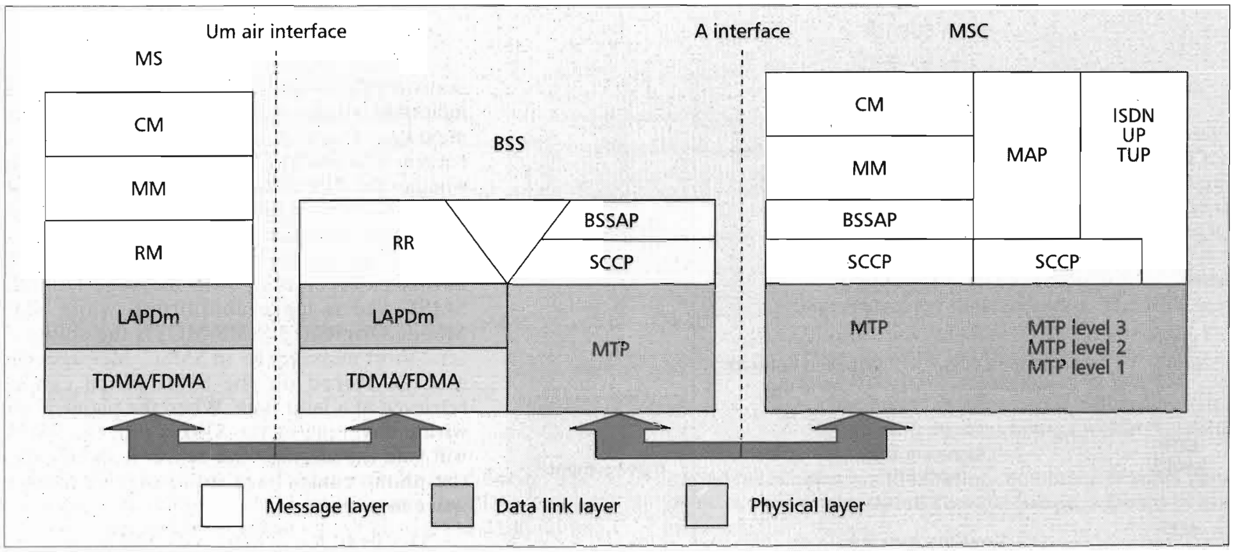
The base station subsystem is composed of two parts, the base transceiver station (BTS) and base station controller (BSC). They communicate across the specified Abis interface, thus allowing network operators to use components made by different suppliers. The BTS houses the radio transceivers that define a cell and handle the radio link protocols with the MS. Depending on the density of the area, more or fewer BTSs are needed to provide the appropriate capacity to the cell. Digital communications system (DCS) networks working at 1800 MHz need twice the number of BTSs to cover the same area as GSM networks, but provide twice the capacity.

The BSC manages the radio resources for one or more BTSs via the standardized Abis interface. It handles radio channel setup, frequency hopping, and handovers. The BSC is the connection between the MS and the mobile switching center (MSC). The BSC also takes care of converting the 13 kb/s voice channel used over the radio link (Um interface) to the standardized 64 kb/s channel used by the public switched telephone network (PSTN).

The Network Subsystem

The MSC is the main component of the network subsystem. Its provides the same functionality as a switching node in a PSTN or integrated services digital network (ISDN), but also takes care of all the functionality needed to handle a mobile subscriber such as registration, authentication, location updating, handovers, and routing to a roaming subscriber. The MSC also acts as a gateway to the PSTN or ISDN, and provides the interface to the SMSC.

The international roaming and call routing capabilities of GSM networks are provided by the home location register (HLR) and visitor location register (VLR) together with the MSC. The HLR database contains all the administrative information about each registered user of a GSM network along with the current location of the MS. The current location of an MS is in the form of a Mobile Station Roaming Number

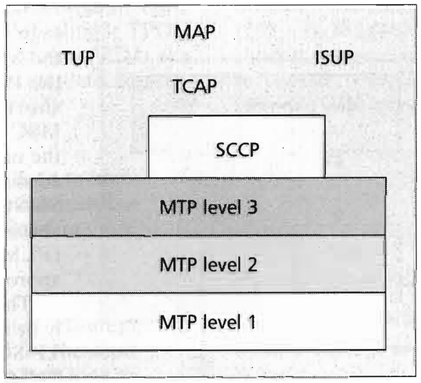


■ **Figure 2.** *The GSM protocol architecture.*

(MSRN), typically the SS7 number of the visited MSC, and used to route a call to the MSC where the mobile is actually located.

The VLR is usually located within the MSC to speed up access to the information required during a call and simplify the signaling. The content of the VLR is a selection of the information from the HLR, basically all necessary information for call control and provision of the subscribed services, for each single mobile currently located in the geographical area controlled by the VLR.

The network subsystem uses two other databases for authentication and security purposes. The Equipment Identity Register (EIR) contains a list of each MS IMEI allowed on the network. The authentication center (AuC) database contains each single PIN stored in the MS SIM.



■ **Figure 3.** *The SS7 protocol stack.*

The GSM Signaling Protocol

The exchange of signaling messages regarding mobility, radio resources, and connection management between the different entities of a GSM network is handled through the protocol architecture, as shown on Fig. 2.

The architecture consists of three layers: physical, data link, and message. The physical layer and channel structure are described in detail by M. Mouly and M. Pautet [4]. Layer 2 implements the data link layer using a modified flavor of the Link Access Protocol (LAPD) to operate within the constraints set by the radio path. On the MS side, the message layer consists of three sublayers: connection management (CM), mobility management (MM), and resource management (RR). The CM sublayer manages call-related supplementary services, SMS, and call-independent supplementary services support. The MM sublayer provides functions to establish, maintain, and release a connection between the MS and the MSC, over which an instance of the CM sublayer can exchange information with its peer. It also performs location updating, IMSI management, and Temporary Mobile Subscriber Identity (TMSI) identification, authentication, and reallocation. The RR sublayer establishes the physical connection over the radio link to transmit call-related signaling information such as the establishment of the signaling and traffic channel between the MS and the BSS.

On the MSC side, the message layer is divided into four sublayers. The Base System Substation Application Part (BSSAP) of the MSC provides the channel switching functions, radio resources management, and internetworking functions. The Message Transfer Part (MTP) and Signaling Connection Control Part (SCCP) protocols are used to implement the data link layer and layer 3 transport functions for carrying the call control and mobility management signaling messages across the A interface. SCCP packets are also used to carry the messages for SMS.

Signaling between the different entity uses the International Telecommunication Union (ITU) SS7, widely used in ISDN and current public networks. SS7 is currently the only element of the GSM infrastructure capable of packet switching as well as circuit switching. It is used to transport control signals and short message packets for SMS. The protocol consists of the Mobile Application Part (MAP), Transaction Capability Application Part (TCAP), SCCP, MTP, and ISDN-User Part (ISUP) or Telephone User Part (TUP). Figure 3 depicts the SS7 protocol stack.

The ISUP provides the signaling functions needed to support switched voice and data applications in the ISDN environment. The TUP provides the basic functionality for call control functions for ordinary national and international telephone calls. The TCAP is an application layer protocol. It allows an application at one node to invoke an execution of a procedure at another node and exchange the results of such invocation. It isolates the user application from the complexity of the transaction layer by automatically handling transaction and invocation state changes, and generating the abort or reject messages in full accordance with ITU and American National Standards Institute (ANSI) standards. The MAP uses the TCAP services to provide the signaling capabilities required to support the mobile capabilities.

The MTP and SCCP (Fig. 4) correspond to the lower three

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