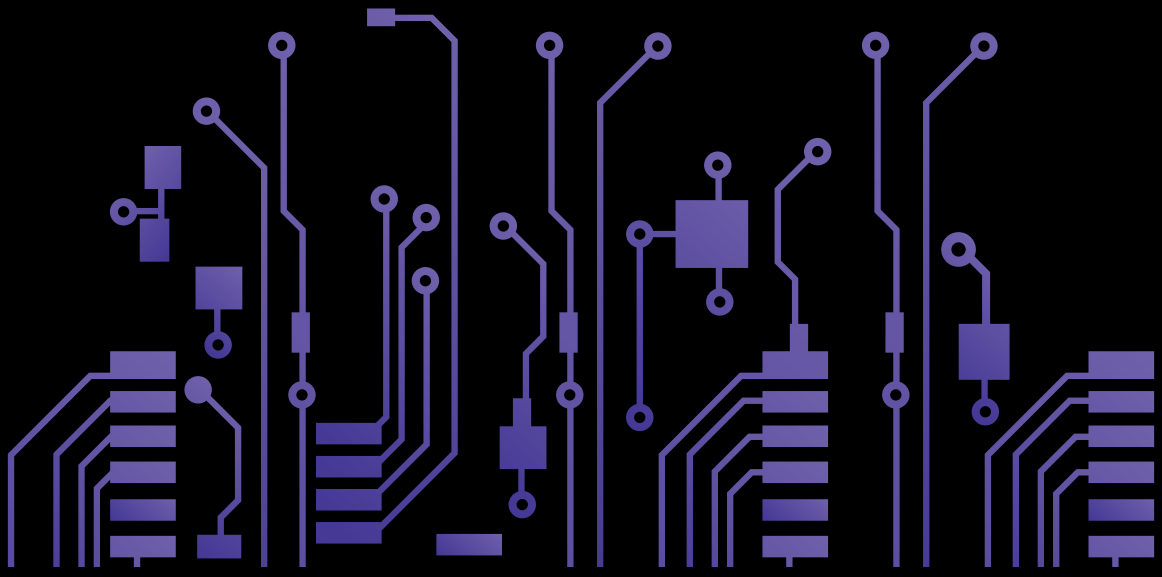
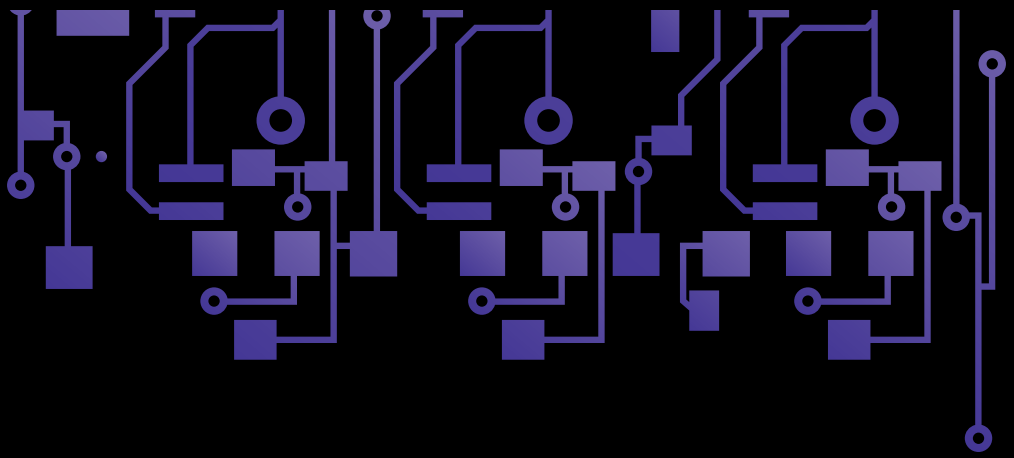


GSM v. CDMA: Technical Comparison of M2M Technologies



Aeris COMMUNICATIONS

Introduction

Aeris provides network and data analytics services for Machine-to-Machine ("M2M") and Internet of Things ("IoT") applications using multiple cellular technologies for our customers. These are the 2G[1] and 3G GSM and CDMA family of cellular technologies—the predecessors to the 4G cellular technology, called LTE, currently in deployment.

This whitepaper compares the GSM and CDMA technology families.

Specifications and Standards Bodies

For consistent interpretation of the capabilities of the cellular technologies, it is vital that detailed specifications are available to everybody in the cellular eco-system. Various international organizations co-operate to assure these uniform interpretations.

Specifically, Standards Development Organizations ("SDOs") in various countries support the cellular technologies. These SDOs, in turn, support two major collaborative projects that develop and provide the Technical Specifications for the technologies.

GSM Family

For GSM cellular technologies, the 3rd Generation Partnership Project ("3GPP") provides the technical specifications for six international SDOs—specifically: ARIB, ATIS, CCSA, ETSI, TIA and TTC[2].

CDMA Family

For CDMA cellular technologies, the 3rd Generation Partnership Project 2 ("3GPP2") provides the technical specifications on the ANSI-41/TIA/EIA-41 network and radio technologies for five SDO's—specifically: ARIB, CCSA, TIA, TTA and TTC[3].

3GPP and 3GPP2 Families

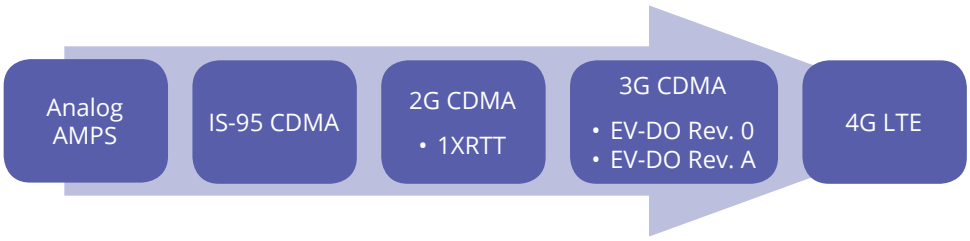
The GSM cellular technologies are sometimes referred to as "3GPP technologies" and the CDMA cellular technologies are sometimes referred to as "3GPP2 technologies".

Additionally, for simplicity in this document, Operators who deployed GSM technologies are called "GSM Operators" and Operators who deployed CDMA technologies are called "CDMA Operators".

Technology Deployments

Historically, the GSM and CDMA Operators took different technology

Figure 1. CDMA Operator Technology Deployments



[1] Please see Appendix D. Acronyms and Glossary for more information.
[2] Please see Appendix A. 3GPP Standards Development Organizations for the list.
[3] Please see Appendix B. 3GPP2 Standards Development Organizations for the list.

deployment paths to arrive at the 4G LTE implementation activity.

As shown in Figure 1. *CDMA Operator Technology Deployments*, the Operators moved from the Analog cellular system, called AMPS, to a digital cellular system using CDMA encoding, as defined by the TIA/IS-95 CDMA standard.

The specific details of *how* the digital bits are encoded in TDMA and CDMA protocols are beyond the scope of this whitepaper – for more information, please refer to a book listed in *Appendix C. Reference Texts on Cellular Technologies*.

This digital cellular deployment eventually also supported a 2G data transport protocol called 1XRTT, per the ANSI-2000 CDMA standard, that allowed the transmission of Internet Protocol ("IP") data on cellular networks. With later enhancements in the encoding protocols, the CDMA Operators deployed faster IP data capabilities over time:

- EV-DO Rev. 0, followed by
- EV-DO Rev. A, for faster performance.

These 3G EV-DO data services are widely used today for cellular IP data services and provide a stable and robust system for many WAN data communications requirements.

In North America, the CDMA Operators have fully deployed 3G EV-DO (including Rev. A) in their entire coverage footprint—matching the coverage of their 2G 1XRTT footprint.

As shown in Figure 2. *GSM Operator Technology Deployments*, Operators moved from AMPS—mostly in North and South American markets—to a digital cellular system using TDMA encoding, per the IS-136 TDMA standard. However, in other parts of the world, notably Europe, cellular operators had deployed *another* digital cellular system—also using TDMA encoding—called the Global System for Mobile Communication ("GSM").

Later, the American operators transitioned their services from IS-136 TDMA to GSM, to take advantage of the economies of scale afforded by the very large number of GSM deployments around the world. In 2G GSM, the IP data services are provided using two protocols: GPRS and EDGE.

2G GSM was followed by a 3G technology called UMTS. In this technology, UMTS abandoned TDMA encoding in favor of W-CDMA encoding because of the higher spectrum efficiency of CDMA compared to TDMA.

When using W-CDMA encoding, high-performance IP data protocols are possible and various data transmission

Figure 2. GSM Operator Technology Deployments

> **"American operators transitioned their services from IS-136 TDMA to GSM, to take advantage of the economies of scale afforded by the very large number of GSM deployments around the world."**

protocols have been deployed in the GSM cellular family:

- HSDPA and HSUPA for excellent downlink and uplink data rates, culminating in
- HSPA and HSPA+ with excellent spectrum efficiency and fast data rates in both directions.

Although not as widely deployed as 3G EV-DO, the HSPA implementations typically provide a superior data rate since they use a wider channel (5MHz instead of 1.25 MHz).

IP Data Throughput

The various IP data protocols available in cellular technologies provide different data rates because of differing encoding protocols, channel bandwidths and the spectrum efficiency of the protocol.

This section outlines theoretical and approximate typical data rates of the cellular IP data transports protocols. For simplicity, data rates for only a few technology configurations are shown in Table 1. *3GPP Family Data Rates*—the *actual* theoretical rates depend on the specific modulation, whether MIMO antennas are used, etc.

Since the wireless channels are a shared resource at the cellular tower, the typical rates is generally lower than theoretical data rates. Many variables affect the data rate: the number of devices accessing the IP network at the tower, time of day, how many sessions are active, etc.

3GPP Family

Table 1. 3GPP Family Data Rates

Technology	Encoding		Downlink (kbits/sec)	Uplink (kbits/sec)
2G GPRS	TDMA	Theoretical	115	20 - 40
		Typical	5 - 20	5 - 10
2G EDGE	TDMA	Theoretical (4-8 slot)	236 - 473	64
		Typical	60 - 100	30
3G UMTS	W-CDMA	Theoretical	384	64
		Typical	200 (estimated)	30 (est.)
3G HSDPA	W-CDMA	Theoretical	14400	384
		Typical	600 - 1100	200 (est.)
3G HSUPA	W-CDMA	Theoretical	384	5760
		Typical	200 (est.)	500 - 1000
3G HSPA / HSPA+	W-CDMA	Theoretical	21000 - 42000	5760 - 11500
		Typical	1500 - 4000 (est.)	500 - 1500 (est.)

Table 1. *3GPP Family Data Rates* does not show some of the recent specified improvements in HSPA and HSPA+ operation and performance. For example, using Dual-Operator HSPA where a mobile device can connect to two cell towers at the same time—theoretically doubling the data rates—or MIMO antennas with multiple data streams.

3GPP2 Family

As can be seen in the tables, the 3G speeds in the GSM family (HSPA, etc.) are faster than the 3G speeds in the CDMA family (EV-DO, etc.). This is not surprising since HSPA uses channel widths of 5MHz, which are wider than EV-DO channel widths of 1.25MHz, and can provide better throughput for similar encoding protocols.

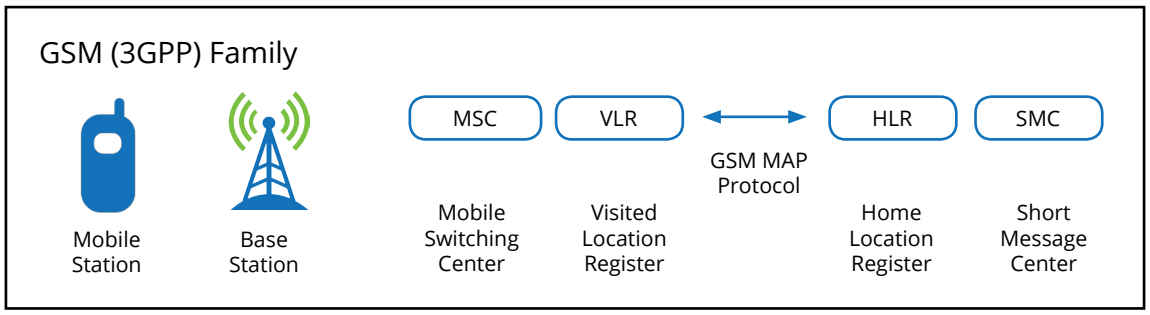
Table 2. 3GPP2 Family Data Rates

Technology	Encoding		Downlink (kbits/sec)	Uplink (kbits/sec)
2G 1XRTT	CDMA	Theoretical	153	153
		Typical	60 - 100	60 - 100
2G EV-DO Rev. 0	CDMA	Theoretical (4-8 slot)	2400	153
		Typical	600 - 900	60-100
3G EV-DO Rev. A	CDMA	Theoretical	3100	1800
		Typical	600 - 1400	400 - 600

Network Infrastructure

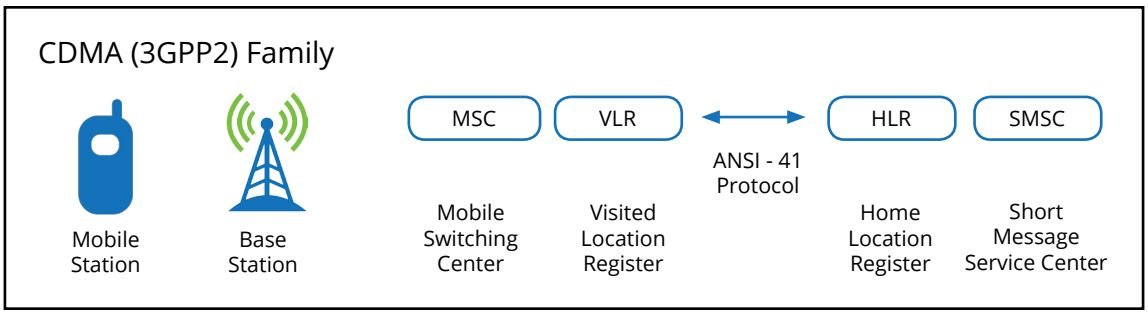
Cellular Operation

The GSM (3GPP) and CDMA (3GPP2) networks for cellular operation are similar in many ways ... sometimes the name of the infrastructure element is a bit different but provides essentially the same function. The interface protocols in the network *may* differ in name and content, but again, provide similar functionality.



The two diagrams show very basic elements for cellular operation—more complete diagrams, with additional information, are available in the cellular standards.

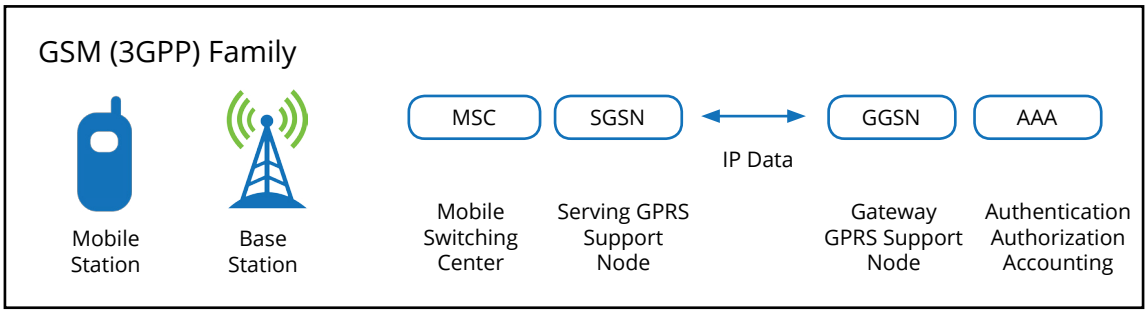
Next to the wireless radio encoding protocols (TDMA, CDMA, and W-CDMA), the control messages from the VLR to the HLR and SMSC show the most differences. The GSM Mobile Application Part ("GSM MAP") control messages are very different from the ANSI-41 control messages. However, both have equivalent control functions—for example, registering a device with the HLR for normal operation upon power-on.

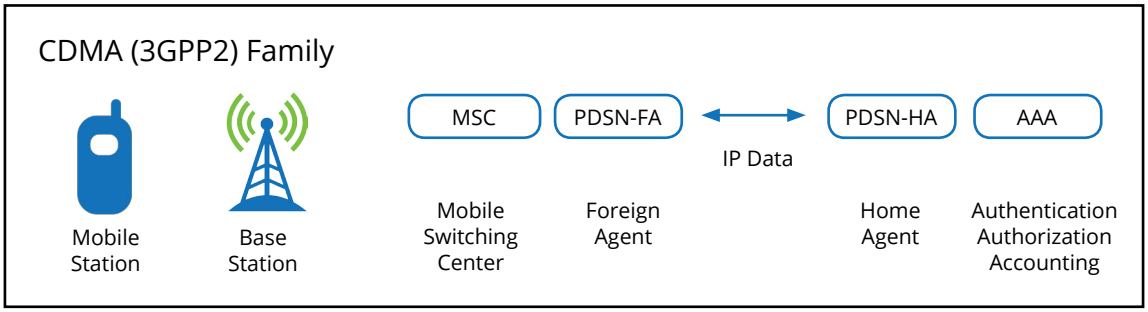


The sequences in the call flows—whether control or message related—between GSM and CDMA devices and the respective networks are, of course, quite different, and beyond the scope of this document.

IP Data Operation

Again, the GSM (3GPP) and CDMA (3GPP2) networks for IP data operation are similar in many ways. Here the names of the network infrastructure elements are quite a bit different (unlike the network for cellular operation), but, again, the functions are generally quite similar.





And, just like cellular operation, the actual sequences in the call flows—whether authentication, authorization, or data related—between GSM and CDMA devices and the respective networks, are quite different, and beyond the scope of this document.

Identifiers and Other Differences

Numbers and Identifiers

GSM and CDMA family devices use different identifiers, although the purpose may be similar. For example, the device cellular network identifier in CDMA is the MIN—a

"In CDMA, cellular devices generally do not use a SIM–at least in the USA–and the account information is usually programmed within the cellular device."

ten digit number—although CDMA devices also contain an IMSI. In GSM networks, the device cellular network identifier is the IMSI—a fifteen-digit number.

The directory number by which a device can be dialed in CDMA is the MDN—the equivalent in GSM is the MSISDN. The MDN is a ten-digit number that generally follows the North American Numbering Plan ("NANP") format, but the MSISDN is dependent on the country where the device is deployed and may contain up to fifteen digits.

SIM Cards

In GSM, cellular devices use a SIM, which contains the account information such as the IMSI and other identifiers. The SIM is usually a small removable card inserted into a SIM hold and electrically connected to the cellular radio, although the concept of an embedded SIM that is physically attached (or included) is gaining favor for certain applications. The removable card also has a unique identifier, called an ICCID.

In CDMA, cellular devices generally do *not* use a SIM—at least in the USA—and the account information is usually programmed within the cellular device. Thus, there is no ICCID associated with a CDMA device.

Thus, when deploying an M2M application using a GSM family cellular radio, the device must use a SIM—whether inserted or embedded.

Unique Device Identifiers

In GSM, each cellular device has a unique serial number called an IMEI (this is different from the ICCID of the SIM).

In CDMA, each cellular device has a unique serial number called an MEID (the MEID is the new replacement for the older ESN).

The IMEI and MEID are different—both identifiers have the same length of digits, but the MEID format allows hexadecimal digits and the IMEI format does not.

Coverage

In the US, the 2G GSM / GPRS, 2G 1XRTT and 3G EV-DO networks provide the largest physical coverage footprint for cellular service today. However, as noted in other Aeris whitepapers, the 2G GSM network is being shut down in a few years by AT&T, the largest provider of that

service—the 2G CDMA network is expected to operate much longer.

Internationally, 2G GSM / GPRS services are far more common than 2G or 3G CDMA technologies, and this service is projected to operate for much longer than in the US.

Summary

From a technology perspective, both technologies are similar in their support of cellular text and IP data services—although there are clear data rate differences. However, in most M2M applications, the technology performance is not a major factor today—eventually, the availability of much higher data rates and lower latency from 4G LTE will make that a preferred platform in the future.

Thus, for M2M devices, the choice of whether to use CDMA or GSM devices and services is generally dependent on the needs of the application, the cost of radio modules, SIM handling and management capability, deployment locations, and technology service longevity. A few Aeris customers choose to deploy *both* families of cellular radios—using CDMA in the USA and GSM elsewhere in the world—for their M2M applications.

Aeris can assist customers to make this decision with care.

Contact Aeris at info@aeris.net or 1-888-GO-AERIS for more information.

Appendix A. 3GPP Standards Development Organizations

Table 3 below shows the six SDO's that are the Organizational Partners for which 3GPP produces Technical Specifications.

Table 3. The 3GPP Standards Development Organizations

SDO	Name	Website
ARIB	The Association of Radio Industries and Businesses, Japan	www.arib.or.jp/english
ATIS	The Alliance for Telecommunications Industry Solutions, USA	www.atis.org
CCSA	China Communications Standards Association	www.ccsa.org.cn/english
ETSI	The European Telecommunications Standards Institute	www.etsi.org
TTA	Telecommunications Technology Association, Korea	www.tta.or.kr/English/index.jsp
TTC	Telecommunication Technology Committee, Japan	www.ttc.or.jp/e/index.html

Appendix B. 3GPP2 Standards Development Organizations

Table 4 below shows the five SDO's that comprise the bodies for which 3GPP2 produces Technical Specifications.

Table 4. The 3GPP2 Standards Development Organizations

SDO	Name	Website
ARIB	The Association of Radio Industries and Businesses, Japan	www.arib.or.jp/english
CCSA	China Communications Standards Association	www.ccsa.org.cn/english
TTA	Telecommunications Technology Association, Korea	www.tta.or.kr/English/index.jsp
TTC	Telecommunication Technology Committee, Japan	www.ttc.or.jp/e/index.html

Appendix C. Texts on Cellular Technologies

"*3G, 4G and Beyond: Bringing Networks, Devices and the Web Together*", Martin Sauter. © 2013 John Wiley and Sons Ltd.

"*GSM Networks: Protocols, Terminology and Implementation*", Gunnar Heine. © 1999 Artech House, Inc.

"*CDMA Systems Engineering Handbook*", Jhong Sam Lee, Leonard E. Miller. © 1998 J. S. Lee Associates, Ltd.

Appendix D. Acronyms and Glossary

1xRTT	Single Operator Radio Transmission Technology (used in ANSI-2000 CDMA).
1xEV-DO	Enhanced Voice-Data Only (also Enhanced Voice-Data Optimized)
2G	Second Generation Cellular
3G	Third Generation Cellular
3GPP	3rd Generation Partnership Project (GSM family of technologies)
3GPP2	3rd Generation Partnership Project 2 (CDMA family of technologies)
4G	Fourth Generation Cellular
AAA	Authentication, Authorization and Accounting (see also RADIUS)
AMPS	Advanced Mobile Phone System, an Analog cellular mobile system using FDMA
ANSI-41	American National Standards Institute Standard 41, for control signal messaging on SS7
ANSI-95	American National Standards Institute Standard 41, for CDMA cellular
ANSI-136	American National Standards Institute Standard 41, for TDMA cellular
ANSI-2000	American National Standards Institute Standard 41, for CDMA2000 cellular
BS	Base Station
BSC	Base Station Controller
CDMA	Code Division Multiple Access
EDGE	Enhanced Data Rates for GSM Evolution
ESN	Electronic Serial Number (in CDMA) ... replaced by the MEID
EV-DO	Enhanced Voice-Data Only (also Enhanced Voice-Data Optimized)
FDMA	Frequency Division Multiple Access
GGSN	Gateway GPRS Support Node (see also SGSN)
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
GSM MAP	GSM Mobile Application Part, for control signal messaging on SS7
HLR	Home Location Register
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HSPA+	Enhanced or Evolved High Speed Packet Access
HSUPA	High Speed Uplink Packet Access
ICCID	Integrated Circuit Chip Identifier
IMEI	International Mobile Equipment Identifier (used in GSM)
IMSI	International Mobile Subscriber Identifier (used in GSM and CDMA)
ITU	International Telecommunications Union
IS-95	Interim Standard 95 (standard for CDMA Cellular)
IS-136	Interim Standard 136 (standard for TDMA Cellular)

LAN	Local Area Network
LTE	Long Term Evolution
MAP	See GSM MAP
MDN	Mobile Directory Number (used in CDMA—conceptually similar to the MSISDN in GSM)
MEID	Mobile Equipment Identifier (used in CDMA)
MIMO	Multiple Input, Multiple Output (in the context of antennas)
MS	Mobile Station (cellular radio handset, or cellular M2M device)
MSC	Mobile Switching Center
MSISDN	Mobile Station ISDN (used in GSM)
RADIUS	Remote Authentication Dial In User Service
SDO	Standards Development Organization
SGSN	Serving GPRS Support Node (see also GGSN)
SMC	Short Message Center
SMS	Short Message Service
SMSC	Short Message Service Center
SS7	Signaling System 7
TDMA	Time Division Multiple Access
UMTS	Universal Mobile Telecommunications System
VLR	Visited Location Register
WAN	Wide Area Network