CDMA2000 International Roaming: A Status Report

CDMA Development Group

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INTRODUCTION

Recently, a businessman from the United Sates arrived in China after a long flight. He turned on his U.S. Sprint PCS CDMA2000® phone and the first thing he noticed was that the time on the display was the correct Beijing time. He initiated a call and was pleased to find that he could place a call to any destination in the world.

Wireless customers have become accustomed to staying connected anywhere they go, including when traveling internationally. The CDMA2000 community is rapidly expanding its international roaming capabilities and services to meet customers' needs; CDMA2000 operators offer roaming in key markets worldwide and are leading the way in providing roaming services across different wireless standards.

The purpose of this paper is to provide an overview of CDMA2000 international roaming today and a snapshot of roaming experiences from CDMA2000 markets around the world. In the appendix, the report provides a general overview of implementation aspects of CDMA2000 roaming.

WHAT IS ROAMING?

Roaming is defined as the ability of a network operator to provide the same services that are available on its home network to its customers, called "roamers," when they are using other systems within the same country or in other countries. There are two types of "roamers" today. From the home carrier's perspective they are defined as:

- "Inbound roamers" – Subscribers of another wireless service provider coming into the home carrier's network and utilizing wireless services
- "Outbound roamers" – The home wireless service provider's subscribers visiting and utilizing another carrier's network

Roaming applies to national and international markets. National roaming is where customers roam from their home network to other networks within the same country. This type of roaming is required when the home network does not provide service in all of the nation's territories and/or states (the United States and Brazil are good examples of this). International roaming involves making calls from outside the home country's borders.

For wireless operators who don't have a national license, providing nationwide seamless coverage is by far more important than international roaming. This is the case in the U.S., where spectrum was awarded in hundreds of small license areas and operators focused on building roaming with other operators within the country first. For this reason, the ANSI-41 standard, which was widely deployed in the U.S., has very robust inter-carrier roaming capabilities. In Europe, on the other hand, operators received national licenses, but because of the close commercial ties and proximity between countries, international roaming was critical. Therefore, the GSM standard which was developed for pan-European coverage incorporated international roaming capabilities in the initial specifications. In past years, the ANSI-41 standard has evolved, and today it provides international roaming capabilities similar to GSM.

This paper will focus on international roaming.

WHY IS INTERNATIONAL ROAMING IMPORTANT?

International roaming is increasingly becoming an important service to wireless operators for two main reasons. The first is to satisfy customer demand, and thereby attract and retain customers. Second, and equally important, is that international roaming can be a significant revenue source for operators.

The growth in demand for international roaming is driven by increased international travel and rising wireless penetration. In the U.S., for example, more than 54 million people traveled abroad and over 40 million visitors came to the U.S. in 2003, and the number of travelers both to and from the U.S. was estimated to climb 9 percent in 2004.[1] As wireless networks have been installed worldwide and wireless phones have become a standard component of everyday life, travelers want to be able to use their wireless devices when they go abroad. In a study conducted in Europe, the Yankee Group reported that 41% of all respondents used their wireless phones while on vacation, and 34% of prepaid wireless phone customers used their phones while abroad.[2]

International roaming is becoming an important source of revenue for operators. IDC estimates that revenues from international roaming will increase from $19 billion in 2000 to $24.2 billion in 2010 and its share of total operator revenues will rise from 1-2% to 5%.[3] Intra-continental roaming (countries within a continent) constitutes the vast majority of roaming revenues (94% in North America and 99% in Europe in 2000.) The revenue from inter-continental roaming (between countries on different continents) is expected to grow significantly, however, to 50% of total roaming revenue for North America and 10% for Europe by 2010. Roaming is also a high-margin business: it uses a small percentage of network resources relative to the high revenue it generates. Ovum estimates that inbound international roaming produces 90% gross margin for some operators.

International roaming revenue statistics do not reflect one of the most significant revenue opportunities international roaming offers: income from high-revenue generating business customers. Business customers often select a service provider based on its international roaming offering; therefore, international roaming can provide an important competitive advantage in attracting and retaining this high revenue-generating market segment.

Challenges of International Roaming

Enabling international roaming involves more than providing back-end services that recognize “roamers” and automatically provision them on the network. Truly universal roaming requires handsets that are capable of multiple technologies and/or are designed to operate in different bands of the radio spectrum. Also, with the growing adoption of data, especially Third Generation (3G) data services, providing seamless connectivity to “home” content will be increasingly important.

Inter-standard roaming

Wireless services today are provisioned by multiple technologies, including analog and digital, and in a broad range of spectrum bands which creates significant challenges for establishing seamless international roaming. First Generation (1G) analog systems still operate in many parts of the world at 800 and 450 MHz. In the 2G world, there are four leading standards (CDMA, GSM, PDC, and TDMA) using multiple frequency bands (800, 900, 1700, 1800 and 1900 MHz). As the world migrates to 3G, the landscape becomes even more complicated, with CDMA2000, TD-SCDMA and WCDMA operating at 2.1 GHz and all other bands used for 1G and 2G services. Thus, to provide true global roaming, phones and platforms need to support all analog, 2G and 3G standards at multiple frequency bands.

The challenge with interstandard roaming is not only the band difference but the conversion from ANSI-41 to GSM MAP. In the past, handset real estate had been so precious that handset manufacturers didn't have a lot of room for all the circuitry, memory capabilities, power control and the ASIC chip. CDMA and GSM handset OEMs were always trying to find ways to increase these capabilities while decreasing the actual size of each component. As time has gone on, CDMA equipment

[1] U.S. Department of Commerce, International Trade Administration, Office of Tourism Industries, “Arrivals to the U.S. 2003,” available from http://tinet.ita.doc.gov
[2] The Yankee Group, October 2003
[3] “How Important Is International Roaming to Wireless Network Migration?”, IDC, 2002

manufactures have been able to reduce the size needed for each of these components allowing for more space on the mother board. This lead, for example, to the development of the Qualcomm MSM6300 chipset, which supports interstandard roaming.

DATA ROAMING

As data services gain in popularity, national and international roaming must encompass these forms of wireless communications as well. Being able to stay in touch while traveling includes being able to use SMS and Instant Messaging services, having access to email and corporate Intranets, and accessing local travel and entertainment content, regardless of where the customer happens to be.

Data roaming requires the same types of agreements and network interconnections as voice roaming. However, there is a critical element of data roaming that needs to be addressed by operators: access to content. While this is not an issue for the customer who wants to use his wireless modem-enabled laptop computer to access corporate data and/or to surf the Internet, it is a challenge when it comes to operator-specific content for handhelds, smartphones and PDA devices. This is an issue that needs to be addressed by all network operators on a global basis.

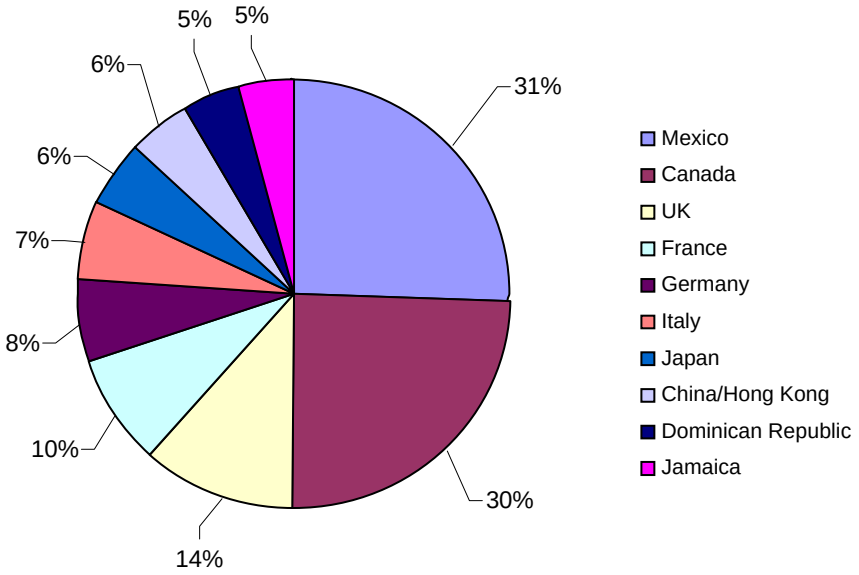
CDMA2000 ROAMING TODAY

CDMA2000 operators offer international roaming to their customers in major travel destinations either through agreements with other CDMA (cdmaOne™ and CDMA2000) operators or GSM carriers. Since CDMA2000 is backwards compatible with cdmaOne, and CDMA2000 handsets support both cdmaOne and analog modes, CDMA2000 subscribers can roam on CDMA2000, cdmaOne or analog networks. In 2004, CDMA2000 operators took the lead in offering true global roaming by introducing multi-mode, multi-band phones working on GSM and CDMA networks.

With more than 230 networks in 67 countries, CDMA has the presence in key global markets, including North, Central and South America, Asia and Australia, to support international roaming. CDMA to CDMA roaming is available in many countries including: Australia, Belarus, Bermuda, Brazil, Canada, China, Dominican Republic, Ecuador, Guam, Hong Kong, Israel, Jamaica, Japan, Mexico, New Zealand, Panama, Peru, Puerto Rico, Russia, South Korea,Taiwan,Thailand, U.S. Virgin Islands, Uruguay, USA, and Venezuela. KDDI in Japan estimates that CDMA to CDMA roaming covers 70% of the Japanese overseas travel market. For the United States, of the top ten visitor origins and U.S. resident travel destinations, six have commercial CDMA2000 networks (see Figures 1 and 2.)

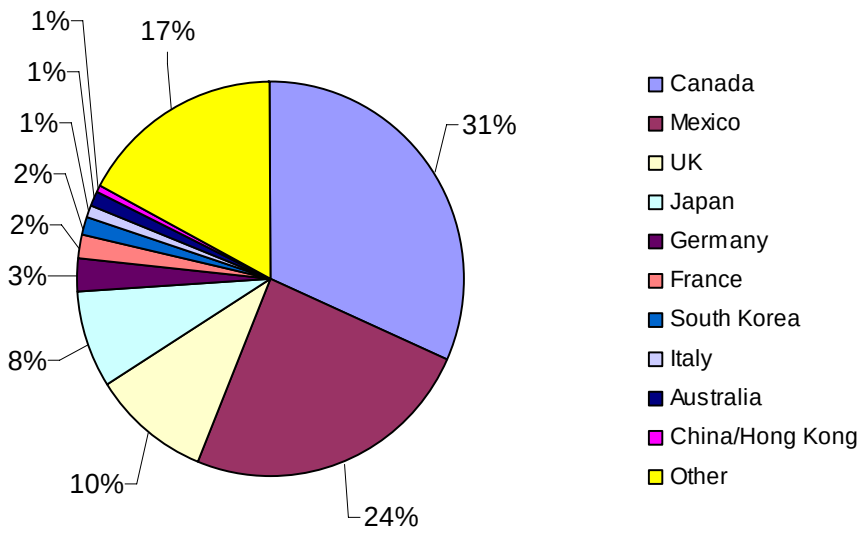
Within the United States, CDMA2000 operators focused on establishing international roaming with neighboring countries Canada and Mexico first, since these countries represent the largest share (55%) of the traffic to and from the U.S. They recognize, however, that inter-continental roaming is becoming an important competitive offering, especially for high revenue-generating business users, and are rapidly enhancing their roaming capabilities. Sprint and Verizon Wireless have established roaming agreements in approximately one hundred fifty markets, both CDMA and GSM, across all continents.

Figure 1. Top Destinations for U.S. Travelers in 2003[4]



[4] U.S. Department of Commerce, International Trade Administration, Office of Tourism Industries, "Arrivals to the U.S. 2003," available from http://tinet.ita.doc.gov

Figure 2. Inbound travelers to the U.S. in 2003



Many CDMA2000 operators have established agreements with GSM operators, enabling them to offer international roaming in regions including Africa, Europe, Asia and the Caribbean. Until recently, CDMA2000 to GSM roaming required that operators provide GSM loaner phones to their subscribers; with the introduction of multi-mode, multi-band phones, CDMA2000 operators can now provide transparent roaming across CDMA2000 and most GSM networks with a single device.

DATA ROAMING

CDMA2000 operators are starting to introduce packet-data roaming services which allow their customers to access their applications when traveling internationally. SK Telecom, for example, offers automatic data roaming in Japan and China. Bell Mobility offers data roaming for their subscribers roaming into the U.S.

The CDMA Development Group (CDG) released the CDMA2000 Packet Data Roaming Exchange (CRX) specification which establishes a framework for providing data roaming either through direct or third party connections and which will facilitate implementation of data roaming between CDMA2000 networks within a country or internationally. More information about CDMA data roaming, including the CRX specifications, is included in Appendix A at the end of this report.

INTERSTANDARD ROAMING

Interstandard Roaming is the ability for wireless interoperability between two or more wireless networks with different signaling protocols to support mobility management and service retention, such as ANSI-41 (CDMA) and GSM MAP. This is accomplished with both infrastructure and handsets.

For service between ANSI-41 and GSM MAP, the infrastructure includes an interworking and interoperability function (IIF) or gateway that interprets and converts messages between the two technologies. The IIF does not duplicate any subscriber identity information. It simply provides a gateway to any visited network with a foreign air interface.

Mobile phones manage subscriber identity information through the use of a Removable User Identify Module for CDMA (R-UIM) which is the equivalent to a GSM Subscriber Identification Module (SIM) card. With the advent of interstandard technology, interstandard phones have been developed by several OEMs. This has facilitated different methods to accomplish the need for subscriber identity information to be managed and sent to the visiting network.

A. Single Slot: The single slot phone contains the CDMA subscriber identity information hard coded into the phone and has a slot for a GSM SIM card. The SIM card allows the subscriber to access the GSM network and manage off-network phone book entries, system selection and data services.

B. Dual Slot: The dual slot phone contains a CDMA R-UIM and a GSM SIM card. The CDMA R-UIM manages subscriber identity information and its services as it relates to the CDMA network while the GSM SIM enables access to the GSM network and manages off-network services.

There are several multi-mode, multi-band phones on the market today. Motorola, LG and Samsung have already launched product; Hitachi, Sanyo and Toshiba will follow in the coming months. China Unicom, Sprint and Verizon Wireless offer these phones and many other operators in Asia and the Americas plan to introduce them soon. For more information on R-UIM and interstandard roaming, refer to Appendix B.

CDMA/GSM phones are the first interstandard products introduced in the market. Chipsets with enhanced functionality, which will allow CDMA2000 subscribers to use data on GSM/GPRS and WCDMA networks, are on their way:

- QUALCOMM's MSM7500 series, which supports CDMA2000 1xEV-DO and GSM/GPRS, will be available in 2005
- QUALCOMM's MSM7600 for CDMA2000 1xEV-DO/1xEV-DV/WCDMA/HSDPA/GSM/GPRS/EDGE is scheduled to be released in 2006

Samsung SCH-A790

- GSM/GPRS 900/1800 MHz
- CDMA2000 1X 800/1900 MHz
- Display: 1766x220 – 2.2” screen, 260K color screen
- 24.5 mm thick
- 1.2 Mega pixel camera + flash COMS VGA 300K pixel camera
- WAP 2.0 (GSM), BREW (CDMA2000)
- SMS, MMS

Motorola A840

- GSM/GPRS 900/1800 MHz
- CDMA2000 1X 800/1900 MHz
- Removable memory card
- Size 94 x 49 x 23 mm
- Weight 115 g
- Display 176x220– 2.2" screen, 265K colors
- 1.2 Mega pixel camera + flash
- SMS, EMS, and MMS
  WAP 2.0 (GSM), BREW (CDMA2000/GPRS)

AROUND THE WORLD WITH CDMA2000 – A SNAPSHOT OF OPERATORS' SERVICES

BERMUDA DIGITAL COMMUNICATIONS

Bermuda Digital Communications Ltd. (BDC) is a good example of a CDMA2000 wireless operator that has successfully deployed international roaming. Bermuda is a vacation spot, with most visitors originating in North America. BDC began as an AMPS (analog) wireless operator using the 800 MHz band and then upgraded to TDMA. It recently deployed CDMA2000 1X and is in the process of adding CDMA2000 1xEV-DO in order to offer high-speed data services to its own customers and to roamers from Sprint, Verizon Wireless and other carriers.

Kurt Eve, the president and CEO of Bermuda Digital Communications, said that when its two competitors began adding GSM to their existing TDMA systems, Bermuda Digital decided to overlay its AMPS/TDMA network with CDMA2000. The consideration was either to compete head-to-head with the other two operators, or to offer another technology that would set BDC apart. BDC chose CDMA2000 because most of its visitors are from North America, where there are more CDMA2000 than GSM customers. BDC believed it would have an advantage.

This assumption has proven to be correct. Today BDC offers both Sprint and Verizon Wireless customers voice roaming services and, before the end of the year, it will offer 1xEV-DO high-speed data.

BDC already enjoys average revenue per user (ARPU) of more than $100 per month. Roaming on its system accounts for about 20% of the network's income. Once the 1xEV-DO system is up and running, BDC believes that its roaming revenue will increase because it will be the only wireless network operator in Bermuda capable of offering broadband data services.

CHINA UNICOM

China Unicom is one of the best examples of a CDMA operator that offers feature-rich roaming services to its customers. China Unicom operates both GSM and CDMA2000 networks and was the first CDMA2000 operator in the world to make use of R-UIM.

China Unicom today offers full voice roaming services into most other parts of the world using a combination of CDMA2000 and GSM. In addition to voice roaming, China Unicom offers data roaming (using CDMA2000 1X) with SK Telecom and intends to expand its number of data roaming partners rapidly. As demand for data services increases on its own network, the company will make data roaming a standard offering like its voice roaming services.

Roaming revenue from one of its biggest partners, SKT in Korea, generates about U.S. $25 million per year for China Unicom. This revenue is growing rapidly and is representative of the potential for roaming income.

China Unicom's primary rationale for spending time and effort on roaming services is to retain its high-end customers. For this reason, the operator not only continues to expand its worldwide roaming agreements, but also offers superior customer service to its roaming customers. For example, upon arrival in the United States, when a China Unicom CDMA2000 customer turns on his phone, it is recognized by the Verizon network, and three SMS messages are automatically sent to the phone. The first message tells the customer how to dial international calls. The second SMS message provides the phone number of the Chinese Embassy in the United States, and the third gives a customer service number to call during the users stay in the United States.

KDDI (JAPAN)

KDDI Corporation is the only CDMA operator in Japan, and offers both CDMA2000 1X and 1xEV-DO services. It is the largest and most successful 3G operator in the country.

KDDI first launched CDMA international roaming with Shinsegi Telecomm in Korea (now SK Telecom) and Hutchison Telephone Co. Ltd. in Hong Kong in April 2000. Today, the operator provides international roaming service to 15 countries and has roaming agreements with 14 CDMA operators including China Unicom, Sprint, SK Telecom and Verizon Wireless. KDDI continues to expand its CDMA roaming service to other regions, such as Latin America. Because the frequency bands in Japan are different than in other parts of the world, CDMA users traveling to Japan need handsets that work on the KDDI network.

KDDI began packet data roaming service with SK Telecom in May 2004 using its CDMA2000 1X network and is in the process of expanding it to other countries.

SPRINT (UNITED STATES)

Sprint offers the most extensive international roaming coverage among CDMA operators today. They provide roaming in more than 150 markets throughout the world, which include CDMA2000 to CDMA2000, CDMA2000 to GSM, CDMA2000 to analog, and, in a few cases, CDMA2000 to WCDMA.

International Roaming with a Sprint PCS Phone

If a Sprint customer has a digital dual band, dual band/tri-mode device, or the digital quad band IP-A790 by Samsung, he/she can roam on CDMA2000 networks in other parts of the world including Latin America, Asia (including China, Thailand, Taiwan), and New Zealand.

Customers heading for a GSM destination have two options:

- **International Roaming with a Sprint PCS International Phone IP-A790 by Samsung**
  Providing the most extensive worldwide coverage of all Sprint offerings, the Sprint PCS International Phone is best suited for the frequent global travelers. This GSM/CDMA international roaming solution provides coverage in more than 130 countries worldwide, including the U.S., with one single phone.

- **International Roaming with a GSM Phone**
  Best suited for the occasional global traveler, the GSM phone allows a Sprint customer to lease or purchase a separate International GSM phone to roam throughout Europe and parts of Asia, South America, Africa, Australia and the Middle East. GSM SIM card is available for Japan (WCDMA phone required – Japan only).

The operator did not provide specifics as to the number of its customers who roam internationally, but noted that those who do are “extremely high value” customers.

VERIZON WIRELESS (UNITED STATES)

Verizon Wireless is a leading CDMA service provider in the United States, and the largest CDMA operator in the world. International roaming is a key component of the operator’s business. Today, Verizon Wireless provides international roaming to key markets worldwide including: Canada, Mexico, Latin America, Europe, Australasia and greater Asia, using

both CDMA and GSM networks. Verizon Wireless was the first operator in the world to introduce the multi-mode, multi-band phone (Samsung A790) and services which allow customers to roam on more than 140+ CDMA and GSM networks worldwide, with a single handset.

When traveling internationally, their customers have access to voicemail and receive voicemail notification. Verizon Wireless is the first carrier in North America to offer data roaming internationally with Blackberry™ devices and PCMCIA cards.

VIVO (BRAZIL)

Even though only a small percent (1%) of VIVO's customer base requires international roaming, the operator offers it in key markets around the world. The vast majority (80%) of its roaming customers travel to the U.S. where they can use either Sprint or Verizon Wireless' CDMA2000 1X networks. For roaming in Latin America, VIVO uses CDMA when available (CDMA is available in 17 markets through the region). When customers travel to a GSM market (Europe or some parts of Latin America), VIVO provides a GSM phone and SIM card for the duration of the visit. The operator is planning to offer multi-mode, multi-band phones in the near future.

CONCLUSION

The CDMA community is rapidly expanding its international roaming capabilities to meet the growing demand for the services. The ANSI-41 standard has evolved to support seamless international roaming on par with GSM and is being continuously enhanced to enable advanced functionality. CDMA2000 operators offer robust international voice roaming services across all continents and are introducing data capabilities. The CDMA industry is leading in introducing multi-mode, multi-band phones and services to provide truly universal roaming services and enable their customers to stay connected anytime and anywhere today and in the future.

APPENDIX A – NETWORK AND STANDARD SUPPORT FOR CDMA GLOBAL ROAMING

Irrespective of whether the wireless subscriber is an inbound or outbound roamer, they expect to have the same services when roaming as they have when in their home network. These services include voice, data and messaging. The prime network nodes within a CDMA operator's network affected by roaming include:

- MSC (Mobile Switching Center)
- HLR and VLR (Home Location Register and Visited Location Register)
- SMS-C (Short Message Service Center)
- MMC (Multimedia Messaging Center)

At minimum, these nodes must support the following features:

MSC – Enhanced International Roaming features including:

- ANSI and ITU Global Title Translations (GTT)
- Extended length of different numbering formats (e.g., E.164 format)
- Signaling between visited network (inter-working between ANSI and ITU SS7 networks)

HLR – Enhanced International Roaming features including:

- R-UIM
- GTT (including adaptation for many countries)
- Internationally unique International Mobile Station Identifier (IMSI)
- International format for Mobile Dialing Number (MDN), Temporary Local Directory Number (TLDN)
- Separation of Mobile Identity Number/International Mobile Station Identifier (MIN/IMSI) and MDN
- Subscriber provisioning

In addition to the wireless network nodes needing to support roaming, the wireless networks have to support **international interconnection** between each other in order to provide the ability to automatically roam. When the roaming subscriber enters a foreign network, the Mobile Station (MS) is automatically identified as belonging to a specific foreign network, and signaling to the subscriber's Home Location Register (HLR) returns an authorization response. Messages as described in section "0 Basic CDMA Roaming" of the ANSI-41 standard are exchanged over a special network interconnection.

CDMA operators use SS7 to provide call control and ANSI-41 signaling internationally. Operators will typically directly connect to an SS7 "backbone network" which is owned and operated by separate service providers/international carriers.

CDMA Global Roaming – Network Functions

Automatic roaming functions are defined by ANSI-41 in the section titled "Automatic Roaming Operations and Basic Automatic Roaming Scenarios." The functions outlined in the standards detail how seamless and automatic service to subscribers across networks is served by multiple Mobile Switching Centers (MSCs). The seamless roaming capabilities specified in ANSI-41 are required to apply to all mobility and end-user features. For example, to deliver an international roaming call, the Temporary Local Directory Number (TLDN) used for call termination routing must be provided in the E.164 international format.

An international roaming call would proceed as follows:

1. A call is received by the home MSC for delivery to the subscriber
2. The Home MSC sends a location request to the HLR
3. A Routing request is sent to the serving MSC
4. The TLDN number is assigned
5. The international TLDN number is sent back to the Home Network
6. The Home MSC routes the call and the serving MSC connects

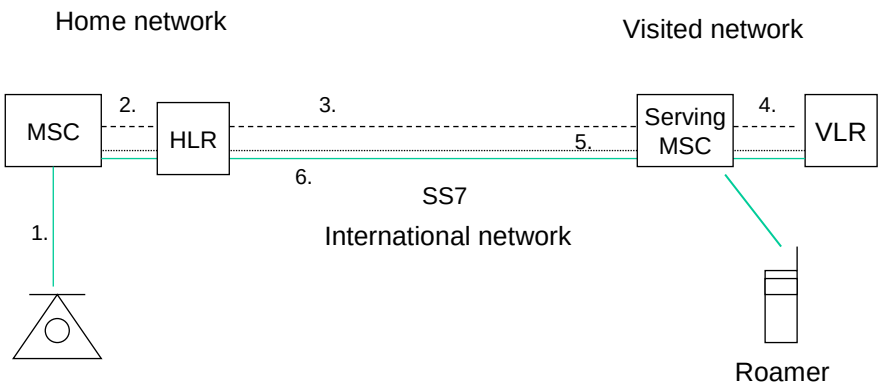


Figure 1.1.2: International Roaming Call Delivery Fixed Line Phone

Automatic roaming functions supported in a wireless network can be grouped into four key categories:

- Mobile Station (MS) - service qualification
- Mobile Station (MS) - location management
- Mobile Station (MS) - state management
- HLR and VLR fault recovery

Service Qualification functions include the validation of the MS and home system for purposes of financial accountability and MS profile information, which provides the specific service capabilities and restrictions. The MS's Home Location Register (HLR) is the database repository for this information. There are three basic ANSI-41 operations involved with MS service qualification. These include:

- Registration Notification
- Qualification Request
- Qualification Directive

Authentication is considered a more advanced function of service qualification, as it requires an additional systems node, the Authentication Center (AC) and administration of secret data called the "A-Key" which is stored only in the MS and HLR and never transmitted over the air.

MS Location Management has two components:

- MS location-updates
- MS location cancellations

Updates create or modify the MS's temporary record in the visited system and in the HLR. Cancellation processes delete the temporary records in the visited system and update records in the HLR. Cancellation is sometimes referred to as deregistration. There are a number of ANSI-41 operations involved with MS Location Management, including; Registration Notification and Cancellation, MS Inactive, Parameter Request, Bulk Deregistration, and Unreliable Roamer Data Directive.

MS State Management involves exchanging the "state" of the MS between the visited system and HLR as either "active" or "inactive." An MS is considered not active if it is not registered, out of radio contact or made intentionally inaccessible by the system. The following ANSI-41 operations are involved in state management: Registration Notification and Cancellation, MS Inactive, Bulk Deregistration, Routing Request and Unreliable Roamer Data Directive.

HLR and VLR fault recovery functions are designed to reduce the effects of link or system failures in the network. In general, when an HLR data failure is detected, the ANSI-41 "Unreliable Roamer Data Directive" may be used and when a failure is detected in the serving system, the Bulk Deregistration operation may be used.

Subscriber Billing

Wireless network operators require the exchange of roaming billing records with roaming partners. The most common practice today is that billing records are sent to a "clearinghouse" to be computed and exchanged with other roaming partners. The clearinghouse is an independent third party facilitating these transactions.

Clearinghouse's have the ability to also translate different switch and billing record formats, signaling and numbering standards as well as to edit and validate all roaming records and provide financial settlement information. Data records can be provided to the clearinghouse regularly (i.e., monthly, daily, even hourly) using magnetic tape once per month, or direct link.

CDMA Data Roaming

Wireless data services, such as Short Message Service and Packet Data are popular solutions used to keep in touch when roaming. Similar to voice services, the roaming agreement between two operators should take data services into consideration, ensuring that both parties to the agreement address the method of billing record exchange and charging for data services.

Short Message Service

In order to receive an SMS message while roaming internationally, the transport network must support SS7, CCITT7 or variation thereof, end to end. The steps to delivering SMS when roaming is as follows:

1. An SMS message is received at the Short Message Service Center (SMS-C)
2. The SMS-C sends an ANSI-41 SMS Request message to the HLR
3. The HLR returns the valid status and routing address in the SMS_Address parameter
4. The SMS-C addresses the SMS message to the serving MSC
5. The serving MSC forwards the message to the roamer
6. Steps 2-5 are repeated if roamer is not available

Figure 1.1.3: Short Message Service Delivery

Packet Data Roaming with Mobile IP

The Mobile IP standard as defined in TIA/EIA-835-C (IETF RFC 2002) allows users with mobile devices, whose IP addresses are associated with their home wireless network, to stay connected when moving to a foreign wireless network, while also maintaining their home IP address. This can prove useful for features and services requiring a consistent static IP address.

When a subscriber leaves the home network with which a device is associated and enters the domain of a foreign network, the foreign network's Foreign Agent (FA) sends a service availability advertisement to the Roaming Mobile Station. The FA is considered a function of the serving system's Packet Data Serving Node (PDSN). The MS then requests service from the FA, and the FA in-turn uses the Mobile IP protocol to inform the home network's Home Agent (HA) of the "care-of address" to which all packets for the user's device should be sent. Mobile IP uses two IP addresses; a fixed home address and a care-of address which changes at each new point of attachment. All Packets bound for the home address are essentially "call forwarded" to the care-of address in the foreign network.

Mobile Station Functions

The International Mobile Station Identifier

The International Mobile Station Identifier (IMSI) is defined by the ITU-T E.212 document. The IMSI is a 15-digit number that uniquely defines the identity of the MS in the network. The IMSI is not used for dialing purposes in the public switched network, but rather, is used by the network to identify the MS. The IMSI will normally have an associated Mobile Directory Number (MDN), which is the number that may be dialed. The MDN and IMSI may be completely different numbers.

The IMSI is made up of a 3-digit Mobile Country Code (MCC) that is assigned to a single country, a 2-3 digit Mobile Network Code (MNC) that is unique to a carrier in that country followed by the Mobile Subscriber Identification Number (MSIN), which may be a maximum of 10 digits. The IMSI functionality is supported by GSM standards and by CDMA2000/ANSI-41 standards.

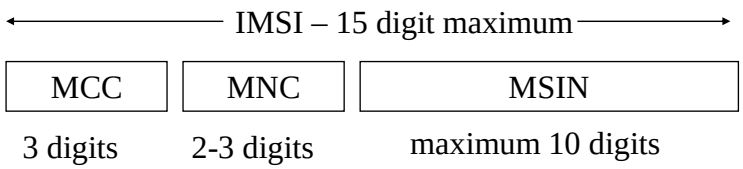


Figure 1.2.1: The IMSI Format

The CDMA standards (IS-95/2000) have always supported the 15-digit E.212 IMSI format, however, due to historic MIN based networking, the implementation by carriers has delayed the introduction of the true IMSI format. In most ANSI-41 networks, the IMSI field has been filled with a "MIN based IMSI" to facilitate continued use of the existing networking operations. The MIN based IMSI's 10 least significant digits are filled with a MIN. The remaining 5 most significant digits may have been filled with previously undefined codes, such as "00000", etc. In the U.S., a special IMSI format has now been defined (310+00+MIN) to allow continued MIN based operations. The two MNC digits are also referred to as IMSI_11_12.

In order to provide ANSI-41 roaming capabilities to non-North American subscribers, the International Roaming MIN (IRM) was defined. The IRM is also 15 digits and recognized by the format [0-1]XXX+6D where X is a digit between 0 and 9, inclusive. IFAST is responsible for assigning the 4-digit IRM Network Identifier prefixes (0XXX or 1XXX) to a carrier, and the assigned carrier allocates the last six digits based on their requirements. The designations are also documented in TIA/EIA/TSB-29.

An 80% expansion of the IRM was recently approved providing the additional codes [2-9]XX[0-1] for administration by IFAST.

The intention of IRMs was always to provide a short-term solution to a long-term problem. Migrating networks to the E.212 IMSI format would address this problem long term and allow for easier inter-standard network roaming (i.e., with GSM/WCDMA). MIN-only systems will not be able to communicate with IMSI-only systems.

Plus Code Dialing

CDMA2000 (TIA/EIA-875) standard defines plus code dialing and CDMA2000 Mobile Stations will be supporting the "+" code dialing function on the keypad. If the network also supports such a function, the "+" code dialing feature can also be used in place of the international dialing prefix when dialing international numbers, which is unique to most countries. This feature is especially useful when roaming in foreign countries with an unknown international prefix to the subscriber. For example, the prefix for dialing an international number from within North America per E.164 format is '011'+CC+NDA+SN; where CC is the Country Code, NDA is the National Destination Code and SN is the Subscriber Number. The roaming subscriber may, or may not be aware of the required prefix, but in any case, need only enter the "+" button in place of the '011' prefix. The network will intelligently interpret the "+" code as the international prefix for that country and route the call accordingly.

Multi-Band Mobile Stations

Multi-Band Mobile Stations support additional frequency bands to allow the MS to be used in networks other than the home network (e.g., 800 MHz , 1900 MHz.) The home carrier may or may not support these other bands, but in most cases the subscriber may utilize these other available band functions when roaming internationally.

For example, the CDMA carriers in North America use two frequency bands – 800 MHz and 1900 MHz. Ideally for a roaming subscriber, the MS would support all standards in all bands, but most Mobile Stations support a subset of these combinations.

Depending on where the subscriber is roaming, and what roaming agreements are in place between the subscriber's home carrier and foreign carrier, the choice of which dual-band or tri-band phone provided is important. Most CDMA devices available today are dual band supporting 800/1900 MHz service.

Preferred Roaming List

The Preferred Roaming List (PRL) contains information to assist the mobile station system selection and acquisition process, particularly when the mobile station is roaming. Essentially, the PRL contains a priority list of network System Identifiers (SIDs) from which the Mobile Station is authorized to access service.

A "SID" typically covers the area of a city or large town. There are currently no strict guidelines for the size of SIDs. Their definition is left to the operators and national authorities. The range of SID assignments per country can be found in ANSI/ TIA/EIA-TSB-29D.

A "NID" is an optional subdivision of a SID. NIDs identify, for example, different rating areas, toll areas, private networks, MSC boundaries, or any other subdivision the operator may want to distinguish within a SID.

When two operators would like to offer international roaming service between each other, PRL information must be exchanged and reviewed to ensure mobile stations will correctly find the preferred system. If the operators are national operators covering a large number of SIDs, the PRLs can be significantly large due to the inclusion of the roaming partner's SID/NID pairs. The PRLs need to be maintained with each new roaming agreement and/or SID/NID change. Administration of the PRL can be done via the CDMA Over-The-Air Service Provisioning (OTASP) feature.

The “Enhanced PRL” concept involves using existing overhead channel information elements to recognize a carrier’s network identification. By having each carrier broadcast its own network code, a mobile station can determine if the current network is within its PRL, and a corresponding behavior and/or priority can be assigned.

With the Enhanced PRL, a mobile station would then only need (in most instances) a single PRL entry to describe an operator, instead of the tens or hundreds of entries that would be required if it had to enter each partner’s individual SID and NID. Describing a roaming partner by its network code also alleviates the management and coordination of updating a customer’s PRLs when the roaming partner decides to change, delete, or add SIDs.

The intended mode of broadcasting carrier identification is by using the Mobile Country Code (MCC) and IMSI_11_12 parameters in the Extended System Parameters Message. The Enhanced PRL is described in detail in CDG Document 86 “PRL Enhancements for International Roaming.”

APPENDIX B: INTERSTANDARD ROAMING

INTER-WORKING AND INTEROPERABILITY FUNCTION (IIF)

Roaming between ANSI-41 based networks and MAP networks is made possible through the use of the inter-working and interoperability function that translates messages between the two protocols, in additional to the support of the device. The recent availability of dual-standard Mobile Stations has provided added utility of this function.

This section briefly describes the network requirements and standards for supporting inter-standard roaming.

The J-STD-038B standard "Network Inter-working between GSM MAP and TIA-41 MAP – CDMA2000 Support" addresses the inter-working and interoperability between ANSI-41 MAP and GSM MAP based networks to support subscriber roaming between networks in both directions. The standard defines the required network message mapping between ANSI-41 MAP and GSM MAP to support the mobile terminal and associated services.

When the MS is in "native mode," it is serviced by the same technology to which its Home Location Register belongs. When the MS is in "foreign mode," the MS is accessing the network of a technology different from the native technology supported in the HLR (i.e., a CDMA2000/ANSI-41 MS is considered in GSM foreign mode when accessing a GSM network).

The figure below depicts the signaling control interfaces between the inter-working and Interoperability Function (IIF) and respective networks. The function of the IIF or gateway is to map messages between GSM and ANSI-41 MAP.

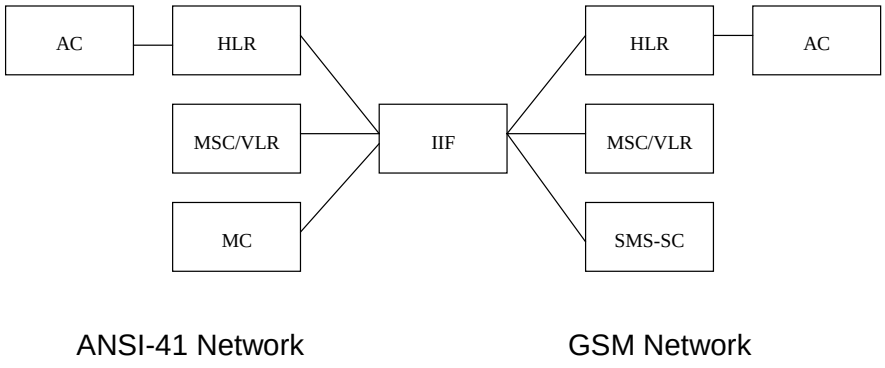


Figure 1.1.4: The IIF Interfaces

The IIF does not duplicate the subscriber's existing HLR, but provides a gateway to any visited networks that use a foreign MAP protocol. The original source of subscription data remains in the home network's HLR. Most of this data shall not reside in the IIF, but shall be dynamically converted and translated between GSM and ANSI-41 MAP messages as needed. Some basic subscriber identity information does however need to be provisioned in the IIF to support this mapping process. Information includes:

- International Mobile Subscriber Identity (IMSI)
- Mobile Identification Number (MIN)
- Electronic Serial Number (ESN)
- Terminal type
- Network Access Mode

Optionally, the IIF may support one-way roaming only from CDMA to GSM network. In this case, no data is provisioned at the IIF level and the ANSI-41 HLR/AC must be compliant with TIA/EIA–868. Subscribers may be using multi-mode mobile stations capable of roaming into a GSM system or R-UIMs (TIA/EIA-820) that are inserted into a GSM terminal which have been programmed with the appropriate added parameters.

J-STD-038B also details the support for authentication across inter-standard networks.

CDMA2000 AND GPRS ROAMING

J-STD-038 Revision A added the capability of an ANSI-41 subscriber using GPRS services when roaming in GSM Foreign Mode. The standards development group is now in the progress of providing support for two-way CDMA2000/ANSI-41 and GPRS roaming which is planned for a possible future revision of J-STD-038.

THE REMOVABLE USER IDENTITY MODULE (R-UIM)

The R-UIM contains a dedicated file structure for CDMA containing Number Assignment Module (NAM) and other operational information. Separate dedicated file structures for GSM or TDMA can also be assigned on the same module. The CDMA dedicated files contain the "MIN" which is stored within the 10 least significant digits of the IMSI_M parameter. If a true IMSI (E.212) has been provided, it will be stored in the IMSI_T parameter. If both IMSI types have been programmed in the R-IUM, selection of one is required for authentication of the MS.

No upgrades are needed to the Serving System to provide support for R-UIM capable roamers. In addition, no air interface, A- interface, or serving system intersystem signaling enhancements are required.

MULTI-STANDARD MOBILE STATIONS

Mobile stations are now available that support both CDMA and GSM standards at multiple frequencies, including SIM and R-UIM support. A Dual-Mode Quad-Band phone would typically support CDMA 800, GSM 900, GSM 1800 and CDMA 1900.

There are several phones on the market that support the R-UIM. Samsung and Motorola introduced CDMA2000/GSM multi-mode, multi-band phones and LG, Sanyo, Toshiba, and Hitachi will soon launch their models. These high-end phones are feature rich and are equivalent to those found on single-technology high-end phones. Nokia's present approach is to provide a series of "twin phones" with the same feature sets for different networks. Customers can own a pair of phones: one for use on their primary network and one for when they are roaming internationally (e.g., a 6225 for GSM and the matching 6220 for CDMA2000).

APPENDIX C - CDMA ROAMING STANDARDS

TIA/EIA-751

The "TIA/EIA-41-D Modifications to Support IMSI" standard provides the network with the ability for mobile stations to register using the "true IMSI" format as designated by the ITU E.212 standard. All ANSI-41 operations previously requiring the Mobile Identification Number (MIN) can alternately use the E.212 IMSI as identifier. The concept of Mobile Station ID (MSID) was also introduced as a generic label to identify the choice between IMSI and MIN within messages.

TIA/EIA-807

The "TIA/EIA-41-D Enhancements for Internationalization" standard defines Global Title Translation and translation types for IMSI (ITU-T E.212) and Mobile Directory Number (ITU-T E.164).

TIA/EIA-808

TIA/EIA-808 - "Incorporating UIM into 3G and IMT- 2000 Systems" standard covers the ANSI-41 modifications for Authentication of Mobile Stations using the R-UIM. The MS Equipment contains the ESN, which is used in the Authentication process. If the R-UIM is moved to different MS Equipment, additional parameters must be exchanged.

TIA/EIA-820 STANDARD FOR R-UIM

The "Removable User Identity Module for Spread Spectrum Systems" standard contains the requirements for the Removable User Identity Module (R-UIM). The composite R-UIM standard is comprised of the Subscriber Identity Module (SIM) specification as used in GSM networks specification and the "delta" document TIA/EIA-820.

TIA/EIA-835-C

The Mobile IP standard as defined in TIA/EIA-835-C (IETF RFC 2002) allows users with mobile devices, whose IP addresses are associated with their home wireless network, to stay connected when moving to a foreign wireless network, while also maintaining their home IP address.

TIA/EIA-875

The TIA/EIA-875 "Enhanced International Dialing, Calling Number Identification and Callback, Calling Party Category Identification" standard covers special international dialing scenarios such as support of "+" code dialing, and enables identification of the calling party category.

Calling Number Identification Presentation support allows up to 15 digits for alphanumeric display. The standard recommends International numbers should be displayed in E.164 number and that the MS may prefix an international indicator (i.e., "+" code).

The standard also allows the subscriber to review the call back number on the alphanumeric display before actually making the call. However, the call back number shall not require editing before use while the subscriber is located within the country in which the call was received.