PRL Design, Maintenance and Testing

CDG Document 130

Version 1.1

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Revision History

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1. Introduction

The Advanced Mobile Phone System is one of the earliest commercial cellular systems and is still deployed widely in North America and other countries. AMPS is found on the cellular (800 MHz) bands only. AMPS is an analog FM system, and thus can suffer from eavesdropping, interference, signal-strength limited power management and uncorrectable multi-path fading.

CDMA was first introduced over the cellular band with dual mode (AMPS/CDMA) capable handsets. The presence of two radio access technologies in a single GEO required a more sophisticated system selection that can provide a mechanism for selection between AMPS and CDMA systems. Initially the handset user interface required the user to specify:

- CDMA only
- AMPS only
- CDMA preferred
- AMPS preferred

This approach had the limitation of requiring user intervention and, at a time when search time was slower than today's devices, the lack of geographic segmentation meant inefficient periodic reselection algorithm when operating on not the most preferred system. The arrival of CDMA into the PCS bands brought a new set of problems of how to specify the PCS frequencies over which to attempt acquisition. The cellular band had a limited number of preferred anchor frequencies (Primary A, Secondary A, Primary B and Secondary B) however the PCS band had a total of 42 preferred CDMA channels. These limitations were addressed by the introduction of the preferred roaming list. The PRL is a data structure in a phone's non-volatile (NV) memory.

The Preferred Roaming List (PRL) is a database that assists the mobile in the acquisition and selection of a serving CDMA network. The PRL is fundamental for operators since it is through the PRL that the home operator informs their mobile devices about systems that are permitted and any order of preference in the permitted systems and even about any systems that are prohibited. Although it is possible to operate (in the 800 MHz cellular band only) without a PRL, it is common today for every CDMA handset to have a PRL. In considering the subject of PRLs, questions often arise in understanding:

- The purpose of a PRL
- The structure of a PRL

- How to build a PRL
- How a PRL is used by the mobile
- How to manage and distribute PRLs
- How an 1xEV-DO PRL is different
- How to test a PRL
- How PRL enhancements work

The PRL provides an operator with the flexibility to specify the search behavior of its mobiles in both home and roaming markets. Through the use of a preferred roaming list, acquisition time is optimized to provide service as quickly as possible. The PRL also contains information to indicate the roaming status of the current serving network.

The record structure of a PRL is defined in the IS-683 family of standards. These standards describe PRLs that are capable of describing systems using IS95, CDMA2000 1x, CDMA2000 1x/IS-95 1xEV-DO, GSM/GPRS and UMTS. The structure of a PRL, and how each of these systems is described in a PRL, is discussed in this paper

A PRL guides the process of system determination and selection but the PRL itself does not describe how that function is realized. The function of selecting a network using the PRL as the selection criteria is not covered by any of the standards and is left to vendor implementation.

1.1 Identification of a CDMA Network

The identification of a network can mean many things to many people. Often there is a regulatory identification of the market.

1.1.1 Regulatory Markets & Frequency Licenses

In the United States in the 1980s, in an attempt to protect against anti-competitive behavior, authorities mandated a duopoly structure for the fledgling cellular industry. At the outset of this mandate, local wire-line companies were automatically granted one of the two licenses in the cellular band in every market in which they provided wire-line service (the B Band). The second license (A Band) for each market was initially drawn by lottery and later auctioned. Later PCS Block auctions also followed.
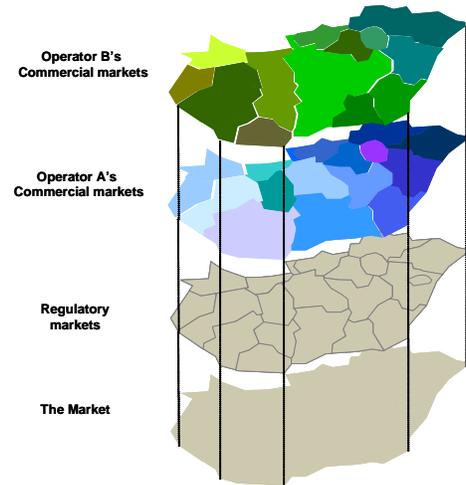
Figure 1-1 Identification of Networks

In most countries a regulatory body governs (or licenses) the use of commercial radio frequency spectrum. The regulator generally divides the market up in two domains, a geographic domain and a frequency domain.

- The geographic domain divisions, sometimes called regulatory markets, are the physical areas of the country; in the United States they are called Geographic Region Service Areas (GRSA)
- The frequency domain divisions are the individual licensed frequency allocations

A license is usually the right to use a particular frequency allocation in a particular regulatory market. Thus, if the regulator divides frequency spectrum into 8 bands, and divides the country into 50 markets, then there are potentially 400 licenses.

A licensee can choose to offer retail commercial service and be an operator or to wholesale the capacity to a retail operator. The term 'operator' generally means the organization that installs the network and sells service to customers. Regulatory markets may be identified by some kind of geographic and frequency designator which may not have meaning outside of the regulatory context.

1.1.1.1 Commercial Markets

Regulatory market divisions, while being good administrative tools, may not align with the operator's commercial markets. Often the commercial market is a combination of a number of licenses which may span many regulatory markets – which may or may not be all in the same frequency band.

From the commercial operators perspective a commercial market can mean many things; it can be a city, or an area of a city, it can a county, state or some other region defined as a network boundary.

In CDMA, every system identifies itself by broadcasting its name. This name comprises its system identification (SID) and its network identification (NID). These identities are configured by the operator. One operator may choose to have all systems in a particular area broadcast the same identity while another may choose a lesser or greater granularity.

1.1.2 Identification of a CDMA System

There are four specific pieces of identity information that a CDMA network broadcasts about itself:

- System Identification Code (SID)
- Network Identification Code (NID)
- Mobile Country Code (MCC)
- Mobile Network Code (MNC) or IMSI_11_12

Of course, the actual radio frequency (band and/or channel) can also be used in identification.

1.1.3 System Identification Code

The system identification code (SID) is a 15-bit binary number that can be represented by a five-digit decimal number. The SID is used by a network to identify itself such that a

mobile device can make a determination on whether or not to attach to the network and whether or not it is roaming. Each SID is globally unique and assigned to a particular operator. The SID is also used within the MSC identity and to properly route roaming call records for billing among roaming partners.

A SID is allocated to a carrier by its national telecommunications authority or an appointed agent. The SID is assigned and administered from the country's allocation of SID range. A SID range is allocated to an administrator by the International Forum on ANSI-41 Technology (IFAST). There are cases where system identification codes are being used outside of the bounds of their IFAST allocation. The known SID conflicts are detailed on the IFAST web site at http://www.IFAST.org.

In the United States, a SID for the cellular band (800MHz) was originally assigned by the Federal Communications Commission (FCC) and was a required part of a license application. In August 2002, the Commission adopted an order[1] which eliminated the SID as a required element of the license and transitioned the administration of SIDs to administrators in the private sector. There are six cellular SID administrators that can issue a SID in the US. USA SID administration for the PCS band (1850 - 1990 MHz) is performed by CIBERNET. PCS SIDs were originally assigned by CIBERNET according to the FCC auctioned PCS license areas[2], however; recently there has been consolidation of SIDs to commercial markets.

1.1.4 Network Identification Code

The Network Identification code (NID) is a 16-bit binary number that can be represented by a five-digit decimal number. The use of a NID by the mobile device to identify a network is optional. The NID is used to subdivide the SID namespace. Each NID is unique to a particular SID. A NID is locally assigned and administered by the operator owning the SID.

1.1.5 Mobile Country Code

The mobile country code (MCC) identifies the country in which the network operates. MCCs are issued by the Telecommunications Standardization Body (TSB) of the International Telecommunications Union (ITU) and are globally unique. A list of existing and valid mobile country codes can be found on the ITU web site at http://www.itu.int/itudoc/itu-t/ob-lists/icc/index.html.

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[1] The FCC eliminated the use of SIDs and the SID assignment process in its entirety as part of the license application and as a part of the FCC Year 2000 Biennial Regulatory Review (Amendment of Part 22 of the Commission's Rules to Modify or Eliminate Outdated Rules Affecting the Cellular Radiotelephone Service and other Commercial Mobile Radio Services, WT Docket No. 01-108, Report and Order, FCC 02-229 (released Sept. 24, 2002), the section 22.941 of the Commission Rules, 47 C.F.R. § 22.941).

[2] PCS license areas, which follow the Rand McNally definition of Major Trading Areas (MTAs) and Basic Trading Areas (BTAs)

1.1.6 Mobile Network Code

A mobile network code (MNC) identifies a particular network within a mobile country code and is thus unique within a particular MCC. While recent standards allow for an MNC of two or three digits, the majority of deployed commercial infrastructure uses a two digit MNC (irrespective of technology). In CDMA the MNC is often referred to as the IMSI_11_12. Every CDMA system broadcasts its MCC and IMSI_11_12 (MNC).

An MNC is issued by in-country administrators (a regulatory body or an appointed agent). Administrators are requested to keep the TSB informed of MNC allocations. A list of existing and valid mobile country codes can be found on the ITU web site at http://www.itu.int/ITU-T/inr/forms/mnc.html.

1.1.7 Home Network Identity

Every commercial, public service, mobile network can be described by the Home Network Identity (HNI). In some technologies, this HNI is sometimes referred to as the PLMN-Id (Public Land Mobile Network Identity). The HNI is comprised of a mobile country code (MCC) and a mobile network code (MNC). Since recent standards allow for an MNC of two or three digits, some administrators now allocate a six-digit HNI (i.e. a three-digit MCC and a three-digit MNC). In the case where the majority of the deployed base of commercial infrastructure can only use a two-digit MNC (again, irrespective of technology) the allocation guidelines have generally been temporarily adjusted so that only an agreed two of the allocated three digits are broadcast and that integrity is preserved. Such is the case in the US.

1.1.8 Radio Frequency – Band Class and Channel

Every CDMA system operates on a particular frequency, or more specifically, a particular channel within a particular band class. Band class is the term used to describe the standards segmentation of the frequency spectrum. Channel describes an allocation of a portion of bandwidth within a band class; channel number only has meaning in the context of a band class. The bandwidth of a channel varies across band classes. Band classes and channels are described in the 3GPP2 document C.S0057. See section 1.1.10.

The band class can be used to further characterize a CDMA system in addition to combining the broadcast identity together with the some classification of the radio frequency on which the system is operating.

1.1.9 Identification Attributes Applicable to PRLs

The short discussion above yields five attributes that can be used to identify a CDMA system:

- System identification
- Network identification
- Mobile country code

- Mobile network code
- Radio frequency (band-class)

In the context of the PRL, two combinations of three of these attributes are available to be used for the purposes of system selection.

The most commonly used combination is:

- System identification code (SID)
- Network identification code (NID)
- Radio frequency (band-class)

Later discussions will show the capability for the PRL to describe systems in terms of the three attributes of:

- Mobile country code (MCC)
- Mobile network code (MNC or IMSI_11_12)
- Radio frequency (band-class)

1.1.10 Applicable Standards

Table 1-1 lists the standards that apply to PRL as they are discussed in this document. Both the TIA name and the 3GPP2 equivalent name is give as is the location where these standards can be downloaded free of charge.

Table 1-1 Applicable Standards and Location

TIA Name	3GPP2 Name	Title	Download Location
TIA/EIA IS-2000	C.S0001-0 v3.0	Introduction to cdma2000 Spread Spectrum Systems Release 0	http://3gpp2.org/Public_html/specs/C.S0001-0_v3.0.pdf
IS-683-A	C.S0016-0 v1.0	Over-the-Air Service Provisioning of Mobile Stations in Spread Spectrum Systems	http://3gpp2.org/Public_html/specs/C.S0016-0with3Gcover.pdf
TIA-683-B	C.S0016-A v2.0	Over-the-Air Service Provisioning of Mobile Stations in Spread Spectrum Systems	http://3gpp2.org/Public_html/specs/C.S0016-A_v2.0.pdf
TIA-683-C	C.S0016-B v1.0	Over-the-Air Service Provisioning of Mobile Stations in Spread Spectrum Standards	http://3gpp2.org/Public_html/Specs/C.S0016-B_v1.0.pdf
TIA-683-D	C.S0016-C v1.0	Over-the-Air Service Provisioning of Mobile Stations in Spread	http://3gpp2.org/Public_html/specs/C.S0016-

TIA Name	3GPP2 Name	Title	Download Location
		Spectrum Standards (4.7MB)	C_v1.0_041025.pdf
IS-820	C.S0023-0 v2.0	Removable User Identity Module (RUIM) for cdma2000 Spread Spectrum Systems (357KB)	http://3gpp2.org/Public_html/specs/CS0023-0.pdf
IS-820-1	C.S0023-0 v4.0	Removable User Identity Module for Spread Spectrum Systems (546KB)	http://3gpp2.org/Public_html/specs/C.S0023-0_v4.0.pdf
TIA-820-A-1	C.S0023-A v1.0	Removable User Identity Module for Spread Spectrum Systems (558KB)	http://3gpp2.org/Public_html/specs/C.S0023-A_v1.0.pdf
TIA-820-A-1	C.S0023-A v2.0	Removable User Identity Module for Spread Spectrum Systems (846KB)	http://3gpp2.org/Public_html/specs/C.S0023-A_v2.0_021004.pdf
TIA-820-A-2[E]	C.S0023-A v3.0	Removable User Identity Module for Spread Spectrum Systems (799KB)	http://3gpp2.org/Public_html/specs/C.S0023-A_v3.0_041220.pdf
TIA-820-B	C.S0023-B v1.0	Removable User Identity Module for Spread Spectrum Systems (830KB)	http://3gpp2.org/Public_html/specs/C.S0023-B_v1.0_040426.pdf
IS-856-0	C.S0024-0 v2.0	cdma2000 High Rate Packet Data Air Interface Specification (1.8MB)	http://3gpp2.org/Public_html/specs/C.S0024_v2.0.pdf
IS-856-1	C.S0024-0 v3.0	cdma2000 High Rate Packet Data Air Interface Specification (2.6MB)	http://3gpp2.org/Public_html/specs/C.S0024-0_v3.0.pdf
IS-856-2	C.S0024-0 v4.0	cdma2000 High Rate Packet Data Air Interface Specification (2.3MB)	http://3gpp2.org/Public_html/specs/C.S0024-0_v4.0.pdf
TIA-856-A	C.S0024-A v1.0	cdma2000 High Rate Packet Data Air Interface Specification (5.4MB)	http://3gpp2.org/Public_html/specs/C.S0024-A_v1.0_040331.pdf
TIA-1030	C.S0057-0 v1.0	Band-class Specification	http://3gpp2.org/Public_html/s

TIA Name	3GPP2 Name	Title	Download Location
		for CDMA-2000 Spread Spectrum Systems	pecs/C.S0057-0_v1.0_020904.pdf
ANSI/TIA/EIA 41-D	N.S0005-0 v1.0	Cellular Radio Telecommunications Intersystem Operation	http://3gpp2.org/Public_html/specs/N.S0005-0_(Cellular_Intersystem)_v1.0_pv.pdf
IS-725-A	N.S0011-0 v1.0	OTASP and OTAPA	http://3gpp2.org/Public_html/specs/N.S0011-0_v1.0.pdf
ANSI/TIA/EIA-TSB-29D	N.S0017-B v1.0	International Implementation of Wireless Telecommunication Systems Compliant With ANSI/TIA/EIA-41	http://3gpp2.org/Public_html/specs/N.S0017-B.pdf

2. Preferred Roaming List Overview

2.1 What is a Preferred Roaming List (PRL)?

The PRL is often considered in two subtly different ways depending on an individual's particular context:

- Some see the PRL as a set of RF channels on which to search for service and the description of systems that can be found on those channels.
- Others look at the PRL as being a list of mobile network systems that a mobile device is allowed to access and the frequencies on which they can be found.

Both are, of course, correct. The preferred roaming list is a device resident database. It does contain an indexed list of frequencies on which to search for particular systems. The PRL contains a list of systems that a device is permitted to access and those that it is explicitly forbidden to access. The list of systems is known as the System Table and the list of frequencies is known as the Acquisition Table.

The PRL contains information to assist the mobile station in system selection and the acquisition process. It indicates which systems the mobile station should use (preferred systems) and those which should not be used by the mobile station (negative systems). In addition to indicating which systems are preferred or negative, the PRL has information, which can help to optimize the acquisition time.

Figure 2-1 Conceptual Representation of the PRL

The PRL is built by an operator, loaded into the mobile device and is not accessible by the user. The full definition of the PRL is fully described in the standards – specifically the IS-683 family of standards, from revision A to revision E.

2.1.1 CDMA's Automatic System Selection

Network selection in CDMA is fully automatic. There is no capability for manual override by the user. While some devices may allow a user to influence the general behavior of selecting a system, regardless of the PRL, CDMA does not provide the user with a selectable list of available systems.

2.2 PRL Structure

The structure of the PRL is shown in Figure 2-2 and comprises three major sections:

- A properties set (header information) that provides general information about the PRL
- An acquisition table which lists all the frequencies that the device can search
- A system table which describes the systems

2.2.1 PRL Header Information

The PRL header information describes the *properties* of the whole PRL. These properties describe aspects such as its name (or identity), default behavior and the type of PRL.

2.2.2 Acquisition Table

The acquisition table contains acquisition records. An acquisition record provides the band and frequencies that the mobile station is to use when searching to acquire a system.

Acquisition records are listed in priority order (highest priority first) in the acquisition table. The channels in the 'CHAN' field of the records are also listed in the priority order.

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Figure 2-3 PRL Structure

2.2.5 System Table

The system table contains records describing a system. The system table is divided into one or more distinct segments; these are called geographical areas, or GEOs. A system record belongs to a geographical area. A geographical region would normally be used to group a set of systems found in the same physical region. Certain other aspects of a system record only have relevance within the context of a GEO, e.g. priority.

A system, in the context of the system table, is identified by its SID and NID. Each system table record has an indicator, which determines within which geographic area a particular system belongs.

Other indicators declare whether the system is preferred (permitted) or negative (prohibited). Allowed systems can have relative priority with respect to each other within a geographic region, effectively making some systems more preferred than others. The priority that a system has is relative to the other systems in the same GEO. The most
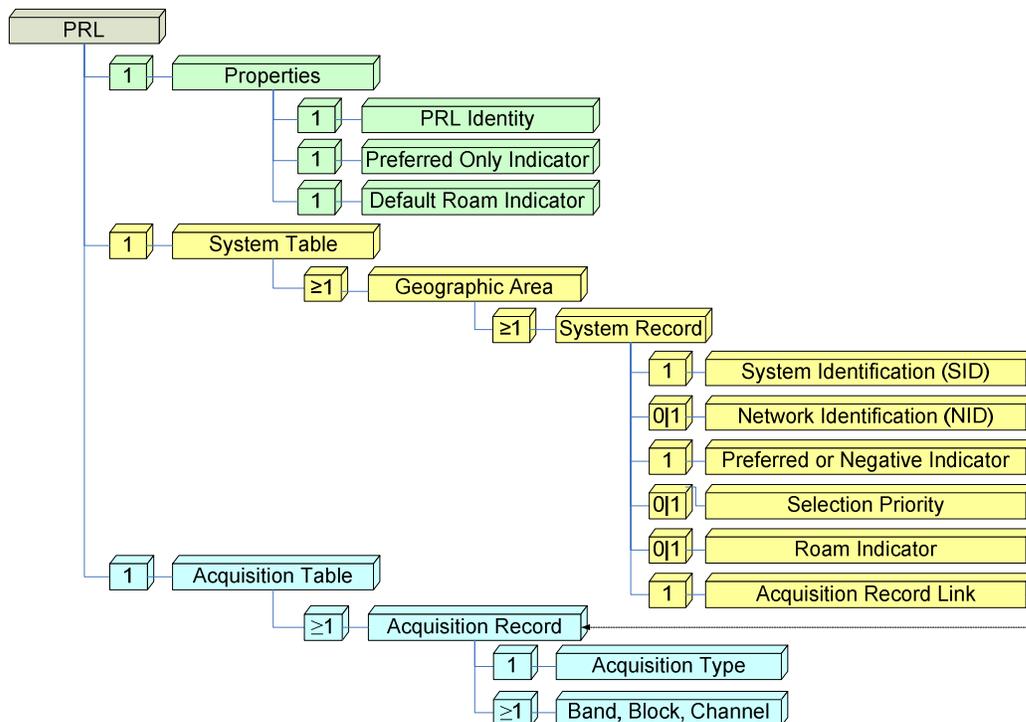
Figure 2-2 PRL Structure

preferred system is the most desired system and what the mobile device will always try to obtain for service. There is no limit to the number of priorities that can be present

within a GEO. There can be multiple systems of equal priority. In describing systems listed in the PRL system table it is useful to consider them as outlined in Table 2-1.

Table 2-1 System Types in Context of the System Table

System Type	Description
Preferred	Defined by the PRL as 'Preferred' – i.e. in the PRL and not explicitly prohibited
Most Preferred	The most preferred system within its GEO
Less Preferred	Preferred but not the most preferred system or negatively preferred system in that GEO
Negative	A system defined in the PRL for which the Neg/Pref field is set to 'Negative'
Available	A system that has been found but is not listed in the PRL's system Table.

A system record contains an acquisition index, which is a link to a particular record in the acquisition table that describes the radio frequencies where this system can be found.

The unique index of a PRL system table entry, as interpreted by the system selection software, is implementation dependent and could be one of:

- The (SID, NID) pair & band-class (of the channels) described in the acquisition record
- The (SID, NID) pair and the specific channels of the acquisition record

It is good practice to design PRLs on the premise that the former is the only one guaranteed to be true.

Also included in the system record is the roaming status that should be indicated by the mobile station when it obtains service from the system described by the system table entry.

2.3 Function of the Preferred Roaming List

The PRL assists the mobile in the acquisition and system selection process as governed by the system determination algorithms of the particular implementation. The PRL informs the device's system determination function as to which systems are permitted, preferred and prohibited. The use of a PRL speeds up acquisition and provides the operator with flexibility in specifying mobile search behavior in both the home and roaming markets.

The operator is able to specify whether a 'roam' condition is to be indicated on the mobile's display and, in the case where the extended roaming indicators (ERI) are supported, a richer set of indicators can be selected for display.

The PRL standards (at various revisions) allow for the specification of a PRL covering CDMA One systems (IS-95), CDMA2000 (1xRTT) systems, IS-856 systems (CDMA2000 1x/IS-95 1xEV-DO) and UMTS/GSM systems.

2.3.1 Operating without a PRL

Without a PRL a mobile station can scan only in the standard channels of Band Class 0 and Band Class 1. The mobile station's system selection behavior, in terms of choosing a preferred system, is determined by non-volatile (NV) memory parameters.[1]

Since PRLs have many advantages, few, if any, mobile devices operate without a PRL.

2.3.2 Disabling the PRL

Generally, all TIA/EIA-2000 compliant devices are manufactured with a PRL. However, there is often a device resident non-volatile (NV) memory parameter[2] that can be used to enable or disable the PRL. If the PRL is disabled then the mobile device uses something called the default roaming list concept for operation on band class 0 and band class 1 networks only. In some cases, a device may go 'offline' when the PRL is disabled.

Operation without a PRL is not common and is not addressed in this document.

2.4 Where is the PRL and How Does it Get There?

The PRL can be stored in either NV-RAM or RUIM. An initial or default PRL would be loaded prior to distribution. A new PRL can be loaded at a customer service center using service programming tools or over the air using Over the Air Service Provisioning (OTASP). See section 3.

Although the PRL is defined in the OTASP specification, OTASP systems are not required in order to use PRLs. However, OTASP facilitates ease of updates once handsets are in the customer's hands and as new roaming partners are added.

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[1] 'NV_SYSTEM_PREF_I'='Standard' and 'NV_PREF_MODE_I' = 'NV_MODE_AUTOMATIC'
[2] 'NV_PRL_ENABLED_I'

3. Updating the PRL Over the Air

Over the Air Service Provisioning (OTASP) is the term used most often to refer to how a PRL can be downloaded over the air to a mobile device. See Figure 3-1.

Some terminology clarification may be useful here:

- Over the air service provisioning (OTASP) is generally understood to mean service provisioning activities that are **initiated by the user**.

- Over the Air Parameter Administration (OTAPA) is generally understood to mean service provisioning activities that are **initiated by the network**.

Figure 3-2 OTASP Architecture

- Over The Air Function (OTAF) is the language used in the standards to describe the functionality required to deliver the ability of OTASP or OTAPA without specifying it to be one or multiple physical systems.

- The OTA platform is the actual system that operators purchase to deliver the over the air function (OTAF). It is this system that maintains the multiple PRLs that have been built by the operator and that are available for download. The number of PRL variations that an OTA platform can store is vendor specific. The PRL that a particular customer should get would be configured by the operator and could depend on various factors, including device type and subscribed service plan.

- System Selection for Preferred Roaming (SSPR) is the standards language for PRL

- Customer Service Center (CSC) is the call center, or automated voice response unit (AVRU), to which a user is connected. The CSC determines what type of service programming is to be performed. SSPR, or PRL download, is only one of the capabilities that are available under OTASP.

3.1 Which Standards Apply to PRL Download Over the Air?

The format for the PRL is actually contained in the standard which describes Over the Air Service Provisioning (OTASP). There are two standards that cover OTASP:

- IS-683 describes the MS to BTS interaction, specifically, defining the OTASP protocols and the messages that can be sent over the air encapsulated in the CDMA *Data Burst Message*. This includes the definition of the PRL.
- IS-725 describes the core network interactions between the OTA platform, the MSC, the CSC and the HLR as appropriate.

3.2 IS-683/IS-725 Over the Air PRL Update Process

There are two ways in which the over the air download can happen, one that the user initiates: OTASP; and one that the network initiates: OTAPA.

3.2.1 User Initiated PRL Download

This is the more common technique, and requires that the user take the initial action by making a call using the activation feature code: *ACT or *228.

- User dials the OTA feature code (*ACT)
- User selects PRL update at voice response unit (VRU) prompt
- OTA platform selects the appropriate PRL to send to the device based on factors including handset, service plan, etc.
- OTA platform downloads PRL to the user over its IS-725 data connection to the MSC and then over the air using the IS-683 protocol
- VRU may play music during this time
- Handset resets on completion of the PRL download

3.2.2 Network Initiated PRL Download

This is where the network initiates an *OTAPA session* with the mobile device and performs the PRL download without user intervention. This requires that both the network and the device are OTAPA capable and that the OTAPA capability is not disabled.

A subscriber parameter administration security mechanism (SPASM) exists to ensure that only authorized entities can download to the device. When the device parameters are protected, the mobile device requests a 'signature' from the network and, at the same time, calculates a signature itself. The OTA system, upon receiving the device's challenge, will request the HLR to obtain an authentication signature (from the authentication center). The OTA system forwards the signature to the MS. Only when the MS reports that the two signatures match can the PRL download proceed.

3.2.3 Update of PRL Outside of Home Network

The standards do not preclude the ability to connect to another service provider's OTA system; however, this requires cooperation and configuration by both operators to:

- Re-direct to the home network CSC and/or OTA system
- Allow roamer's home network OTA system to communicate with partner network's serving MSC
- Verify all MSC capabilities

Of course there is the obvious problem that the PRL must have permitted access to the serving system in order to be able to make the call to the CSC at all.

Assuming that the PRL contains sufficient information to access the serving system, the only reason to perform an update remotely would be if there was a change in the systems or preferences for that market or if 'fuller detail' for the market was needed. Each of these situations would be part of any PRL management strategy.

Remote PRL download is something that partner operators would have to individually consider and plan to accommodate. The serving network would need to route to the appropriate CSC and OTA platform.

Current trends would appear to limit service programming, including PRL updates, to the 'home network' jurisdiction. PRL updates are generally not available outside the 'home' network and even then, in some environments, PRL updates may not be available outside of the user's Home Service Area within that network

3.3 Non IS-683 Standard PRL Update (using SMS)

In some markets, SMS is used as the transport and distribution mechanism for the PRL. Generally, this can only apply to markets where the operator has specified mobile devices to use the removable user identity module (RUIM) and where those device have additional supporting software installed (this software is referred to as the UIM toolkit or UTK).

In this case, the PRL is segmented and sent in one or more SMS messages and transmitted to the mobile station with an identified sequence. This technique requires the specification and recognition of a special form of teleservice for an IS-637-A SMS. Software support on both the handset and the RUIM is normally required to reformulate the one or more special SMS messages into a reconstituted PRL that can be committed to the PRL memory location.

4. PRLs for 1x/IS-95 & Analog Systems

This section takes a deeper look at how a network identifies itself, how the mobile recognizes a network and how to specify a system in the PRL. This section fully describes the contents of the PRL.

4.1 How the CDMA Network Identifies Itself

Recapping from earlier, every CDMA system operates on a particular frequency or CDMA channel. CDMA systems have a frequency re-use of one, achieved by a timing offset between across cells. Based on this we can say that every CDMA system is uniquely identifiable by the combination of:

- System Identification Code (SID)
- Network Identification Code (NID)
- Radio Frequency Channel (Band-class, channel)
- Timing offset (actually known as a PN offset)

Clearly, to try and describe every cell in the home and visited networks is too detailed, and it is not necessary. The PRL limits its level of granularity, for unique system identification to:

- System Identification Code (SID)
- Network Identification Code (NID)
- Band Class.

Every CDMA base station broadcasts its system and network identities in system overhead messages.

Extending the previous discussion on licenses and commercial markets, Figure 4-1shows a situation where operators have licenses in adjacent markets and on different frequency bands.

In this example, the operators consider the two regulatory markets to be the same commercial market and, therefore, assign the same SID to each.

Armed with this information, the PRL can now be cracked open and its definitions and contents fully explained from the standards perspective, and also, how one might see it presented in a PRL editor.
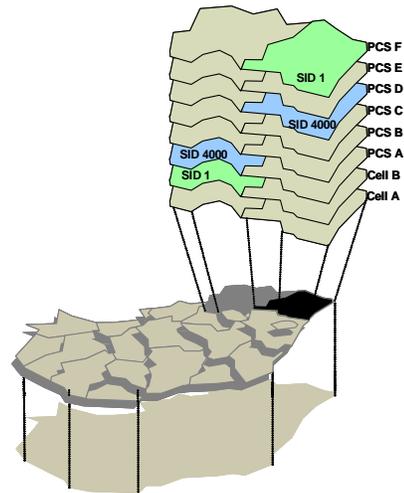
Figure 4-1 Same SID on Different Frequencies

4.2 Anatomy of the PRL from Editor

The PRL has three major components, the header, the system table and the acquisition table (see Figure 4-2). In this section we look at the PRL as you might see it in PRL editor and then that to the standard definitions of the PRL data structures. In each instance, a discussion follows to explain

the meaning relate.

Figure 4-2 Example PRL Editor View

4.3 PRL Header Information

4.3.1 Editor View

The PRL Header information describes the *properties* of the whole PRL. These properties describe aspects such as its name (or identity), default behavior and the type of PRL.

Figure 4-3 shows how a PRL editor may display the PRL properties

Figure 4-3 Example Editor View of PRL Header

4.3.2 What it Describes and What it Means

The information in the header as defined by the standard is described in Table 4-1. Only the shaded portions are displayed in the editor. The rest (the un-shaded part of the table) really describes the size, packaging and housekeeping overhead which we can rely on tools, such as a PRL editor, to add based on the dimensions of the final PRL.

Table 4-1 PRL Header Information

Field	Length (bits)
PR_LIST_SIZE	16
PR_LIST_ID	16
PREF_ONLY	1
DEF_ROAM_IND	8
NUM_ACQ_RECS	9
NUM_SYS_RECS	14
ACQ_TABLE	variable
SYS_TABLE	variable
RESERVED	0 to 7 (as needed)
PR_LIST_CRC	16

The *Roaming List Type* in this particular editor view refers to which particular standards revision describes this PRL (this one is IS-683B). This would be seen generally in a PRL

editor which supports multiple versions of IS-683. To understand what this editor view is actually describing let's look at what the standard says is in the header and link these two views.

- **Preferred Roaming List ID**: what the standard calls PR_LIST_ID, it is a number between 0 and 65,535 that can be used to identify and version control a PRL.

- **Preferred only**: called PREF_ONLY in the standards and indicates if **only systems in the PRL** are to be used. If *preferred only* is not checked (i.e. set to 0) then this is what is sometimes called a 'permissive PRL' and means that systems not described in the PRL can be used. This is something worth noting as it can be the cause of unexpected behavior. Use of this flag does not mean that the PRL is ignored; rather it means that service can be provided by any system that is not described in the PRL and that the system selection process will continue to search for a more preferred system as indicated by the PRL. This can be useful to ensure coverage where it is present and accessible to the user but may not have been included in the PRL (provided that the user can register or the system rejects an invalid registration).

- **Default Roaming Indicator**: is DEF_ROAM_IND in the standards and is the roaming indication to be used for systems that are not described in the PRL and would apply when the *Preferred only* is not checked. The values that can be used in this field are the same as those that would be used in the System Record of the System Table which is described later.

4.4 Acquisition Table

The acquisition table defines, in priority order, the radio environment (frequencies) that are to be searched for service. The acquisition table is comprised of a minimum of one and up to 512 acquisition records. Each acquisition record is of a specific type and describes one or a set of frequencies to search.

The priority ordering of the records in the acquisition table is derived from their sequential order and it is generally used by the system selection process to construct scan lists reflecting the order in which frequencies appear in the acquisition table. Also, where a set of frequencies are listed within a record of the acquisition table the order in which they are listed is often an implied ordering for scan lists.

An example of what an acquisition table might look like in a PRL editor is shown in Figure 4-4.

Figure 4-4 Example Editor View of an Acquisition Table

The type of acquisition records that can be defined in a PRL are dependent on the revision of the standard that is in use for that particular PRL. The particular types as they apply to revisions A through C are listed in Table 4-2. Some of the more common acquisition records are described in the following sections.

Table 4-2 Types of Acquisition Record by Standard Revision

Standard Revision	Types of Acquisition Records That Can be Defined
683-A	- Cellular Analog - Cellular CDMA (Standard Channels) - Cellular CDMA (Custom Channels) - Cellular – CDMA Preferred - PCS CDMA using Blocks - PCS CDMA using Channels
683-B	All 683-A records and additionally - JTACS CDMA (Standard Channels) - JTACS CDMA (Custom Channels) - 2Ghz Band(Channel)
683-C	All 683-B records and additionally - CDMA Generic (800-MHz-Cellular, PCS, TACS, JTACS, Korean-PCS, NMT-450, IMT-2000, 700-MHz-Cellular.) - HDR Generic

4.4.1 Cellular Analog Acquisition Record

This record is used to instruct the mobile device to look for AMPS Cellular service, in band class 0 (800 MHz cellular) frequencies.

Figure 4-5 shows the editor view of the analog cellular acquisition record and Table 4-3 shows the actual field names and lengths described in the standard.
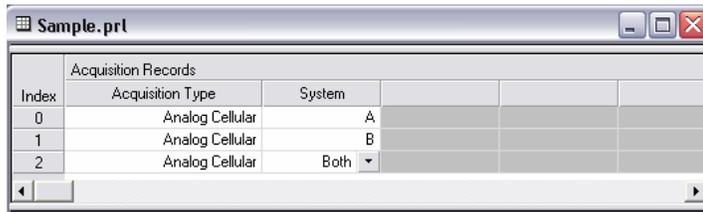
Acquisition Record Field	Length (bits)
ACQ_TYPE	4
A_B	2

Figure 4-5 Cellular Analog Acquisition Record Editor View

Table 4-3 Analog Acquisition Record Fields

4.4.1.1 Acquisition Type

The Cellular Analog acquisition record has an 'ACQ_TYPE' value of '1' (binary 0001). An editor will generally show a meaningful descriptive term for this, as in the example shown where it is shown as 'Analog Cellular.'

Exactly where the device should search for cellular analog service is defined by the next field.

4.4.1.2 Systems

This is the band within the 800 MHz cellular frequencies. This system is called the 'A_B' field in the standards and can take one of three legal values. These values allow the device to be directed to look for analog systems in:

- A band only
- B band only
- Both A and B bands

Table 4-4 shows the actual values as represented in the standard and their meaning.

Table 4-4 A_B Field Values

A_B Selection Type	Meaning
'00'	System A
'01'	System B
'10'	Reserved
'11'	Both A & B

4.4.2 Cellular CDMA (Standard Channels) Acquisition Record

This record is used to instruct the mobile device to look for CDMA service, and CDMA only, in band class 0; more specifically, only on the *standard* channels of a particular sub-band of band class 0 (the 800 MHz A or B cellular frequencies).

Figure 4-6 CDMA Standard Acquisition Record Editor View

Figure 4-6 shows one particular editor view of the CDMA cellular, standard channels acquisition record. Table 4-5 shows the actual field names and lengths described in the standard.

Table 4-5 CDMA Standard Channel Acquisition Record Fields

Acquisition Record Field	Length (bits)
ACQ_TYPE	4
PRI_SEC	2
A_B	2

4.4.2.1 Acquisition Type

An acquisition record describing CDMA cellular standard channel systems has an 'ACQ_TYPE' value of '**2**' (binary 0010).

An editor will probably not display this actual value and would generally use a more descriptive name, as in Figure 4-6, where it is shown as 'CDMA Cellular' (Standard).

4.4.2.2 Systems

This describes the band within the 800 MHz cellular frequencies. This *system* field is known as the 'A_B' field in the standards and can take one of three legal values. These values allow the device to be directed to look for CDMA systems in A band only, B band only or both A and B bands. Table 4-6 shows the actual values as represented in the standard and their meaning.

4.4.2.3 Channel

For this type of record the channel as shown in the editor example is an indicator to the mobile device if it is to look on the standard primary channel or the standard secondary channel or both the primary and secondary.

This *channel* editor field is known as the 'PRI_SEC' field in the standards and can take one of three legal values Table 4-7 shows the actual values as represented in the standard and their meaning.

Table 4-6 A_B Field values

A_B Selection Type	Meaning
'00'	System A
'01'	System B
'10'	Reserved
'11'	Both A & B

Table 4-7 PRI_SEC Field Values

PRI_SEC	Meaning
'00'	Reserved
'01'	Primary CDMA Channel
'10'	Secondary CDMA Channel
'11'	Primary or Secondary CDMA Channels

4.4.3 CDMA Standard Channels

A question that often arises when service providers use the 'cellular CDMA standard channels' acquisition record type in the acquisition table is how the mobile know what the CDMA channels are.

For band class 0 only, the actual CDMA channels come from NV-RAM[1] and, as may have already been deduced from the tables above, there are four such channels, namely, primary-A, primary-B, secondary-A, and secondary-B. These channels are programmed into NV by the operator (or specified by the operator to the manufacturer in the Product Release Information (PRI)).

In the United States they are typically set to the preferred set of channels that are defined in IS-2000 as shown in Table 4-8.

Table 4-8 IS-2000 Standard CDMA Cellular Channels

Band	Standard Channel	Channel Number
A	Primary	283
	Secondary	691
B	Primary	384
	Secondary	777

An operator that has primary and/or secondary channels that are different in the home market than in the roaming market, and, uses either 'Cellular CDMA Standard Channel' or 'CDMA Preferred' (see section 4.4.4) in their PRL should be aware of the potential effects in the roaming markets.

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[1] NV_PCDMACH_I - primary-A and primary-B, NV_SCDMACH_I -secondary-A and secondary-B

4.4.4 Cellular CDMA (Custom Channels) Acquisition Record

This acquisition record is used to search for CDMA service in band class 0 (800 MHz cellular frequency band) on a list (up to 32) of specific channels. Furthermore, it means that channels are searched in the order in which they are listed

Figure 4-7 shows one particular editor view of the CDMA cellular, custom channels acquisition record. Table 4-9 shows the actual field names and lengths described in the standard.
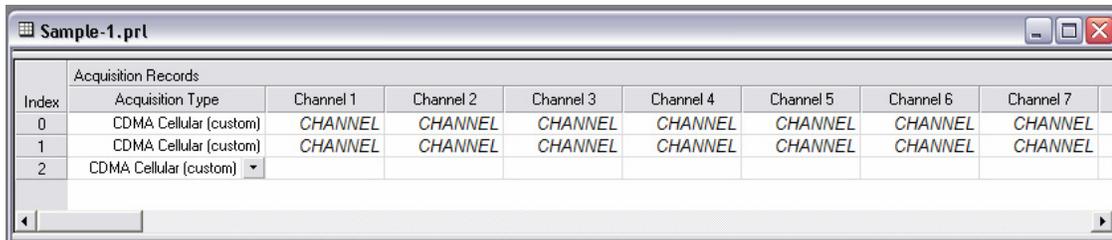
Sample-1.prl							
Acquisition Records							
Index	Acquisition Type	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7
0	CDMA Cellular (custom)	CHANNEL	CHANNEL	CHANNEL	CHANNEL	CHANNEL	CHANNEL	CHANNEL
1	CDMA Cellular (custom)	CHANNEL	CHANNEL	CHANNEL	CHANNEL	CHANNEL	CHANNEL	CHANNEL
2	CDMA Cellular (custom)							

Figure 4-7 CDMA Cellular Custom Acquisition Record Editor View

4.4.4.1 Acquisition Type

An acquisition record describing custom channels in the cellular band (Band Class 0) has an 'ACQ_TYPE' value of '3' (binary 0011). An editor may not display this value and instead use a descriptive term for this, as in the example of Figure 4-6, where it is shown as 'CDMA Cellular (Custom).'

4.4.4.2 Channels

This section describes the channels within the 800 MHz cellular bands. This *channel* field is known as the 'CHAN' field in the standards. There can be from 1 to 32 channels specified in one acquisition record. Table 4-10 shows the channel values that can be used in the Cellular CDMA Custom Channels acquisition record.

The standards describe the NUM_CHANS field also which indicates how many channels are in this record (1 to 32). Normally, if an editor or some equivalent tool is used then the tool would calculate and maintain this as part of its housekeeping.

Table 4-9 CDMA Custom Channel Acquisition Record Fields

Acquisition Record Field	Length (bits)
ACQ_TYPE	4
NUM_CHANS	5
NUM_CHANS occurrences of	
CHAN	11

Table 4-10 CHAN Field Values

CHAN	Meaning
1..799	List of CDMA channels to search
801..1039	
1041..1199	
1201..1600	

4.4.5 Cellular CDMA Preferred Acquisition Record

This record is used to instruct the mobile device to search, in band class 0, for CDMA service first (on the standard channels in a particular band); and, if no CDMA service is found, to look for AMPS Cellular service *in the same band.* This would generally be done before moving to any other band/channel.

If the intention is to select a CDMA system over an analog system on a particular channel then this is the record to use. If the intention is to find all CDMA systems on all (or any combination of) standard channels before selecting any analog system then the acquisition table should be explicitly structured that way. Without careful design inadvertent selection of analog over CDMA may occur.

Figure 4-8 shows one particular editor view of the CDMA cellular, standard channels acquisition record. Table 4-5 shows the actual field names and lengths described in the standard.
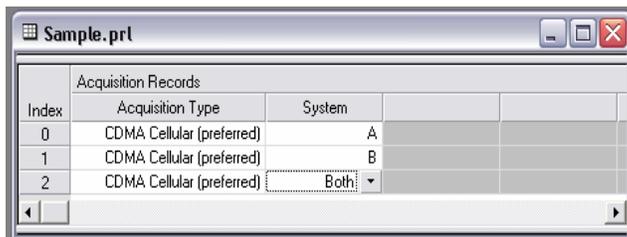
Figure 4-8 CDMA Preferred Acquisition Record Editor View

Table 4-11 CDMA Preferred Acquisition Record Fields

Acquisition Record Field	Length (bits)
ACQ_TYPE	4
A_B	2

4.4.5.1 Acquisition Type

An acquisition record describing custom channels in the cellular band (Band Class 0) has an 'ACQ_TYPE' value of '4' (binary 0100) (see Table 4-11). Editors often display a

more human readable form, as in Figure 4-8 where it is shown as 'CDMA Cellular (Preferred).'

4.4.5.2 Systems

The *system* fields shown in the editor example describes the band within the 800 MHz cellular frequencies. These values allow the device to be directed to look for CDMA systems in A Band only, B Band only or both A and B bands This *system* field is known as the 'A_B' field in the standards and can take one of three legal values.

Table 4-12 shows the actual values (as represented in the standard) and their meaning.

4.4.5.3 Channel

For this type of record, the channel (as shown in the editor example) is an indicator to the mobile device as to whether it is to look on the standard primary channel or the standard secondary channel or both the primary and secondary.

This *channel* editor field is known in the standards as the 'PRI_SEC' field and can take one of three legal values. Table 4-13 shows the actual values as represented in the standard and their meaning.

Table 4-12 CDMA Preferred A_B Values

A_B Selection Type	Meaning
'00'	System A
'01'	System B
'10'	Reserved
'11'	Both A & B

Table 4-13 PRI_SEC Field Values

PRI_SEC	Meaning
'00'	Reserved
'01'	Primary CDMA Channel
'10'	Secondary CDMA Channel
'11'	Both Primary and Secondary CDMA Channels

4.4.6 PCS CDMA (Using Blocks) Acquisition Record

This record is used to instruct the mobile device to look for CDMA service on the *preferred* CDMA channels in a particular block of band class 1 (1900 MHz PCS frequencies).

Up to eight blocks can be specified (although tools such as editors often limit this to 6 since there are only 6 defined PCS blocks). The order in which the blocks are listed is generally the order that they would be searched. Figure 4-8 shows one particular editor view of the *CDMA PCS*, using the blocks acquisition record. Table 4-14 shows the actual field names and lengths described in the standard.
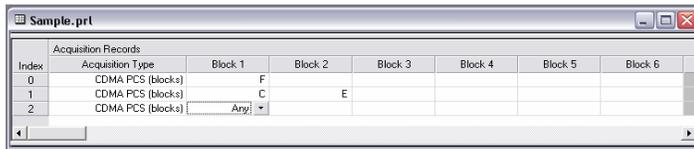
Figure 4-9 CDMA PCS using Blocks Acquisition Record Editor View

Table 4-14 CDMA PCS by Block Acquisition Record Fields

Acquisition Record Field	Length (bits)
ACQ_TYPE	4
NUM_BLOCKS	3
NUM_BLOCKS occurrences of	
BLOCK	3

4.4.6.1 Acquisition Type

An acquisition record describing blocks in the PCS band (Band Class 1) has an 'ACQ_TYPE' value of '5' (binary 0101) and has the structure as shown in Table 4-14. Typically editors would not show the actual type value. Figure 4-9 shows a possible editor display form of this field as 'CDMA PCS (blocks).'

4.4.6.2 Block

For this type of record the block (as shown in the editor example) is an indicator to the mobile device as to which PCS block or blocks to search for CDMA service.

This *Block n* editor field is known as the 'BLOCK' field also in the standards and can take one of seven legal values Table 4-15 shows the actual values as represented in the standard and their meaning.

Table 4-15 BLOCK Field Values

Block	Meaning
'000'	CDMA Preferred Channels in PCS Block **A**
'001'	CDMA Preferred Channels in PCS Block **B**
'010	CDMA Preferred Channels in PCS Block **C**
'011'	CDMA Preferred Channels in PCS Block **D**
'100'	CDMA Preferred Channels in PCS Block **E**
'101	CDMA Preferred Channels in PCS Block **F**
'110	Reserved
'111'	CDMA Preferred Channels in ANY PCS Block

4.4.7 CDMA PCS Preferred Channels

The preferred channels of the PCS blocks are defined in the 3GPP2 document C.S0057. (Band-class Specification for CDMA 2000 Spread Spectrum Systems).

When using the 'by blocks' acquisition record this infers that all of the preferred channels are placed in the scan list to be searched for CDMA service.

The preferred channels for CDMA in the PCS blocks are shown in Table 4-16.

Table 4-16 Preferred CDMA PCS Channels

PCS Block	Channel Number
A	25, 50, 75, 100, 125, 150, 175, 200, 225, 250, 275
B	425, 450, 475, 500, 525, 550, 575, 600, 625, 650, 675
C	925, 950, 975, 1000, 1025, 1050, 1075, 1100, 1125, 1150, 1175
D	325, 350, 375
E	725, 750, 775
F	825, 850, 875

4.4.8 PCS CDMA (Using Channels) Acquisition Record

This record is used to instruct the mobile device to look for CDMA service on the channels listed in band class 1 (1900 MHz PCS frequencies).

Up to 32 channels can be specified. The order in which the channels are listed is generally the order that they would be searched. Figure 4-10 shows one particular editor view of the *CDMA PCS, using Channels* acquisition record. Table 4-17 shows the actual field names and lengths described in the standard.
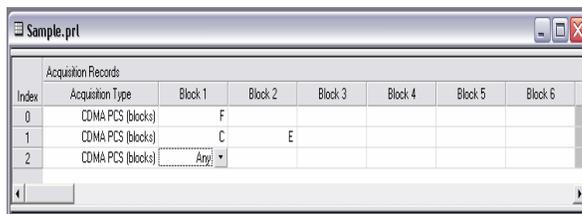
Figure 4-10 CDMA PCS Using Channels Acquisition Record Editor View

Table 4-17 CDMA PCS by Channel Acquisition Record Fields

Acquisition Record Field	Length (bits)
ACQ_TYPE	4
NUM_CHANS	5
NUM_CHANS occurrences of	
CHAN	11

4.4.8.1 Acquisition Type

An editor will generally show a meaningful descriptive term for the acquisition type, as in the example of Figure 4-10, where it is shown as 'CDMA PCS (Channel)'; however, in the standards this is described by the 'ACQ_TYPE' field having the actual value '**6**' to represent CDMA PCS (using Channels).

4.4.8.2 Channels

This channel fields in the editor describe the channels to be searched within the 1900 MHz PCS bands. This *channel* field is known as the 'CHAN' field in the standards. There can be from 1 to 32 channels specified in one acquisition record. Table 4-18 shows the channel values that can be used in the PCS CDMA using Channels acquisition record.

Table 4-18 PCS CHAN Field Values

CHAN	Meaning
1..799	List of CDMA channels to search
1041..1199	List of CDMA channels to search
801..1039	List of CDMA channels to search
1201..1600	List of CDMA channels to search

The standards describe the NUM_CHANS field which also indicates how many channels are in this record (1 to 32). Normally, if an editor or some equivalent tool is used then the tool would calculate and maintain this as part of its housekeeping.

4.4.9 Generic CDMA Acquisition Record

In revision C of IS-683 (3GPP2 C.S0016) two new acquisition records became available, namely Generic CDMA and Generic High Speed Packet Data (HSPD). Generic HSPD is described in section 9. The Generic CDMA acquisition record enables the description of any channel in any band class. This record is used to instruct the mobile device is to search, in the order listed, for CDMA service on a specific channel of a specific band-class.

Up to 16 band-class and channel pairs can be specified in one record. The order in which the channels are listed is generally the order that they would be searched. Figure 4-10 shows one particular editor view of the *CDMA Generic* acquisition record. This record is in the *Extended Acquisition Record Format.* This extended format is merely an encoding extension but would be transparent in tools such as PRL editors. Table 4-17 shows the actual field names and lengths described in the standard in its extended acquisition record format.
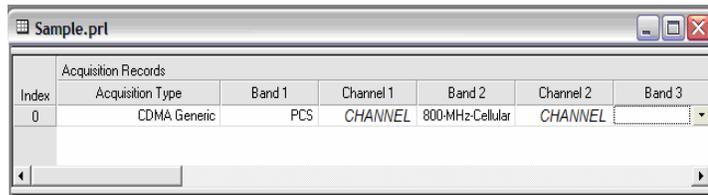
Figure 4-11 CDMA Generic Acquisition Record Editor View

4.4.9.1 Acquisition Type

An editor will generally show a meaningful descriptive term for this, as in the example of Figure 4-11, where it is shown as 'CDMA Generic.' In the standards the actual mechanism to identify a CDMA Generic acquisition type record is by setting the actual (decimal) value of '**10**' for the 'ACQ_TYPE' field. See Table 4-19.

Table 4-19 CDMA Generic Acquisition Record Fields

Acquisition Record Field	Length (bits)
ACQ_TYPE	4
LENGTH	5
LENGTH/2 occurrences of	
BAND_CLASS	5
CHAN	11

4.4.9.2 Band-class and Channel Pairs

Up to 16 band-class and channel pairs can be defined. An editor generally shows this as Band-n and Channel-n. There are a number of defined band-classes; some of the more commonly used are shown in Table 4-20. Alongside each band-class are the legal values for channels within that band-class. Some of these values may only be conditionally valid. For complete information on actual channel values and frequencies for all band-classes refer to the 'Band-class Specification for CDMA 2000 spread Spectrum Systems,' 3GPP2 C.S0057.

Table 4-20 Some Band-class and Channel Legal Combinations Defined by C.S0057

BAND_CLASS	Band Description	CHAN
0	800 MHz Cellular	1 – 311; 356 – 644; 689 – 694; 739 – 777; 1013 – 1023
1	1900 MHz PCS	25 – 1175
4	Korean PCS	25 – 575

BAND_CLASS	Band Description	CHAN
5	450 MHz	26 – 275[6]; 564 – 681; 717 – 846; 1070 – 1229; 1266 –-1442; 1323 – 1985
6	2 GHz (IMT-2000)	25 – 1175

Editors may not enforce the channel validity. The standards define the list of band-class and channel pairs as a repeating sequence of the 'BAND_CLASS' and 'CHAN' fields as shown in Table 4-19. There must be one channel specified for each band-class in the acquisition record.

4.5 System Table

The system table contains the descriptions of all the systems that are permitted to provide service or prohibited from providing service. Each system is described in a system record. See Figure 4-12.

Figure 4-12 Example Editor View of a System Table

The system table is comprised of a minimum of one and up to 16,384 system records; the actual number may be subject to the physical amount of storage available on the device. See section 4.6. Each system record describes one or more CDMA systems that are permitted or prohibited.

In the context of the PRL a system is identified by a broadcast identity ([System Identification, Network Identification] or [Mobile Country Code, Mobile Network Code]) and the frequency band on which the system was found (see section 1.1.2)

System records are explicitly grouped together. Groups of systems are termed *Geographical Areas* (as was described in section 2.2.5). Permitted (or *preferred*) systems in can be assigned a priority. Priority ordering in the system table is explicit unlike the implicit priority ordering of the records in the acquisition table. Priority ordering

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[6] In Band-class 5 only channels 126 through 275 are valid or conditionally valid for block A, only channels 106 through 235 are valid for Block B and only channels 26 through 168 are valid for Block C. See 3GPP2 C.P0057 for details on valid channels and frequencies.

only has scope and relevance within the grouping context of the *Geographical Area*. An example of what a system table might look like in a PRL editor is given in Figure 4-12.

4.5.1 System Type and System Record Type

In defining system records, a PRL editor often allows the specification of a system type. The system type in the PRL editor is in descriptive form ('1x/IS-95,' 'HRPD/IS-856' for 1xEV-DO etc.). The system type would generally translate to a system record type.

One thing to be aware of is that system record types did not exist prior to IS-683-C when a new form of system record was introduced, known as the *extended system record format*. The extended system record format enabled the PRL description of systems with different sets of attributes than those used to describe the basic 1x/IS-95 systems. The first such system to be defined as a new type was the high rate packet data system (1xEV-DO). Prior to this, all system records were of the same type, which is referred to in this document as the *Basic System Record.* Often when people talk of the extended PRL, they are referring to the extended record formats that are offered in IS-683C. With the increasing presence of 1xEV-DO systems the use of extended system record format is becoming more common.

With the new extended system record format it became possible to identify a type of system record as an explicit field. The system types as given in a PRL editor and the types of system records used to describe them in the actual PRL system table are listed Table 4-21.

Table 4-21 Editor System Types and Corresponding System Record Types

Standard Version	Types of System Record & Relationship	
	PRL Editor System Type	**Standard System Record Type**
683-A, 683-B	IS-95, CDMA2000 1x	Only one [Basic] System Record
683-C	IS-95, CDMA2000 1x	[Basic] System Record
		Extended System Record, TYPE= **0**
	High Rate Packet Data (IS-856,1xEV-DO)	Extended System Record, TYPE= **1**'
683-E	IS-95, CDMA2000 1x	[Basic] System Record
		Extended System Record, TYPE= **0**
	IS-856 (1xEV-DO)	Extended System Record, TYPE= **1**
	PLMN (GSM/UMTS)	Extended System Record, TYPE= **2**

Table 4-22 SSPR_P_REV Values and Meaning

SSPR_P_REV value	Supports PRL conforming to	SSPR_P_REV value	Supports PRL conforming to
1	IS-683-A	3	IS-683-C
2	IS-683-B	4	IS-683-D

As can be seen from the table the basic system record of IS-683 A and B can be expressed in a the extended system record format using a Type=0.

A stored variable in the mobile device indicates which type of PRL that the device can support. This variable is called SSPR_P_REV. An SSPR_P_REV value of '1' indicates that the only the basic record formats can be supported. An SSPR_P_REV of '3' indicates support of an Extended Preferred Roaming List containing Extended System Records.

4.5.2 Basic 1x/IS-95 System Record

The systems that are to be preferred or barred are described in a system record of the system table. An editor view of the system table is shown in Table 4-13. Each line is a system record. The specific fields of a system record are shown in Figure 4-13

Figure 4-13 Example Editor View of a IS95/CDMA200 1x/IS-95 System Record

Table 4-23 [Basic] System Record Fields (IS-683 A & B)

System Record Field	Length (bits)
SID	15
NID_INCL	2
NID	0 or 16
PREF_NEG	1
GEO	1
PRI	0 or 1
ACQ_INDEX	9
ROAM_IND	0 or 8

The following sections describe each element of the PRL's system record.

4.5.2.1 Negative/Preferred

This field is set to '1' if the mobile station is allowed to operate on the system associated with this record. This field is set to '0' if the mobile station is not allowed to operate on the system associated with this record.

4.5.2.2 Geography

The concept of a GEO was introduced in section 2.2.5. This field is how that strategy of segmentation of the system table is implemented. If this is the first system record, this field is set to '0.' If this is not the first system record, then this field is set as follows: If the system associated with this record is in the same geographical region as the system associated with the previous system record, this field is set to '1'; otherwise, this field is set to '0.'

In an editor this is normally seen as 'SAME' and 'NEW' as opposed to '1' and '0.' The important aspect of the GEO flag is that it is a relative description with respect to the **previous** system table entry; i.e. a GEO is either the 'SAME' as the previous or it is not the same as the previous in which case it is 'NEW': another GEO.

4.5.2.3 Priority

Only a preferred system can have priority, negative systems are all equally disliked and equally prohibited, so if the PREF_NEG field of this system record is equal to '0' then this field is omitted. Preferred systems on the other hand can be declared in preference order, and indeed systems can share the same level of preference. The declaration of preference is the implicit instruction to the handset's system selection function that it must try and always reach the most-preferred system.

The priority field is a relative description with respect to the **next** system table entry; i.e. priority is either the 'SAME' as the next or it is 'MORE' than the next record. Since priority only has relevance within the context of a *Geographical area*, the last preferred system record in a *GEO*, or if the next record describes a prohibited system, this field has no meaning and is set to '0.'

If the system associated with this system record is **more** desirable than the system associated with the next system record, this field is set to '1.' If the system described by this system record is as desirable as the next described system (i.e. it has the **same** priority) then this field is set to '0.'

The important thing to remember here is that unlike the GEO, the priority setting of a system record affects the subsequent record.

4.5.2.4 Acquisition Index

This field is set to the index of the acquisition record that specifies the acquisition parameters for the system associated with this record. (The index of the nth acquisition record is n-1.) For example, the index of the first acquisition record in ACQ_TABLE is 0, and the index for the fourth acquisition record is 3.

4.5.2.5 Roam Indicator

Only a preferred (or available) system will display a roaming indicator. Negative systems will not be able to provide service; hence, for those systems, this field is omitted.

4.5.2.6 SID - System Identification

This field is set to the SID broadcast by the system that this record represents. The SID is a 15-bit binary field that can be represented by a 5-digit decimal number between 0 and 32,763. A non-zero value for SID is a specific broadcast SID. *The value of '0' serves as a SID wildcard and is generally described as any other SID that is not specified in any other system record.*

A specific or wildcard SID still means that the system is on a frequency described by the acquisition record associated with it by the ACQ_INDEX.

4.5.2.7 NID - Network Identification

The NID is an optional field and its presence is indicated by the use of the NID_INCL field. A NID_INCL value equal to '01' indicates that the NID is included and is set to the NID of the network associated with this record; otherwise, this field is omitted.

The maximum NID value (65535) denotes any NID (i.e., serves as an NID wildcard). Not including the NID field is equivalent to including it and setting it to '1111111111111111.' The value '0' denotes a NID of the public system.

Table 4-24 shows the values and meaning of the NID_INCL field.

Table 4-24 The NID Included Field

NID_INCL Parameter	Description
'00'	NID not included. Assume NID value '1111111111111111'
'01'	NID included
'10'	NID not included. Assume NID value '0000000000000000'
'11'	Reserved

4.6 Size of the PRL

4.6.1 Acquisition Table Record Sizes

The acquisition table, in general, is not where the real estate battle is lost or won on PRLs. As is shown in Table 4-25, it is possible to have some fairly large records in the acquisition table.

Table 4-25 Sizes of Acquisition Records

Acquisition Record Type	Min Size Bits	Bits per Extra Element	Max num Extra Elements	Max Size (bits)
CDMA Standard	8	-	-	8
CDMA Preferred	8	-	-	8
CDMA Custom	20	11	31	361
PCS (Block)	10	3	5	25
PCS (Custom)	20	11	31	361
CDMA Generic	25	16	15	265

An interesting note here is that using PCS custom records can be much more expensive that using PCS by block records, e.g. using PCS Custom to identify 5 of the 11 block 'A' channels costs 75 bits whereas including all channels in block A costs only 10 bits in its own record. While avoiding unused channels may have been more important in early implementations of devices; they are generally able to scan much faster today so the efficiencies may not be as real.

4.6.2 System Table Records

Table 4-26 shows the sizes of different types of system records (i.e. negative and preferred systems) and how they vary based on having an NID as part of the record or not. The system table is often where the headaches come from trying to get a large number of records in to a small space. The average system record (with no NID) costs 37 bits. However, as some carriers have in excess of 200 SIDs (200 SIDs = 640 bits), then it becomes clear that adding roaming partners can become an issue.

Table 4-26 Sizes of System Records

System Record Type	SID	NID Incl	NID	Pref Neg	GEO	PRI	Acq Index	Roam Index	Size (bits)
Preferred System with NID	15	2	16	1	1	1	9	8	53
Preferred System no NID	15	2	0	1	1	1	9	8	37
Negative System with NID	15	2	16	1	1	0	9	0	44
Negative System no NID	15	2	0	1	1	0	9	0	28

Figure 4-14 shows a representation of the size of a system table required to hold preferred system records based on no NID being included.
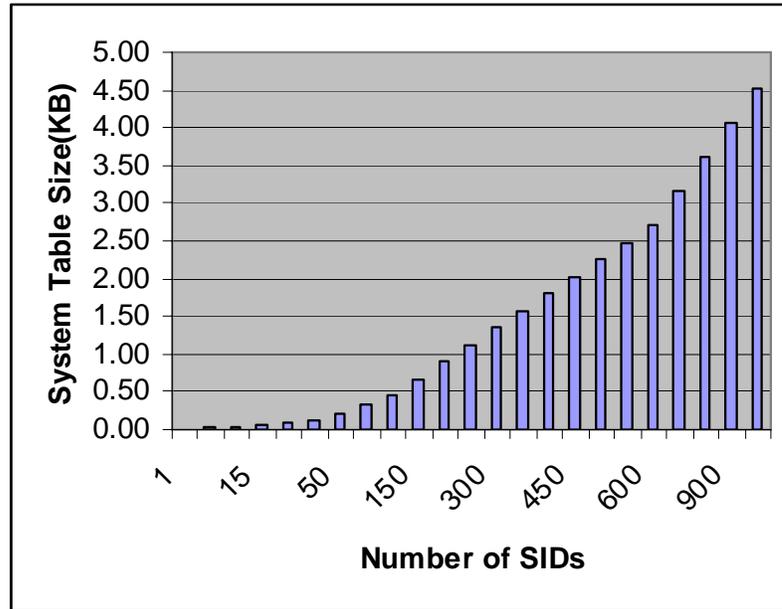
Figure 4-14 IS-683A/B System Table Size for Preferred (No NID) Entries

5. System Determination and the PRL

5.1 System Determination

System selection is that process which the device uses to attempt to:

- Identify the best system for a given mobile device to operate based on the device configuration and the conditions at the location
- Acquire the best system as quickly as possible

For a given set of input stimuli the output of any CDMA system determination (SD) is to:

- Try to acquire a specific system
- Stay and operate on the currently acquired system
- Enter power save mode

System determination uses the information in various external factors to achieve this output. These factors are:

- Static, programmable information such as a list of preferred and forbidden systems, a list of radio access technologies
- Dynamic information such as the system ID broadcast by available CDMA systems, the RF conditions and protocols in use on available CDMA systems
- User activity

Performing these tasks can be complicated by the need to support multiple radio access technologies, in a single device, to enable coexistence of technologies such as AMPS or GSM together with CDMA. Roaming agreements between operators can lead to complexity in the preference order of systems in the PRL. Often, operators have their own specific system selection requirements, which can evolve with the technology and their networks. Operator-specific requirements arise for a number of reasons (to overcome network limitations, to support new features, to enforce a desired behavior) but the result is that there are various forms of system determination in deployed handsets. Any description here is a general guideline.

For devices using the Preferred Roaming List, the PRL provides the data upon which system determination operates. System determination, as shown in Figure 5-1, can be understood to have two distinct stages:

- First, system scanning to find a system
- Second, applying system selection criteria to the system that has been found
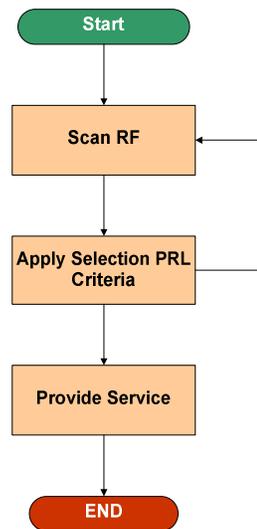
Figure 5-1 Overall System Determination Process

Although, in reality, the two functions are very closely coupled, for the purposes of explanation, each will be described separately.

5.1.1 Phone Settings Can Affect System Determination

There are mobile devise settings that, if present, can affect system determination operation. These settings may not be user-accessible in commercial devices. The default values of these settings would be determined by the operator's product release information (PRI) provided to the mobile device manufacturer.

5.1.1.1 Mode Preference

Mode preference can be used to identify the type of network that the device is configured to access. This preference setting can restrict the mobile device to CDMA service only or allow the mobile device to select any network automatically (i.e. including analog) based on the rules defined in the PRL. Typical values for this parameter would be:

- CDMA Only
- Automatic

If this preference setting is set to 'CDMA only,' it would over-ride the PRL and cause all analog systems to be ignored.

5.1.1.2 Band Preference

The band preference configures the device as to which frequencies (in terms of band class) that it may search for service. This preference setting specifies the band preference for the phone and may have typical settings such as:

- Band-class 0 (cellular)

- Band-class 1 (PCS)
- Any band-class

If this preference is set to, for example, 'PCS only,' then this would over-ride the PRL and render all other systems in other bands inaccessible. This may be user selectable or be determined by the capabilities of the device (e.g. some devices may only support a single band-class).

5.1.1.3 Roaming Preference

A setting, that is often user accessible, specifies the roaming preference for the mobile device. Possible settings include:

- Home only
- Roam anywhere

This setting can restrict the mobile device to systems indicated as 'home only' which would over-ride selection of any 'roaming' system in the PRL. The 'roam anywhere' equivalent setting would not introduce any further restriction on the PRL.

5.1.1.4 Home SID/NID List

Some mobile devices have the capability to store a list of system descriptions (SID/NID) that are regarded as 'home systems.' A system defined in this list is defined to be non-roaming and, depending on the implementation, may override the system as described in the PRL's system table. There can be up to 20 pairs of CDMA SID/NIDs in this list (depending on implementation and possibly subject to handset requirements).

5.1.1.5 SID/NID Lockout List

The CDMA SID/NID lockout list describes a list of systems on which the mobile device is prohibited from providing service. Depending upon the implementation, this list may be able to hold up to 10 SID/NID pairs. The list is stored in the mobile device's non-volatile memory. A system listed in the CDMA SID/NID lockout list may over-ride its description in the PRL and be regarded as a prohibited (negative) system during the system selection process.

5.2 System Scanning

The mobile device and the network have a symbiotic and yet fickle relationship. A mobile device is always in search of a network to which it can attach. All the CDMA and analog networks can potentially provide that attachment. One of the device's primary functions is not just to find an attachment, but to find the attachment that suits it best at that moment. Of course the network can also be a picky partner and reject the attachment advances of the mobile device. The PRL is the mobile device's little black book of networks it can call upon for attachment and, furthermore, which attachments are considered 'best' and better than others. Each network is on a particular channel within a

particular band (band-class and channel) and then each server has a particular identity (SID/NID). See Figure 5-2.
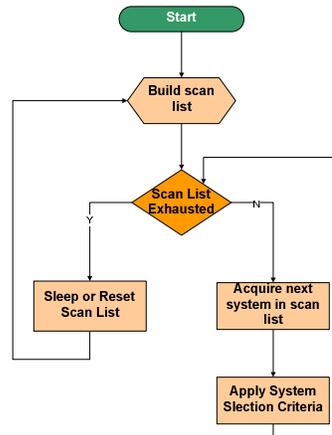
Figure 5-2 System Scanning

In the world of commercial mobile networks there are many systems available to choose from that operate on different frequencies and channels (as was discussed in section 1.1). A commercial mobile device, by design, is capable of operating on potentially many different channels and frequencies; it must, therefore, search some or all of the channels that may be able to provide service.

Candidate channels that may provide service are indicated to the mobile, primarily through the descriptions contained in the acquisition table of the PRL. The mobile device has to translate this table into a list of channels to search, known as a scan list.

System determination has the responsibility to build the channels to scan and then (in line with the responsibilities outlined in section 5.1) select the best serving system on those channels.

5.2.1 Use of the Acquisition Table

The acquisition table is generally understood to be a priority ordered list of frequencies to search. As earlier discussions showed, the acquisition table can contain descriptions that encompass a number of channels. To this end, the acquisition table is used as an important source to construct a complete list of frequencies and channels to search. These lists are commonly referred to as scan lists and are described further below.

5.2.1.1 Channel Expansion from Mnemonics in Acquisition Records

Where an acquisition table entry implies multiple frequencies by use of mnemonic, these mnemonics are expanded into the discrete channels and those discrete channels form part of the scan lists. By way of illustration, a couple of examples of this are listed below:

- A Cellular CDMA standard channels acquisition record to search on both the primary and secondary channels of both the A and B band would be expanded for each of the primary and secondary channels in each cellular band and would yield four scan candidates (It is important to understand the meaning of standard channels for band-class 0 as explained in section 4.4.3)
- A PCS using blocks acquisition record to search all blocks would expand to use the preferred channels in each of the PCS blocks (see section 4.4.7) and would yield 42 scan candidates

Table 5-1 shows the channel expansions for the band-class 0 (US) and band-class 1.

Table 5-1 Channel Expansions

Band-class (Band)	Mnemonic		Expansion	# of Channels
0 (Cellular/800)	A	Primary	283	1
		Secondary	691	1
		Both	283, 691	2
	B	Primary	384	1
		Secondary	777	1
		Both	384, 777	2
	Both	Primary	283, 384	2
		Secondary	691, 777	2
		Both	283, 691, 384, 777	4
1 (PCS/1900)	A		25, 50, 75, 100, 125, 150, 175, 200, 225, 250, 275	11
	B		425, 450, 475, 500, 525, 550, 575, 600, 625, 650, 675	11
	C		925, 950, 975, 1000, 1025, 1050, 1075, 1100, 1125, 1150, 1175	11
	D		325, 350, 375	3
	E		725, 750, 775	3
	F		825, 850, 875	3
	ANY		25, 50, 75, 100, 125, 150, 175, 200, 225, 250, 275, 325, 350, 375, 425, 450, 475, 500, 525, 550, 575, 600, 625, 650, 675, 725, 750, 775, 825, 850, 875, 925, 950, 975, 1000, 1025, 1050, 1075, 1100, 1125, 1150, 1175,	42

These are the channels that are scanned to look for a CDMA pilot but, this does not mean that they are the only channels on which the device will receive service. It should

be remembered that a CDMA system can advertise (and redirect to) other channels that are in use. Additional channels can be communicated in overhead messages, and, the mobile device hashes, using a standardized hashing function, to one of the CDMA channels. (See section 5.3.12.1)

5.2.1.2 Invalid Channels

While this may not be a rule, a cautionary note here is that for band-class 0 (800 MHz) scanning some implementations of system determination may enforce the US guard-bands as being invalid CDMA channels. (See Table C-1 for a description of channels and valid CDMA bands within band-classes 0 and 1.) This can be significant in building PRLs to roam in CDMA regions where channels usage may not necessarily conform to the North American standard primary and secondary definitions (e.g. Korea and India). The guard band channels for band-class 0 are described in Table 5-2.

Table 5-2 Band-Class 0 Guard Band Channels

Guard Band		Potentially Invalid Channels	
Band-class	Sub-Band	From	To
0	A	312	355
	B	334	355
	B	645	666
	A'	667	688
	A'	695	716
	B'	717	738
	B'	778	799
	A''	991	1012

Though, in many implementations this may not be a factor, which channels, if any, are considered invalid should be checked with the device manufacturer.

5.2.2 Recent Channel or Most Recently Used List

Mobile devices implementing system determination using the preferred roaming list (PRL) typically maintain a most recently used (MRU) table, (sometimes known as the recent channel list or RCL) which keeps the most recent channels (frequencies) on which service was provided. The number of entries in an MRU list is implementation dependent but a typical number may be 12.

5.2.3 Types of Scan Lists

A CDMA mobile device builds a scan list dynamically. When building scan lists, their names and their use is not standardized and is left to the implementation. Therefore, how the scan list is constructed would be a function of the particular vendor's implementation of system determination but in general would be formed from:

- Channels from the most recently used channels
- Channels from the acquisition table in the PRL

There are different types of scan lists that the mobile device can build that would be used by different scans.

5.2.3.1 Normal Scan List

The mobile device builds a normal scan list using two sources; the acquisition table (as described in sections 2.2.4 and 4.4) and the most recently used set of channels (MRU list, see section 5.2.2). The exact way that the normal scan list is constructed is implementation dependent.

The acquisition table is generally used as a priority ordered list of frequencies to search, with the first acquisition table entry forming the first entries in the normal scan list.

Where multiple discrete channels are listed these are normally inserted into the scan list in the order that they appear in the acquisition record; from channel 1 to channel n.

The way in which the MRU channel list is used in the formation of the normal scan list is implementation-dependent. The MRU list in some implementations may be placed at the head of the scan list while in some others it may be placed at periodic slots in the list, for example, every fifth entry.

Once the two sources are combined, again depending on the particular implementation, there may be some further optimizations that can include actions such as the deletion of:

- Duplicate entries
- Channels caused by suitable identification in the preferences (see section 5.1.1)
- Channels that can be specifically identified as negative systems

5.2.3.2 Better System Reselection or Alternate Scan List

The alternate scan list is a list of channels on which more preferred systems than the current serving system, within the current GEO, may be found. It is formed from channels in the same GEO. As before, system preferences can cause deletions; and, as always, negative systems would be deleted.

The scan containing channels of more systems in the same geographic area is referred to as the alternate scan list or the better system reselection scan list.

5.2.3.3 System Lost Scan List

The system lost scan list is an ordered list of channels formed from the last acquired system (that has just been lost), channels in the same GEO as the last system, the recent channel list (MRU) and the acquisition table.

The exact placement of the system lost in this scan list is a direct function of the system lost policies (sometimes called the system loss reacquisition schedule) that are built into system determination. These policies are often specified by a network operator as part

of their handset requirements and therefore may vary for devices from different operators.

One such policy is called the REACQ_0_1_2_3_4s schedule which places the lost system at head of the scan list then after every other 1, 2, 3 and 4 entries in the scan list. An example of this schedule is shown in Figure 5-3.
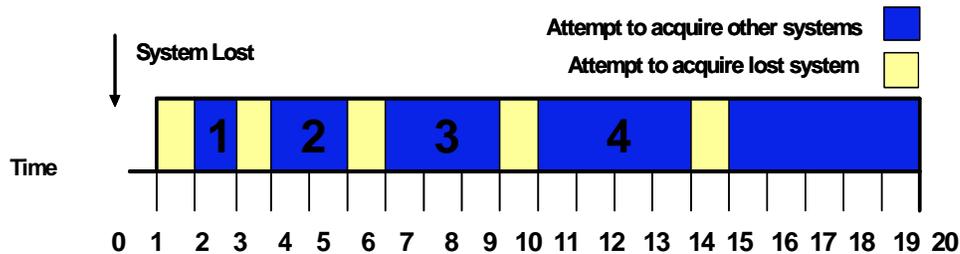
Figure 5-3 Example System Lost Reacquisition Schedule

There can be any combination of puncturing mechanisms, such as:

- PING_5 schedule in which case the lost system is placed at the head of the list and every 5th entry thereafter
- 2_7 schedule in which case the lost channel is probed twice and then again after five other channels have been tried

Section 5.1.1 discussed the settings of preference mode and system preference. If the preference mode is set to other than 'automatic' (for example 'digital only'), the scan list is built in the same order as before except that only channels that access 'digital systems' are added (from the recent channel list and the acquisition table). Similarly, with a preference set to 'home only,' service would not be provided on roam systems.

5.2.4 How Long Does it Take to Scan?

The question often asked in any discussion on system selection is 'how long it takes the phone to scan.' This is often difficult to quantify because it depends on many things that system selection is not responsible for, not least the speed of the searcher in the device itself and also on the type of scan being performed. In general, there are three types of scan; a *full scan*, a *mini scan* and a *micro scan.* The number of channels that can be searched in time interval depends on searcher capabilities of the device.

5.2.4.1 Full Scan

The performance of a full scan can acquire a CDMA signal as low as -15dB E_c/I_o. Depending on the device (implementation and processor speeds, etc) a full scan can takes as long as 1.2 seconds all the way down to as short as between 200-300ms .

5.2.4.2 Mini Scan

The mini scan is a less rigorous search, than a full scan, which is able to acquire a CDMA signal as low as -13dB E_c/I_o. Again, the speed of a mini scan is device and implementation dependent and can be anything between 100 and 600 milliseconds (approx).

5.2.4.3 Micro Scan

This type of scan is one that looks for any energy on the CDMA channel. If energy is detected then a mini-scan may be performed. The time for such a scan is device and implementation dependent and may take as long as 100 milliseconds.

5.3 System Selection

Once a system is detected by the scanning process, the only thing that has been determined is that a CDMA or analog system has been found, as yet, no selection criteria have been applied to fulfill the goal of system determination, i.e. find the best system to provide service.

This second stage of is often referred to as the system selection process It is during this stage that priorities and preferences are applied. It should be remembered that exactly when system determination is invoked, even how it is performed, is not standardized. Nonetheless, the general behavior is well understood and it is still possible to describe the typical events that may cause system determination to happen. Some of these are caused by the mobile and some of these are caused by the network.

In the earlier discussions the selection process was left as a generic statement of *apply selection criteria*, in this section the aspects of system selection process are considered. Figure 5-4 shows a generic example of the elements that all CDMA system selection processes must exhibit. The diagram also shows the typical stages at which the PRL and device settings are used in the system determination process.
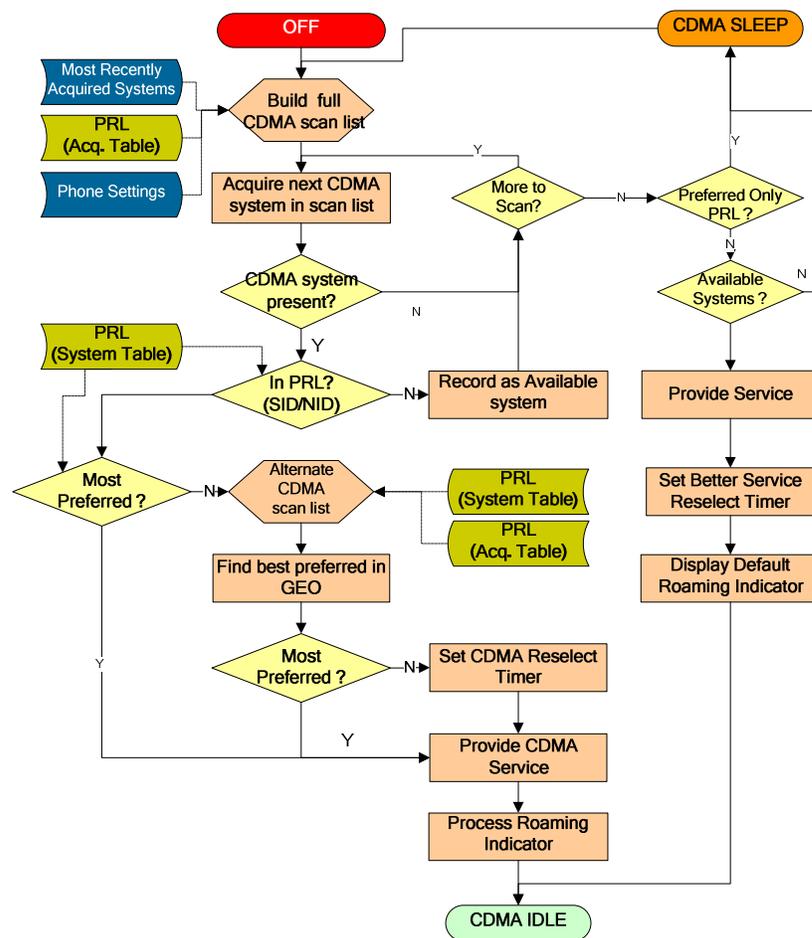
Figure 5-4 Example System Selection

5.3.1 When System Selection Occurs

There are various conditions that can cause system selection to occur. Some of the more common ones are:

- **MS Power-up**: When the device is switched on and it looks for service. This is sometimes referred to as initial acquisition.

- **Less Preferred Service**: Service from any system that is not the 'Most Preferred' generally causes the device to attempt to obtain service on the system that the PRL has declared as the most preferred. This is often referred to as [better service] system reselection.

- **After a call**: Upon release of the traffic channel it will begin to look for the system again. This is referred to as call termination reacquisition.

- **System Lost**: When the mobile detects that it has lost the signal of its serving system, it generally begins to search for service again.

5.3.2 Initial Acquisition

When the mobile is powered on, it performs initial acquisition. It attempts to acquire a system on the channels of the normal scan list, starting from the top (see section 5.2.3). If a system is acquired, which is not listed in the PRL, then, that system is recorded as an available system (on an available systems list) and scanning progresses to the next entry in the scan list.

If a system is acquired that is listed in the PRL's system table and, is the most desirable system in that specific geographic region, then service is provided on that system and all scanning stops until the system is lost.

An acquired system that is listed in the PRL (system table) that it is not the most desirable system in the geographic region will cause the device to search using the better service scan list.

5.3.3 Acquiring a System that Appears in Multiple GEOs

A SID that is repeated in more than one GEO is called multi-GEO SID. When a multi-GEO SID is acquired, a *composite* GEO is created that is a combination of all the GEOs that contain the multi-GEO SID, the 1st GEO in which the SID is encountered typically becomes the pivot point and is used to determine the relative priority of the systems in the other GEO. The composite GEO is used to build the more preferred list (for better service reselection).

Figure 5-5 shows the combining of two GEOs into a composite GEO when a multi-GEO SID is encountered. In the example, the composite GEO pivots on the position of the SID 4 in the first GEO encountered.

First GEO:			Later GEO:			Composite GEO:	
SID, NID	Pri Order		SID, NID	Pri Order		SID, NID	Pri Order
10500, 65535	1	**+**	10600, 65535	1	**=**	10500, 65535	1
4051, 65535	2		4, 65535	2		4051, 65535	2
4, 65535	3		4028, 65535	3		10600, 65535	2
						4, 65535	3
						4028, 65535	4

Figure 5-5 Combining GEOs of Multi-SIDs GEOs

5.3.4 Avoidance of Unusable Systems

A mobile device may encounter a system upon which it cannot provide service. A mobile device can declare a system to be unusable for a number of reasons, some of which are:

- P_REV mismatch
- System's SID/NID is rejected by PRL

- Sync channel is acquired but not the paging channel
- Bad overhead messages
- Registration is rejected
- Max access probes

Most system selection implementations will avoid systems considered to be unusable; although, for exactly how long they are unusable, it is implementation dependent. A typical time to avoid an unusable system would be 30 to 60 seconds – normally referred to as the avoidance timer. Avoiding a system does not imply that system is re-acquired after an avoidance timer expires it just means that it is eligible to be scanned again. During the avoidance time the channel is omitted from the normal scanning process. When the avoidance timer expires, the channel reenters the next scanning schedule.

5.3.4.1 Max-Access Probe Exit Scan

When an access attempt fails with maximum number of permitted access probes[7], the mobile device would normally use a maximum access probe exit scan list for reacquisition. This list is similar to a power-up scan but lacks the channel on which the access attempt failed.

5.3.5 Better Service Reselection

When the mobile device ends up providing service on a 'less-preferred' system[8] (which is any system that is not the most preferred), '*Better Service Reselection*' occurs (often just simply referred to as reselection). This is the implementation of a policy something like 'OK, stay here for now but keep trying to get to a more preferred system until operating on the most preferred system.' This continues until the most desirable system in the geographic region is acquired or the system is lost. The device implements this policy by use of the following mechanisms:

- A reselection timer
- A reselection period
- The better system scan list
- A better service scan

5.3.5.1 Reselection Timer & Reselection Period

The mobile device has a timer that is set running when service is offered on any less preferred system. The timer runs for a period of time, known as the reselection period,

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[7] Access Probe is a term used to collectively mean a system access message, sent on the access channel, and the specific power level with which it is sent. If the mobile device does not get a response, it sends subsequent access probes (same message at increased power levels); often described as 'raising its voice until it is heard.' There are a predefined maximum number of probes a device can send and a maximum power it can use.

[8] Table 2-1 describes preferred, less preferred and most preferred systems

after which, the mobile device again attempts to acquire the most preferred system in the geographic region. The reselection period is typically three minutes.

5.3.5.2 Better Service Scan List

The better service scan list is the scan list described in section 5.2.3.

5.3.5.3 Better Service Scan

Expiration of the reselection timer causes the device to search for more preferred systems in the same GEO. If the device is obtaining service from an 'available' system (see section 5.3.10), it searches all channels in the acquisition table. If reselection acquires the most preferred system, then, service is provided and the reselection timer is not set, i.e. no more reselection will occur.

If a more preferred, but not the most preferred, system is acquired then service is provided and the reselection timer is reset. Better service reselection will continue once the timer expires.

5.3.5.4 Side Effects of Reselection

Reselection means that the device is scanning the RF environment; such scanning consumes more power than simply being idle on a channel. Reselection, therefore, will impact battery life. When a mobile device is searching for service, it is not monitoring over-head channels, such as the quick paging or paging channels. Reselection, therefore, can cause missed pages (missed mobile terminated calls or SMS messages). Because of this, preferences in a GEO should be designed so as to strike a balance between, the number of preferred systems, and, the user experience (in terms of battery life and missed pages). Where there is little chance of a device obtaining the most preferred system, reselection is not useful. This happens in situations where further geographic separation is applied, e.g.:

- Placing two disparate regions (or countries) in the same GEO and then making one region the most preferred
- Placing one system in a GEO that is only available at the border of that region and making it the most preferred

Each of these circumstances can cause reselection to occur frequently when served by a less preferred system, even though there is little or no chance of obtaining better service.

5.3.5.5 Better Service Reselection While on an AMPS System

In some implementations, AMPS is considered to be a generally less desirable system and the reselection period, while being served on an AMPS system, is often lower. This can be down to 2 minutes or as low as one minute depending on factors such as device type (tri-band or dual band) and the implementation.

5.3.6 Call Termination Reacquisition

Upon entering idle state and following a call release, a CDMA device normally would perform a reselection which is often referred to as call termination reacquisition. This reselection is performed for a fixed amount of time (typically 4 seconds) after the end of a call when the mobile is not on the most preferred system.

5.3.7 System Lost

When a mobile device has declared that it has lost a system[9] it invokes its system lost reselection policy. The device implements this policy by use of the following mechanisms:

- A system loss reacquisition schedule
- The system loss scan list
- A system loss service scan

Section 5.2.3 describes how the system lost scan list consists of channels from the lost system, channels corresponding to preferred systems in the same geographic region as the lost system, channels from the MRU table, and channels from the acquisition table. The system loss reselection is similar to the better service reselection except for the earlier noted changes in how the scan list is constructed.

The 'schedule' of attempts to reselect the system, that has just been lost, is set and driven by the construction of the system lost scan list. As in better service reselection, if a system is acquired and it is less-preferred, then better service reselection will be performed. It is worth noting that often the system determination will search through the GEO first.

5.3.8 Matching System Table Described Systems

Once a system is acquired, it must be identified in the system table so as to locate the GEO within which the device is currently operating. Once located, the system's criteria must be applied. Identifying a system record in the system table is often referred to as matching. Exactly how an acquired system is matched against the system table, is determined by the matching policies, which can vary widely across implementations. Nonetheless, all will exhibit general behavior in terms of:

- Index keys into the system table
- Wildcards in systems description
- Band-class and channel matching

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[9] The signal level that a mobile device declares that loses a system is implementation-dependent. A CDMA system is normally unusable at E_c/I_o of -16dB.

5.3.8.1 Index Key into the System Table

A system is matched in the system table by a composite index of the system's broadcast identity together with the description of the frequency on which the system is located. The component key fields of the composite index are:

- SID
- NID
- Band-class (channel in some implementations)

This composite index is further complicated by the fact that these component elements can have non-unique values. In section 4.5.2, we saw that a PRL SID value of 0 and a PRL NID value of 65535 were designated wildcard values. A PRL wildcard value for SID will match any broadcast SID, and similarly, a wildcard NID value will match any broadcast NID. Previous discussion also showed how acquisition records can contain mnemonics, which expand to multiple channel values.

The presence of these non-unique values means that matching criteria are required in order to match an acquired system to a particular system entry in the PRL's system table.

In most implementations, the finest granularity of match is the one used (i.e. most unambiguous). When wildcards are used, the general order of resolution tends to be SID resolution followed by NID resolution.

Example: Consider a system table with two entries in the same GEO of:

- 0001: SID=00004; NID=05001; PREF=PREFERRED; ACQ_INDEX = 1
- 0002: SID=00004; NID=65535; PREF=NEGATIVE; ACQ_INDEX=1

In the case of acquiring the [00004, 05001] system, since it is a more specific match than [00004, *], it would therefore be identified as a preferred system. Any other NID in SID 00004 would be blocked as a negative system.

5.3.8.2 Band-class and Channel Matching

If the part of the index key that was ambiguous was the band-class and band/channel then discrimination is less clear. In most implementations the level of granularity would be limited to the band-class; however, there are some implementations that perform channel matching. Any use of differences within the band-class to differentiate systems should be verified with the mobile device vendor to ensure the desired behavior will result.

Example: Consider a system table with two entries in the same GEO of:

- 0001: SID=00004; NID=65535; PREF=PREFERRED; ACQ_INDEX = [PCS CHAN 25]
- 0002: SID=00004; NID=65535; PREF=NEGATIVE; ACQ_INDEX=[PCS BLOCK ANY]

The case of acquiring the [00004, *] on PCS 25 is an attempt at channel matching to permit access to a system which is otherwise blocked. (sentence not clear)

Any attempt to block service from one provider on a particular channel but allow it on other channels in the same band class would require that the system determination implementation support and perform matching down to the channel level.

5.3.9 Applying Priorities in Selecting a System

Having located a system within its GEO the system selection process must decide whether to stay on the acquired system or whether to continue to look for one that is more preferred. For the first acquired system, this is a decision of whether to stay or keep looking and then, for situations of reselection, the question becomes a comparison of whether the newly acquired system is better than the one you are on.

Exactly what these criteria are and how they are applied can vary widely across implementations; however, all will exhibit general behavior in terms of:

- Roaming preference & home SID/NID/list.
- SID/NID lockout list
- Priority
- Equal priority selection criteria

The first two can be considered to be filters that are applied to the system table to modify set from which selection can be made. The latter two can be considered as choice criteria from the resultant set of selectable systems.

5.3.9.1 Roaming Preferences

Earlier in this section we noted that the roaming preference can affect system selection. The roaming preference setting can be a system table filter that reduces the systems available for selection. If the roaming preference has a setting of 'Home Only' then any system in the system table with a roaming indicator other than '*Roaming Indicator Off*' becomes unavailable for selection.

If the device has a populated 'home SID/NID list,' then, any systems listed become identified as selectable non-roaming systems. Use of this list with a PRL has the following side effects:

- Systems in the list that are not in the PRL enter the selectable set regardless of the PREF_ONLY setting in the PRL properties
- Systems in the list that are listed in the PRL as roaming systems become selectable as non-roaming systems
- Systems in the list that are listed in the PRL as negative systems shed their barred status and become selectable

The 'home SID/NID list' is a legacy from the days prior to PRLs and is typically not used in conjunction with a PRL.

5.3.9.2 SID/NID Lockout List

Section 5.1.1 described how some devices may have a SID/NID lockout list. This list too is effectively a system table filter. Any system listed becomes unavailable for selection. Use of this list with a PRL has the following side effects:

- Systems in the list that are listed in the PRL are barred from selection regardless of their description in the PRL
- Systems in the list that are not in the PRL are barred from selection as an available system (see section 5.3.10) regardless of the PREF_ONLY setting in the PRL properties

The 'SID/NID lockout list' is a legacy from the days prior to PRLs and is typically not used in conjunction with a PRL.

5.3.9.3 Priority

Priority is normally the primary distinguishing factor for system selection within a GEO, and it is the major indicator of whether a system is most preferred or not. It should be remembered that the scope of priority is limited to within the GEO. The prime objective of system selection is to get to the most preferred system.

Each system record does not require a unique priority; the same priority can be applied to multiple systems. When systems have the same priority they are all share level in the pecking order of systems. This means that situations arise where priority does not distinguish between systems. In most cases this is perfectly fine and means that any one is as equally selectable as the other; however, there are situations where priority alone may not be enough, such as:

- Two systems have the same preference and different roaming indications
- Selection would require selection between two GEOs

5.3.9.3.1 Equal Priority, Different Roaming Indicator

Where two systems in the same GEO are compared and the only discernable difference is the roaming indicator, then, in general, a system will be more preferred if it is not roaming.

5.3.9.3.2 GEO Changes & System Selection

In the situation where the acquired system and the current serving system are listed in different GEOs then there are normally some rules to follow to ensure that the 'best system' is used. Some typical rules that would be applied would be:

- In the case where only one of the systems is listed in the PRL, then it is normally the PRL system that would be preferred.
- Where both systems are listed in different GEOs and the roaming indicators are different then typically 'roaming indicator off' would be preferred over 'roaming indicator on' or 'roaming indicator flashing'; and, 'roaming indicator on' would be preferred over 'roaming indicator flashing.'

- When one of the systems is of a higher preference order in its GEO then it would probably be preferred over the other.
- All other things being equal, the system operating on the channel that appears first in the acquisition table may be preferred.
- If one system is CDMA and the other is AMPS, typically the CDMA system would be preferred over AMPS.

5.3.10 Available System & 'Open' PRLs

If at any time, (during any system selection or reselection), a system is acquired that is not described by the PRL, then that system is recorded as an available system (on an available systems list).

Section 2.2.3 discussed the properties of a PRL. One of those properties was '*Preferred only*' property. This property takes a TRUE or FALSE value. A TRUE (1) value indicates a 'Closed PRL' which means that service may not be provided on any system that is not explicitly listed in the PRL. A FALSE value (0) indicates an '*open PRL*' which means that service can be provided on a system from the available systems lists if no preferred system can be found. Where more than one system is on the available systems list system selection may prioritize CDMA systems over analog systems.

5.3.11 No Selectable System

If the scan list is exhausted and service cannot be provided, system selection behavior is implementation dependent (and may be specified by the operator in their handset requirements). Some implementations may reset the scan list and begin scanning again; and perhaps even repeat this for some period of time. . If still no service is found after scanning for a period of time, the device may deploy some mechanism, to conserve power when no service is available. The exact mechanisms used, the timings involved and even how and when a mobile device will exit a power conservation state are dependent on the particular implementation.

Figure 5-6 shows a illustrative timeline of the selection behavior, when no service is found. Some points to bear in mind:

- The length of time of the initial search period is implementation dependent.
- The length of time between searches may lengthen by some expansion factor as subsequent searches do not find service. Any increasing window behavior and the expansion factor is implementation dependent.
- What may trigger a mobile device to begin searching again and the length of any search window is implementation dependent.
- Often any user intervention, such as a key press, can cause a forced exit of any power conservation mode which may cause a reset the power conservation cycle

Some or all of these behaviors may in fact be included in an operators' handsets specification.
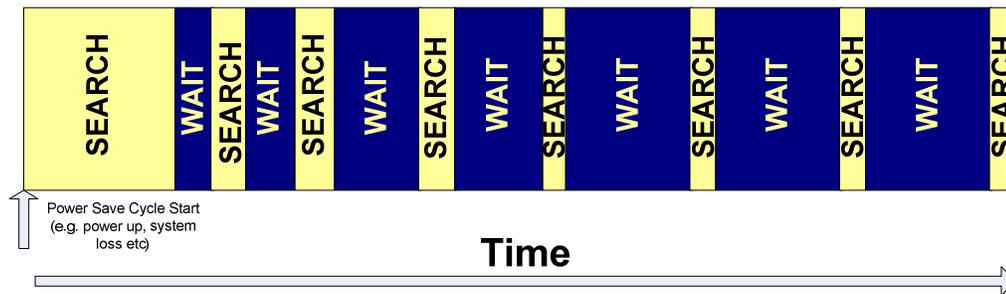
Figure 5-6 No Service – Example Power Save Cycle

5.3.12 Changes in SID, NID or Band-class

The management of the recent channel list is implementation dependent; but, typically, the band and channel from which the device acquired the CDMA Sync channel is placed in the recent channel list. Thereafter, typically, during idle operation if the channel changes, the new channel would be placed in the recent channel list, provided that the band and channel are in the acquisition table and the device is not operating on an available system.

Questions often arise on behavior when any changes that occur in the SID, the NID or the band-class change while in idle mode. There are two aspects to consider here:

- What gets recorded in the recent channel list or MRU
- How the PRL is involved

In some implementations a change alone in the band-class may cause no update to the recent channel list, while in others, the new band-class and channel are placed in MRU, regardless of PRL matching.

Typically, any change in any one of the SID, the NID or the band-class would re-invoke system selection using the PRL. If the newly encountered system is not the most preferred, better service reselection would be performed. There are various network conditions or messages where a SID, NID or band-class may occur which are discussed below; however, it should be noted that these messages more often occur without any change in any of these three items. Some of the situations where a SID, NID or band-class change can be detected by the mobile are:

- Channel list message
- Idle handoff
- Hand off direction
- Extended channel assignment message
- Redirection

5.3.12.1 CDMA Channel List Message

A market can be served by multiple frequencies. When a CDMA base station operates on more than one channel it indicates the channels in use to the mobile device in a CDMA channel list message (CCLM). Upon receipt of this message, using a predefined hashing algorithm, the device calculates on which of the listed channels it should operate.

If the device hashes to a channel in a different band-class[10], or if a change in the SID or NID is detected on the new channel the device will reenter system selection.

5.3.12.2 Idle Hand-off

A mobile always looks for the strongest pilot. When it moves to a new base station that has different band-class, SID or NID would cause system selection to be performed to acquire the most preferred system in the same geographic region. If it cannot acquire the most preferred system, it re-tries when the reselection timer expires.

5.3.12.3 Hand-off Direction

The CDMA general handoff direction message may contain band-class and CDMA channel information for the mobile device to use. A band-class change would cause system determination to be consulted. If there was no band-class change but the new system has a different SID or NID then system selection would be performed.

5.3.12.4 Redirection

A system may issue a global system redirection message to direct devices to a different frequency. The GSRM can contain band-class and CDMA channel information for the MS to use for reacquisition. A band-class change would cause system determination to be consulted. If there was no band-class change but the new system has a different SID or NID then system selection would be performed.

5.3.12.5 Extended Channel Assignment

In idle mode, the network can use the extended channel assignment message to redirect the mobile to a paging channel. This ECAM may optionally include a new Band-class and CDMA Channel. A band-class change would cause system selection to be performed. If there was no band-class change but the new system has a different SID or NID then system selection would be performed.

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[10] Inter-band class hashing is only available in CDMA 2000 1xRTT Revision D.

6. Processes for Managing & Developing PRLs

The PRL is a database that is used by system determination to determine where to search for systems and which systems offer the 'best' service.

Any search result is directly related to the sources that are searched. The PRL can be considered to be the searchable data for the system selection process. The system selection search engine can only perform a job as good as the search data provided by the PRL database.

One of the most important aspects of a PRL is that it is the output of a process (see Figure 6-1). The contents of the PRL can only ever be as good as the source data that is used to build it and, consequently, the system selection capability of the handset can only be as good the data in the PRL provided to it. The source data to build a PRL can come from many disparate sources. The key here is that the careful management and currency of input data is essential to producing a reliable, maintainable and traceable PRL design.
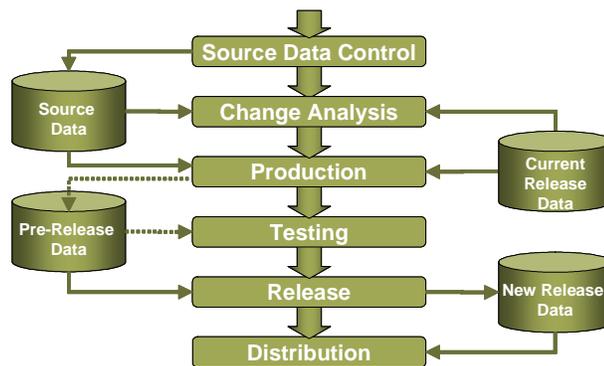
Figure 6-1 Example PRL Process

Achieving a good and manageable PRL requires a solid process that carefully manages the input data right through to the deposit of the PRL into the mobile device. Any weakness in this process can ultimately lead to the perception by the operator that the roaming process is over arduous. Perhaps more harmful, once unleashed into the customer domain, there is the risk that a poor PRL can cause the perception, by the end user, that the network and service have poor coverage, cannot or do not roam, are unavailable or are just unreliable.

6.1 Source Data Management

The source data to build a PRL can come from a number of sources, both internal and external (see Figure 6-2):
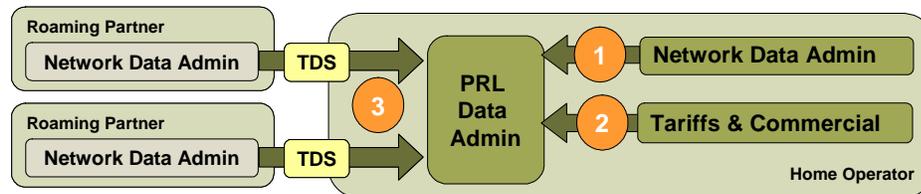
Figure 6-2 PRL Data Sources

- **Internally from the Network Data department**: SIDs and NIDs are a key part of the network configuration data that must be provided to various other interested departments, of which the department responsible for PRLs would be one. SID and NID information result from any number of other processes within the operator organization, which can include initial network planning, ongoing network build-out, network modernization and upgrade or on-going network optimization and rationalization. Any of these processes can result in SIDs and NIDs being assigned, reassigned or consolidated.

- **Internally from the department responsible for negotiated wholesale roaming tariffs**: In the case where more than one roaming partner is used in particular roaming markets, these tariffs would generally provide the basis for preferring one network over another. Preferences such as these are indicated to system selection by the PRL. Over time, tariffs may be renegotiated and preferences may change that would mean it is commercially important to ensure that the appropriate preference is applied to the appropriate roaming partner's network for system selection

- **Externally from roaming partners**: Data is exchanged between operators in a format commonly referred to as the Technical Data Sheet[11] (TDS). Of the information contained in the TDS, the sections of interest for building PRLs are those describing the Broadcast SID/NID information and the associated BIDs of the commercial markets of a roaming partner's network.

Without management of source data, building and tracking PRLs can become an arduous task. This can be achieved with something as plain as rigorous manual logs or in some electronic form, such as, a database, spreadsheet or even a commercially available configuration management system. There is 100% certainty of change as business changes and new roaming partners cause changes to the network information.

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[11] The general format for the Technical Data Sheet that is used between carriers is provided in the CDG Reference Document #81. In many cases carriers' particular format may vary but the general content will be similar.

A version control process will ensure that future change (in either the production PRLs or personnel that produce them) is, at least, manageable.

6.2 Change Identification Analysis

Knowing which information is the most current, and, where it is located is a critical first stage. However, once any one of these sources change, there immediately gives rise to some key questions:

- Does this change affect any of the currently released or in-development PRLs?
- If so, which ones?
- If so, is this a change I need, or can afford to absorb at this time?
- If so, how and when should this change be propagated to the PRL work stream?

These questions, in essence, describe the functions of change analysis for the PRL process. Depending on how automated or linked configuration record keeping is, this may be a work function that can be an automated process or manual analysis. Either way, the goal has to be the examination of new data to identify any impacted released data. See Figure 6-3.
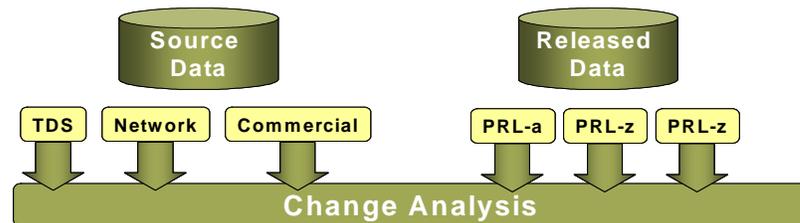
Figure 6-3 PRL Change Identification Analysis

Once the impacted PRLs are identified, the analysis should extend to figuring out the scope of the change and how it should be included. There can be many factors that affect the priority of an identified change, such as:

- Resources available to effect the change
- Revenue (or other) impacts of [not doing] the change
- Relative importance of the affected area to the customer base
- When in the PRL process new data arrives, i.e. cut-off or data-freeze dates

All of the factors discussed above are considered and then the result is described in the change details and/or work orders for PRL production.

6.3 PRL Production
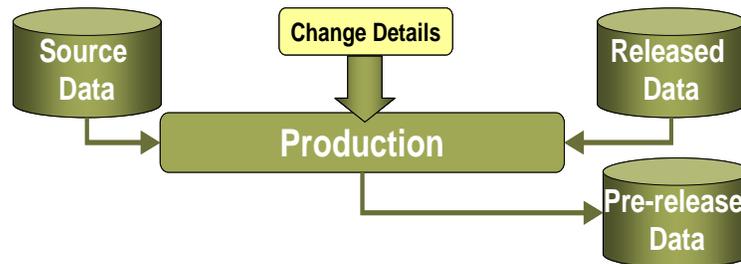
Figure 6-4 PRL Production

Clearly, one has the upper hand, when beginning the production of a PRL, if all source data is known and current, and, the changes that affect a PRL are identified. See Figure 6-4. However, other aspects can enter into how a PRL is designed, some typical constraints might be:

- Physical storage space available in a particular device. Storage space available for a PRL can range from as low a 1 KB up to and beyond 6 KB. The limits often faced are 1K, 3K, 4K, 6K and 8K.

- As a result of the size constraint or otherwise, PRLs may be separated by regional, national and international categorization.

- Staff availability to manage multiple options. While there may be many novel ways to design PRLs, in the real world, operators are faced with the very real constraints of the resources available to produce and maintain them.

- Other process elements constraints. Again in the real world there can be resource limitations of other aspects of the process that cause constraints to be placed on the design of a PRL. Some common issues would be, in the testing phase: resources available to test multiple PRLs; or, in the distribution phase: the number of PRLs that can be distributed by the OTA systems.

While PRL production may be constrained by these considerations, it should always have solid design and implementation practices, backed up with a reliable record keeping system. These core elements directly relate to how maintainable and traceable PRLs are. For example, they should address how the PRL_ID property is populated, and should provide sufficient information to yield the full configuration trail of the PRL.

A PRL, produced without a solid and traceable process, becomes exponentially more expensive to revise. If the design of the PRL is not documented, design decisions can be lost and errors, previously designed out, can creep back in, causing extra production iterations.

As with most things, the expense of an error in the PRL is directly related to the stage the error is detected. If the PRL is already widely distributed, there is an inherent nervousness at modifying it. This nervousness increases as staff turnover happens, and, in the absence of documented design, some of the learned black art is lost and those

lessons have to be relearned. This is an anxiety that is only mollified by the presence (and use) of solid process. At the very least, each PRL release should clearly identify any and all source data, any and all constraints that have been applied, and, any and all design decisions that have been made. This process can be as automated or as manual as the operator desires, either will suffice provided the aforementioned essential aspects are captured.

6.4 PRL Testing

As with most things in life, the earlier an error is discovered, the quicker and easier it is to address. PRLs are no exception to this principle. However, because a PRL is describing so many different radio environments and serving systems (both local and remote), the number of test traces tend to be high and the configuration of a test harness is not as straightforward as some other test scenarios. See Figure 6-5.
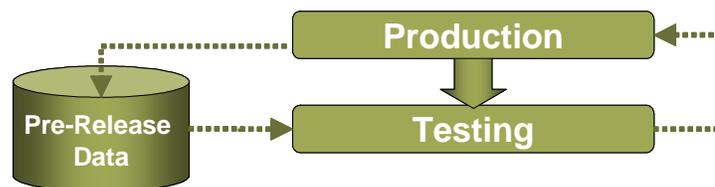
Figure 6-5 PRL Testing Stage

The rigor of the testing generally depends on the time and resources available. There are various forms of testing that can be applied, both with a PRL in a standalone environment without a handset (off-target testing) and with a PRL loaded into a handset which is then placed in a real RF environment (on-target testing).

On-target testing can vary in its forms. In the situation where an operator has access to a network test facility, radio environments can be simulated, a device loaded with the pre-release PRL. Where no such facility exists often in-market testing is performed. Since this is the most expensive form of testing and is fraught with coordination difficulties, it tends to be only a selective subset of the PRL that is tested. These in market tests can include:

- Home market field testing
- Home country field testing
- Foreign country field testing

PRL testing is an area that warrants more discussion. Section 7.6.7 is dedicated to PRL testing and discusses the various types of testing and introduces some sample tests that can be performed.

6.5 Release of New PRL

Figure 6-6 Release Stage of New PRL Related Data

A pre-release PRL from the production stage is generally given the seal of approval and elevated to a status of 'released' based on the successful testing performed on the pre-release PRL.

Often the group that builds a PRL to include roaming partners also has the responsibility to release their own network information to roaming partners. The release products of such a group include:

- New PRLs
- New technical data sheets (TDS)

An important part of any release function is the ability to identify what has been released. Release product identity can take many forms such as date or release numbers. The PRL has the PRL list ID which allows a label to be placed in the PRL and identify which release product it is. TDS information often uses a document number or the release date in the title and the TDS itself to identify the release number.

The release of a new TDS can be the result of many diverse activities across a network such as core network changes, SID consolidation, network build-out, technology upgrades, etc. All of these can have a direct impact on roaming partners and must be communicated in a timely manner. Not all TDS changes will cause them to have to change their PRL (i.e. no effect on inbound roaming access) but core network changes such as line ranges, point codes, switch IDs, temporary local directory number (TLDN) ranges can have a dramatic effect on outbound roaming and impact the success rate of an inbound roamers ability to receive calls.

6.6 Identifying the Upgrade Targets for a New PRL

The distribution of a new release of a PRL generally involves two phases; the first one is to non-customer targets, in preparation for the second phase which addresses the in-service targets. See Figure 6-7.
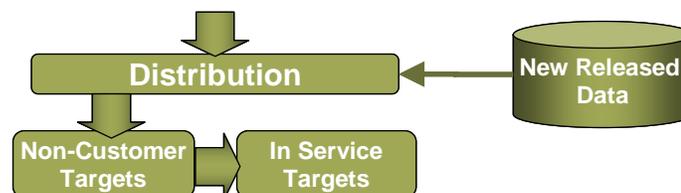
Figure 6-7 Distribution Stage of PRLs

6.6.1 Non-Customer Targets

Non-customer targets can be internal distribution hubs and, in these cases, the PRL will be released with a specific date and/or action time from which it will be placed in-service. Examples of these distribution hubs include:

- OTASP platforms
- Roaming partner test groups (for any previously distributed handsets and/or RUIMs).

In the situation where inventory must also be updated and the OTASP platforms cannot be used for this purpose, there may be other hubs that require the release, including:

- Retail outlet inventory,
- Warehoused inventory,
- Handset manufacturers
- Customer service centers

6.6.2 Identification of In-Service Customer Targets

As with any change it may not affect all of the in-service PRLs. Also, it may be desirable to prioritize the update targets by one of various possible criteria. Some possible criteria are described in the following sections.

6.6.2.1 By PRL ID

Every PRL has a field that describes its identity, as was discussed in section 4.3 above 'PRL Header Information.' Any in-service mobile that has a PRL version identity that has been updated can be identified as a target for update.

This would be achieved by a query report run against the operational support system that holds the data that relates PRL version ID to MIN and or ESN.

6.6.2.2 By Device Type

An operator may have PRL identities further classified and versioned by device type. In this situation it would be necessary to perform a query report on the operational support system that maintains the device type to MIN/ESN relationship information.

6.6.2.3 By Specific Customer(s)

Often the two previous target identification methods may yield a large list of in-service handsets that require an updated PRL. In some cases it may be beneficial to prioritize such a list to ensure the most affected network users are updated first. This would be of particular interest when upgrading the PRL, which directly affects roaming revenue; for example, frequent roamers to a foreign market where significant change has occurred or where a change in inter-operator, commercial wholesale relationship makes one partner more preferred than previously.

Some form of usage data analysis is required to determine which subscribers have roamed onto SIDs that are affected by changes in the new PRL. How this is done is dependent on the operational support systems implementation in the operator's network. An example would be query reports of the billing system to determine which customers may have significant call revenue on a BID that relates to the SID of the area that has changed.

6.7 Updated PRL Distribution

The physical means of distribution often needs to be considered. A new PRL loaded into the handset can get there by one of two means:

- **Over a wire**: At a customer service center over the air using an OTASP (Over the Air Service Provisioning, see IS-683)
- **Over the air**: OTASP, OTAPA or other non-standard SMS mechanisms (less reliable)

For distribution hubs, updates can take the form of electronic or physical file transfers. Some appropriate processes will deal with loading into the inventory at that location.

Over the air distribution makes PRL updates a much easier and less expensive option, once handsets are in the customers' hands. In some cases, a PRL update can only be performed by a user-initiated download. This requires some form of notification to in-service devices to request that customers perform the download (e.g. *228 user initiated OTASP or a notification to visit a service center for upgrade).

Where network-initiated updates are implemented, the user involvement is removed and the PRL is automatically sent to the handset by the operator, at an appropriate opportunity (using an OTAPA or some other non-user intervention scheme).

6.8 Process Timeline

The success and smoothness of a PRL process can often be helped by ensuring that the timeline is well communicated across all parties.

The process cycle needs to strike a compromise between a short enough cycle, to propagate important changes as soon as possible, and a long enough cycle, to ensure a timely and successful PRL release.

Often, carriers find that the production can be done fairly quickly but, most of the time is required in the coordination of test resources, especially, since that can involve field testing and verification.

Figure 6-8 shows an example process that results in a PRL release on a quarterly cycle with the stages through to internal test taking 4 weeks and a further 4-6 weeks for field testing. The release and distribution phases are really a function of the number of affected handsets and the capabilities in the network to distribute the PRLs.
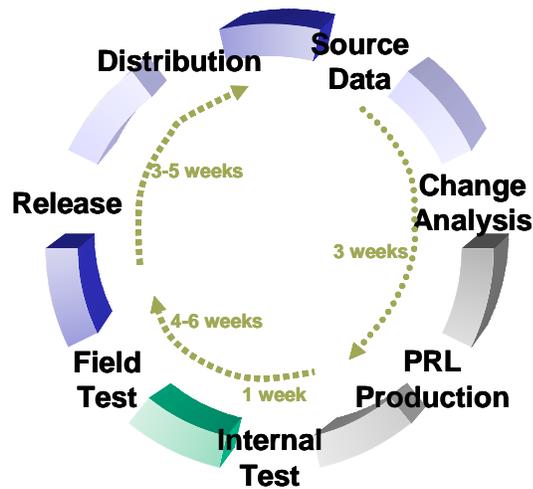
Figure 6-8 PRL Process Example Timeline

Another major factor of any process may be the number of discrete PRLs that are being managed. If there are a number of PRLs (due to device, calling plan, technology or otherwise specific constraints), then every PRL may not be updated at every cycle. The best PRL process is the one that works best to achieve the best available quality with the resources available. Resource constraints may mean that, although the PRL cycle runs quarterly, only half the PRLs are part of any one cycle; which may mean a bi-annual update cycle (subject to the compromises discussed earlier).

7. PRL Production

This section begins with a discussion on understanding the constraints within which a PRL can be produced. This is likely one of the most important aspects of PRL design and production.

PRLs require design, and this design often has to be performed within a set of constraints. This section deals with:

- PRL constraints
- Services in a PRL

7.1 PRL Constraints

Normally, anything that requires design means that some design decisions have to be made. Design decisions are often subject to some real world constraints. The design of a PRL is no different. There are two major constraint areas that any PRL designer needs to understand before beginning any work; these are:

- Policy constraints
- Device constraints

Policy constraints define the implementation guidelines and strategy for the PRL. Policy constraints define both the PRL structure and the coverage plan to be implemented. PRL policy governs not only how PRL properties but also structure that the designer will follow. PRL policy constraints are discussed in section 7.1.2.

Device constraints are a way expressing the mobile device landscape for which PRLs must be designed and delivered. Device constraints are discussed in section 7.1.1.

7.1.1 Device Constraints

CDMA devices can vary widely and often different devices can have different capabilities. While there are many aspects of a device that can characterize it, this section is concerned only with those that relate to the PRL or its use. Device constraints can be categorized as:

- Band class (frequency) constraints
- System technology constraints
- Software version capability constraints
- Physical memory constraints

7.1.1.1 Band-class Support

Some devices are single band and support only one band class; for example 0, 1, 5 etc. Others are dual band and can support both band class 0 and 1. Generally this should not become a constraint since system selection software would normally ignore any acquisition records for a band class that it does not support (subject to any limitations on invalid channels; see section 7.1.1.2). However this may be a chosen constraint to help alleviate other constraints, such as memory map limitations. If band class is introduced as a constraint, then Table 7-1 shows the records that can be used for each band class.

Table 7-1 Band-Classes and Applicable PRL Acquisition Records

Band Class	Band Description	Applicable Acquisition Record		PRL Revision
		Type	Description	
0	800 MHz Cellular	1	Cellular Analog	A, B, C
		2	Cellular CDMA (Standard Channels)	A, B, C
		3	Cellular CDMA (Custom Channels)	A, B, C
		4	Cellular – CDMA Preferred	A, B, C
		10	CDMA Generic	C
		11	HDR Generic	C
1	1900 MHz PCS	5	PCS CDMA using Blocks	A, B, C
		6	PCS CDMA using Channels	A, B, C
		10	CDMA Generic	C
		11	HDR Generic	C
4	Korean PCS	10	CDMA Generic	C
		11	HDR Generic	C
5	450 MHz	10	CDMA Generic	C
		11	HDR Generic	C
6	2 GHz (IMT-2000)	9	2Ghz Band(Channel)	B
		10	CDMA Generic	C
		11	HDR Generic	C

7.1.1.2 Invalid Channel Devices

Some mobile devices may consider the US guard-bands as invalid CDMA channels. (See section 5.2.1 and Table 5-2.) Some carriers outside the US may offer service in these channels and list them in their technical data sheets. It is important to understand any devices' behavior when a channel that is considered invalid is present in the PRL. In some cases, the behavior may require that no invalid channels be permitted in the PRL of a particular device.

7.1.1.3 Technology Support

Obviously any device, from this paper's perspective, will support CDMA. However, not all devices will have support for AMPS analog cellular service. CDMA devices may not support all CDMA services. Some older devices may not support 1x/IS-95 and only be capable of IS-95, although these are becoming less common. Other CDMA devices that do support 1x/IS-95 may not support packet data services. Devices such as PC data

cards may not have voice service support. 1xEV-DO PC data cards may be data only while 1xEV-DO handset devices will support voice and data.

The constraining factors here would be the supported PRL version and the presence of acquisition and system record entries that are unusable by the device. This constraint normally only becomes a factor when it is used to alleviate memory map constraints.

7.1.1.4 Available PRL Memory

A PRL is loaded into non-volatile (NV) memory. The memory can be located in the device's NV-RAM or in an RUIM smart card. Both have a memory map definition and part of that definition is the amount of space allocated to store the PRL.

In the case of NV-RAM the memory map may have been part of the operator's handset requirements specifications or it may simply be the manufacturers default. NV-RAM memory maps, once defined, are generally not changeable in the device. RUIM memory maps are generally specified by the operator to the smart-card vendor and, subject to card and network support, the memory map can be modified once in service (see PRL & the RUIM).

Typical allocations in the memory map for PRL range from 1kB, 4kB, 6kB and 8kB.

Available PRL memory is a hard constraint and the one that operators most often have to plan around. PRLs have to be designed to fit into the space available. Adding roaming partners that have a significant number of SIDs can quickly cause a PRL to reach its allocation limit.

7.1.1.5 Recording PRL Device Constraints

The device constraints should be known to the PRL designer and form part of the information set used to build a PRL. It may be convenient for the PRL designer to use a simple tracking sheet for devices, such as that shown in Table 7-2.

Table 7-2 Sample Tracking Sheet for PRL Developers

Device Model			Band-class		Technology				Invalid Channels	Memory Map -PRL.
					1x		AMPS	DO		
Manufacturer	Model #	SW Ver	0	1	Voice	Data				

7.1.2 Policy Constraints

Policy constraints are the guidelines an operator chooses to enforce across all PRL development. These policies can be as basic as the PRL properties to the implementation of the coverage plan and application of preferences accordingly to the policy on addressing other [device] constraints.

7.1.2.1 PRL Properties Policy

The PRL properties that must be defined are the PRL preference type and the PRL identity. The PRL preference type determines whether or not the handset is permitted to use systems other than those described by the PRL.

The PRL is, in all cases, network configuration data that happens to be distributed in the handset. As such it must be identifiable for the purposes of version control and troubleshooting. It is normal for a naming policy to be in place to structure the PRL ID for this purpose. Generally, a policy on numbering is implemented. Whether a PRL is *open* or *closed* varies from operator to operator.

7.1.2.2 Support System Constraints

PRL distribution is an important factor in any network. Where automatic distribution over the air is deployed, this functionality is delivered by a number of operational support systems in the network infrastructure. Depending on the OTA system implementations or some other related system issues there can be constraints imposed that can include:

- Size limitations on the PRLs managed by the platforms
- Number of PRLs that can be managed by the platforms
- Number of devices that can be managed by the platforms
- PRL revision levels (IS-683-A, B or C etc) that can be supported

7.1.2.3 Mitigation Constraints

Mitigation constraints are those policies designed and established to directly mitigate or work around particular device or network constraints such as hard memory limitations. Examples of mitigation constraints are:

- **Single PRL support**: This is a constraint usually imposed to mitigate the limitations of available resources or support system capabilities. It means that an operator chooses to implement a single PRL for all devices and that that PRL must be compatible with all devices.

- **Maximum size limit on PRL**: This is a constraint imposed to mitigate the situation of limited memory map allocation for PRLs. Often an operator has multiple deployed devices which have varying memory capacity for PRL. The operator may choose to limit the maximum size of the PRL to a lowest common denominator size.

- **Global Segmentation of Roaming Markets**: This constraint is another way to mitigate the available PRL memory constraint but can only be supported if there is no single PRL constraint in effect. This effectively creates a number of PRLs of home plus a sub-set of roaming partners. The sub-set is defined by region, such as SE Asia, Americas, etc.

- **Number of Roaming Partners**: Another way to mitigate the available PRL memory constraint is to impose a constraint that limits the number of roaming partners that can be included in a PRL

- **Support System Constraints**: Imposing limitations on the size and number of PRLs or on how many device variants can be supported may be a way of mitigating the constraints of the support systems in place that are used to manage and distribute PRLs.

7.1.2.4 Use of Wildcards

A SID value of zero is a wildcard that describes any and all SIDs (subject to the conditions described in section 5.3.8). A NID value of 65535 is a wildcard which describes all NIDs for the given SID. The PRL policy should define whether:

- SID wildcards are permitted in a PRL and under what circumstances.
- NIDs are to be used in the PRL for system selection. The use of a NID costs an extra 16 bits in the system record and may impact any memory constraint. Also, the level of network detail of a partner network is further increased and, consequently, so is the level of tracking required to maintain its accuracy

7.1.2.5 GEO Definition Policy

The coverage plan is often a statement of the coverage in any given area and roaming partner preferences. It does not describe how GEOs are to be defined. There may be a policy to guide on how GEOs are to be defined or simply a policy requiring a description of each GEO and the rationale behind its definition. The recommendation is one GEO per country for roaming markets.

7.1.2.6 Prohibited/Negative Systems Placement Policy

The placement of negative systems in the system table can vary. In some cases, a policy can dictate that all negative systems are placed in their own GEO or a combined GEO. In other cases, policy may dictate that negative systems are located in the same GEO as the preferred systems of the same market. Maintainability is increased if negative systems appear at the bottom of their appropriate GEO and it ensures that the frequencies of preferred systems of the GEO are immediately scanned.

7.1.2.7 Policy of the Use of SIDs in Multiple GEOs

Often, toward the border of coverage, operators find that a SID that was least preferred in the home area becomes the most preferred as home coverage fades and roaming partner coverage takes over. This border coverage condition causes operators to consider use of the same SID in more than one GEO. When the same SID appears in multiple GEOs one of the following situations will apply:

- Each instance is unique because each refers to an acquisition record of different technologies (AMPS, CDMA, etc.)
- Each instance is unique because each refers to a different acquisition record each with a different band class (0: cellular, 1: PCS etc.)

- Two or more instances are indiscernible: they are referred to as *multi*-GEO SIDs. Instances of the same SID in different GEOs are indistinguishable when they either:
  - Refer to the same acquisition record
  - Refer to different acquisition records of the same band class

When instances of a SID/NID pair are indiscernible they subject to the formation of a composite GEO. A composite GEO is formed from the GEOs that contain the common instance, and affect subsequent system selection while being served by the multi-GEO SID.

The effects of having multi-GEO SIDs is shown in the example of Figure 7-1 where the PRL extract shows a carrier preferring its subscribers use its network (SIDs 104, 105). A neighbor operators network (SID 100) seeps into coverage at border areas. The home GEO includes SID 100. Outside of home coverage, the partner's SID 100 is the most preferred. 100 is a multi-GEO SID. The net result is that when SID 100 is encountered the device will always search for the home 104 and 105 systems.

This is not necessarily an undesirable behavior. It is good to establish a policy to guide its use.

Home GEO			Bordering Roaming GEO:			Composite GEO:	
SID, NID	Pri Order		SID, NID	Pri Order		SID, NID	Pri Order
104, 65535	1	+	100, 65535	1	=	104, 65535	1
105, 65535	2		101, 65535	2		105, 65535	2
100, 65535	3		102, 65535	3		100, 65535	2
						4, 65535	3
						4028, 65535	4

Home system   Roaming partner Multi GEO SID   Roaming Partner system
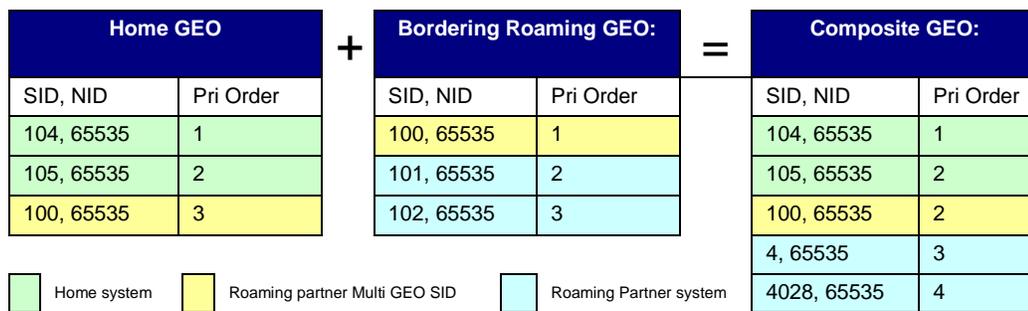
Figure 7-1 Resultant GEO of Border GEOs using Multi-GEO SIDs

7.2 Coverage Plan

The PRL is, above all else, the implementation of the coverage plan of the operator. The coverage plan describes:

- Roaming partners
- Areas where coverage is available
- Technologies available in those areas
- Where multiple partners exist in an area, the relative preferences (priority) of those operators networks

PRL production depends on having access to this information to design GEOs appropriately and place systems in the correct priority order.

7.2.1 Preferences in a PRL

The setting of preferences in the PRL is the enforcement of those policies in the handset and, effectively, the programming of system selection with your network's policies. The coverage plan may have suggested policies such as:

- Roaming partners all equally preferred
- Preferences based on carriers (not location):
    - Based on roaming agreements
    - Based on services offered
- Different carrier preferences in different geographical regions. Preferences can vary across GEOs

Preferences only apply within the scope of a GEO. Preference is established using the PRIORITY field of the system record. A device served by a less-preferred system will have battery life impacts and may miss pages while searching for other systems.

When dealing with roaming partners the PRL needs to implement the policy which describes the desired market coverage (e.g. total, major city areas etc.). In situations where more than one roaming partner exists in a particular market, the PRL developer must be guided by policy as to which partner is most preferred.

Another important consideration is how much of the partner network is to be used as part of the roaming footprint. Partner preference policy should be recorded so that there is traceability in the design of the PRL and so that subsequent updates maintain the same policy.

7.2.2 How a Partner is Given Priority in the PRL

Preferences only apply within the scope of a GEO. Preference is established using the PRIORITY field of the system record. A device served by a less preferred system will have battery life impacts and may miss pages while searching for other systems.

7.2.2.1 Priority Preference Based on Roaming Partner

This is the easiest to visualize and is always a good starting point to try and imagine any necessary variations. Where two partners exist which one is preferred? Policies, in general, would identify preferences based on roaming partners. Often this policy reflects a preference based on roaming agreements. Ordering is important; the most preferred operator's systems are listed first. Carrier A may be preferred over Carrier B; i.e., Carrier A markets would have **higher** priority over Carrier B markets and Carrier A markets within the same GEO should have **equal** priority. Carrier B markets within the same GEO should have **equal** priority. Reselection exits occur when served by a less preferred Carrier B system.

7.2.2.2 Priority Preference Based on Technology

Clearly there are some cases where this may not apply. For example, if the most preferred roaming partner has a lot of analog service battery life will be relatively short and subscribers might be unhappy.

It is a good idea to have a clear guideline about which technology is preferred. It should be clear to the PRL developer whether partner or technology selection is more important.

7.2.2.3 Varying Preferences Across GEOs

In applying these criteria and inconsistencies start to appear for different regions in the same country then that is an indication that one GEO per country may not be sufficient. For example, one carrier could be more preferred carrier in the Southwest while another could be the more preferred in the Northeast. In such cases, extra care is required to ensure that the right priorities are established in each GEO.

7.2.2.4 Roaming Partners all Equally Preferred

Potentially, all roaming partners could have equal preference (i.e., PRIORITY = SAME in system table). In this case the ordering is not important.

7.2.2.5 Preferential Treatment Based on Services Offered

The PRL policy describes a selection of a partner based on the services available to the roamer, for example, access to 1x/IS-95 or 1xEV-DO packet data services, access to location-based services, access to IMS or picture messaging services or access to push-to-talk services. If the coverage plan policies have been developed in this way the most preferred systems will be grouped not by operator but by 'service offering.' This is viable but extra care must be taken to ensure that reselection exits are not too frequent.

7.3 Information Required PRL Production

Any PRL production requires the collection of all the information that is to be used to build the PRL. This information includes:

- PRL Policy (the PRL device and policy constraints)
- Coverage plan
- Roaming partner delivered data
- Derived information

One way to view PRL production is the combination of information from a multitude of sources. That information is used to construct a PRL in a form understandable to humans and then into a form that allows for the specification of a PRL (in human readable form). That form must then be represented in a binary form for use by the mobile device.

As roaming partners, devices, coverage and network capabilities are added, required information changes. In section 6. we discussed the need for process in PRLs. This

section takes more of a pragmatic look at the information chain to get to a PRL. The process discussions highlighted the need for careful version control of:

- The production PRLs
- Which versions of production PRLs are deployed and where
- All the sub components (source data elements) that are used to arrive at a PRL

Clearly, without traceability of source data maintaining PRLs can become an arduous task resulting in a longer time to get production PRLs in the market and potentially adversely affect the roaming revenue stream.

7.3.1 Record Keeping

Discussion has shown the key elements that are factored into the production of every PRL, namely:

- PRL policies and device constraints
- Coverage plan

A growing wireless business can rely upon the certainty of change. The policies and device constraints may not change too frequently.

The coverage plan is the inclusion of other partner networks to extend the footprint. As business grows new roaming partners will extend coverage. Existing roaming partners will report changes to the network information. Some sort of version control process will ensure that future change (in either the production PRLs or personnel that produce them) is, at least, manageable.

How this management is achieved is the choice of the operator and can range from something as simple as rigorous manual logs (for record keeping and cataloging) to a commercially available configuration management system. This is a situation where the presence of a process is much more important than any automation and tools. A bad system automated just makes bad things happen faster.

7.3.2 Information from a Roaming Partner

Operators exchange information to enable roaming in a vehicle known as the technical data sheet (TDS). The TDS contains many informational elements relevant to many more aspects of network inter-operation than just the PRL. The TDS covers many aspects of network including HLRs, billing IDs, MSC-IDs, point codes, TLDNs, etc. But, for the PRL, the key elements are those that describe the network's service areas in terms of:

- MCC & MNC
- SIDs
- NIDs (if applicable)
- Band class

- Blocks or bands
- Channels

7.3.3 Derived Sources

Derived data sources are often necessary since the quality and format of TDS information can vary widely and may need to be augmented or restated in a different format to be more readable or usable.

7.4 PRL Design & Techniques

PRL production should require the combination of the major constraints covered up until now to yield an overall PRL policy comprising configuration management and control. The design of the PRL is the implementation of the PRL policies and coverage plan that has been developed by an operator. At the top level, the design should address:

- Device constraints
- Policy constraints
- Coverage plan

The formulation of a PRL policy is then used in the design of PRL properties and GEOs as shown in Figure 7-2.
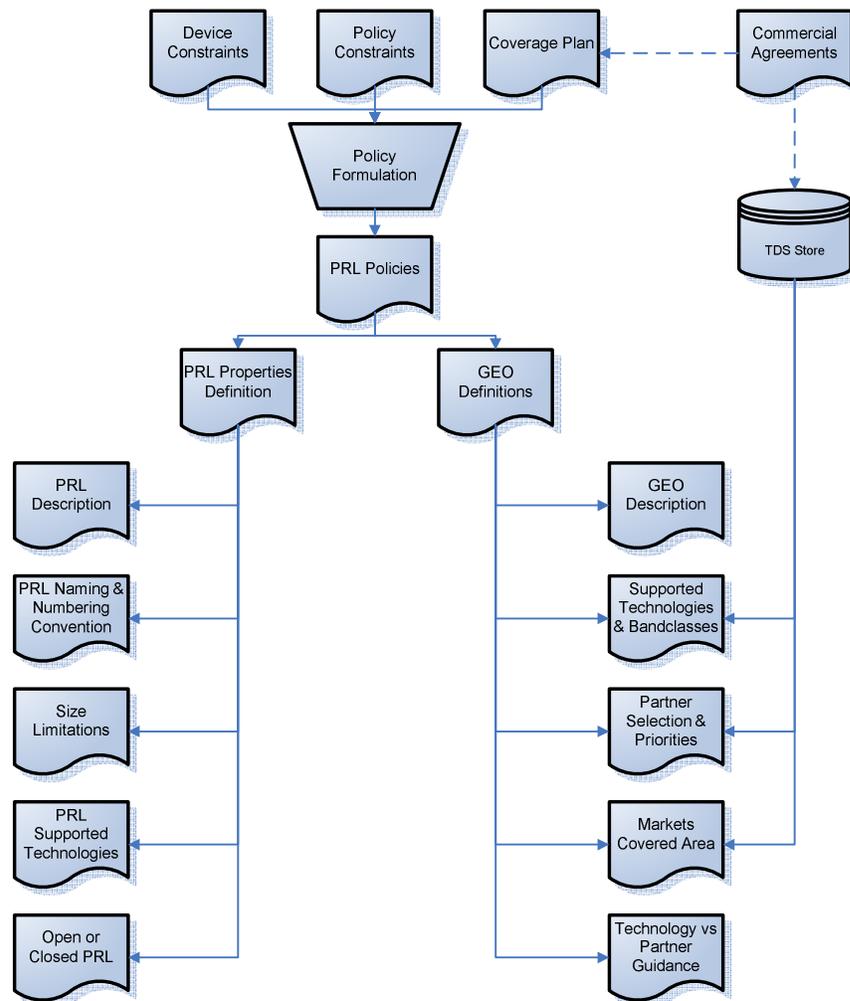
Figure 7-2 PRL Design Overview

7.4.1 PRL Properties Design

At the top level, the design should address:

- Whether the PRL is open or closed (i.e., PREF_ONLY is FLASE or TRUE, respectively)
- Whether extended roaming indicators are to be used
- The structure of the PRL ID

7.4.2 GEO Design

The prime function of the GEO is to group service areas into a larger logical area. Every PRL must have at least one GEO.

Care should be taken in designing geographical areas such that they represent logical separation of areas based upon coverage. Small geographic areas are good and easily maintained. Irrespective of the size of a GEO the following questions must be answered:

- What is the coverage area of this GEO?
- What partner networks, if any, are to be included in this GEO?
- What is the priority of the networks in the GEO?
- Which markets (SIDs) are to be included in the GEO?
- Are there any specific markets to be excluded?
- Does partner priority govern the technology choice; i.e., is the partner priority to be honored whether the service is provided on CDMA or AMPS?
- Which acquisition records are required?

7.4.3 Representing Other Carriers' Networks in My PRL

When dealing with a new roaming partner with a complicated network in terms of SIDs, channels or coverage, there is the great temptation to obtain a copy of their PRL and insert it into an existing PRL. This verbatim inclusion is dangerous for the following reasons:

- GEOs are different
- The coverage plan is different
- PRL policies are different
- Roaming partners are different

7.4.4 Coexisting CDMA One and CDMA2000 Systems

Where CDMA One and CDMA2000 systems co-exist, the PRL for CDMA2000 mobile stations should be implemented such that CDMA2000 and CDMA One systems are separate records in the system table, in the same geographic region. The CDMA2000 system should be preferred over a CDMA One system in the same geographic region. Depending on network configuration, the two systems may have different SID and NID or they may have the same SID but different NIDs.

With this implementation, even though the mobile station acquires a CDMA One system, it is directed to acquire the CDMA2000 system in the same geographic region.

7.4.5 Consolidated SIDs

In many markets the process of SID consolidation has become prevalent. SID consolidation is the term often used to describe the process by which an area of the network is re-assigned with a single SID when it was previously described at greater granularity by a number of SIDs

Operators should take care to consider the effects of SID consolidation on partner PRL design. A general guideline here may be to ensure that where a SID is consolidated into a larger grouping that the old SID is replaced by a NID within the new SID. This is particularly important in the case where more than one CDMA operator exists in the described coverage area. The danger of not following such a guideline may mean that an operator is forced to make a decision between leaving a coverage hole and selecting a particular roaming partner over a wider area than is needed or desired.

An example of such a situation would be where, for example, Operator A, previously relied upon a particular SID to provide coverage in one area from Operator B, but did not require Operator B coverage across the whole new consolidated region. Without the presence of NIDs, Operator A users would select operator B in a previously unrelated area that is now described by the consolidated SID. It may be possible to work around this by restating the coverage area concerned using the acquisition index to re-introduce the granularity but often the system determination matching criteria may only operate at the band-class level and may not operate to the channel level. In any case, such a work-around could burden the roaming partner with more complex and less intuitive PRL design that may be more difficult to maintain.

7.4.6 Border Coverage Issues

Every coverage area has its border. Partner SIDs that provide service in another GEO can seep into the coverage area of the home system at the borders. This border coverage condition can be addressed with the use of multi-GEO SID; subject to the policies in place. See section 7.1.2.7 .

7.5 PRL Tools
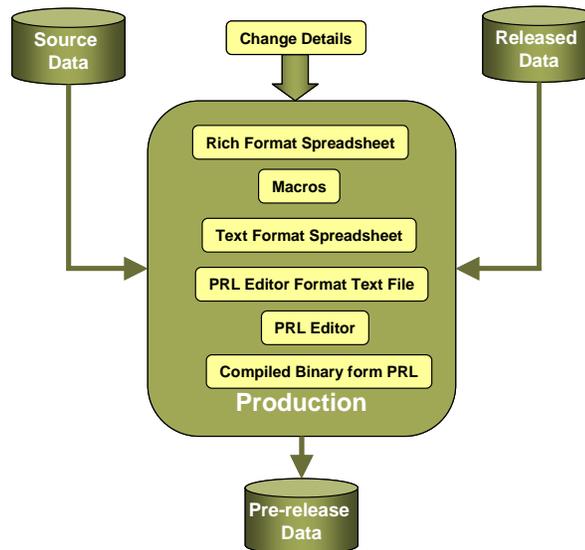
Figure 7-3 PRL Production Tools

7.5.1 PRL Editors

Most handset manufacturers provide some form of PRL editor tool. These tools can be problematic when large PRLs are involved. Some of the problems that can be encountered are:

- Single line by line entry
- No or limited undo functions
- Limited cut, copy and paste
- Nowhere to add additional information such as carrier name, market name or design decisions
- Can be restricted to binary format for input and output files

The discipline to save frequently and track major edits as they are complete is often the price to pay for this environment.

7.5.2 Spreadsheet Production & Macros

Understanding the limitations of the PRL editor is all well and good, but many people with PRL responsibilities find themselves in the situation of OTA systems not yet in place, stringent time pressures and only the PRL editors to work with. The good news is that the PRL editor limitations can be mitigated to some extent. In general, spread sheet applications provide much richer editing environments. In addition to the columns needed for the PRL, developers can have all sorts of supplementary information present,

such as the region, market, carrier name, TDS cross reference and whatever else their process requires.

Using a spread sheet is great but if starting with a binary PRL, how does the PRL get into the spreadsheet and, once the editing and construction are all done, how does it get into the binary form again? There are basically three options here:

- Using the PRL editor as a compiler
- Tools that transparently handle PRLs negating the need for a PRL editor
- Working with text-only PRLs

7.5.2.1 Using the PRL Editor as a Compiler

In many cases where the PRL editor does support the reading and writing of the PRL as a text file then the majority of the PRL design and construction can be performed in a richer editing environment – such as a spreadsheet. In this way, provided it is exported back to its basic text format, the PRL editor can be used as a compiler step to produce the binary PRL format.

The text form of the PRL is normally accessed by invoking the 'text view' option.

Working in a spreadsheet in this manner allows market, carrier and channel information all to be recorded on the main PRL editing tool, allowing for easier understanding. To work in a spreadsheet, the following items may be required:

- Macros compile to the editor's text form
- Text form read by PRL editor
- Binary form output by PRL editor

7.5.2.2 Tools Other Than a PRL Editor

Tools that read and write the PRL directly to and from its binary form can negate the need to use a PRL editor at all. One such tool is the QUALCOMM Engineering Services Group PRL presto tool which is able to read and write PRLs in IS683 A, B and C formats. See Figure 7-4. The configuration tools allow the appropriate PRL information to be identified in various column locations.
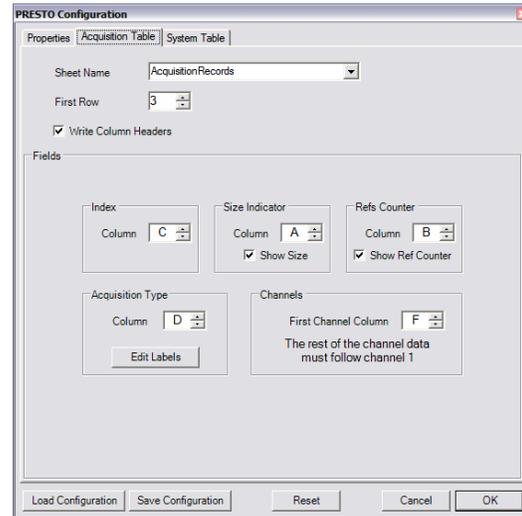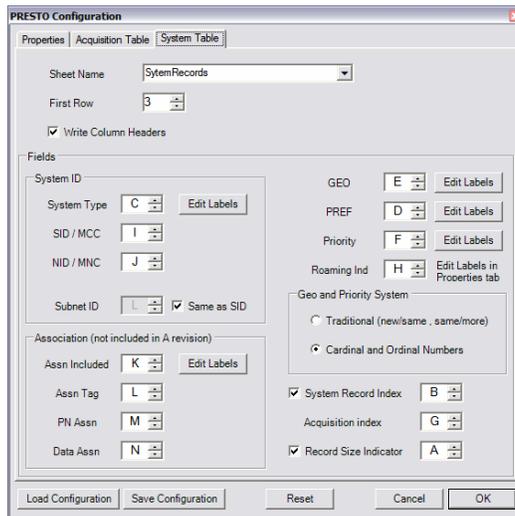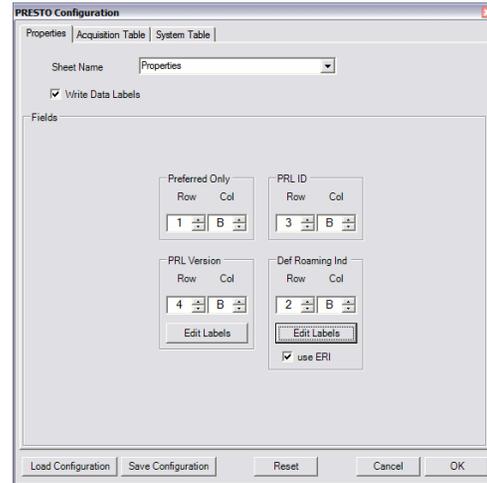
Figure 7-4 PRL Presto Tool Configuration

Of course, any suitable macro, that decodes and encodes as per IS-683, could be written and invoked from within Excel. An example of a PRL reader macro is given in the section B.2.3.

7.5.2.3 Working with Text-only PRLs

The PRL editor itself can be eradicated by some of the newer OTA platforms that have their own text script input format for PRLs. These text formats are converted to the binary form for distribution by the OTA system.

7.5.3 Auditor Tools

The use of auditing tools is an excellent way to verify that the PRL contains valid information. Auditing tools provide a form of static testing. Generally an auditor tool would perform the following tasks:

- Verify that every entry in the PRL is described in technical data sheets and that the description is correct
- Identify any systems in the PRL that are not described in the technical data
- Identify any channels that are not described for a particular system in the technical data
- Identify all unreferenced channels in the acquisition table

Predicate is a utility from QUALCOMM that performs this type of static auditing. See Figure 7-5. Generally auditing is difficult for today's CDMA PRL developers because of the wide range of formats in use for the exchange of technical data sheets.
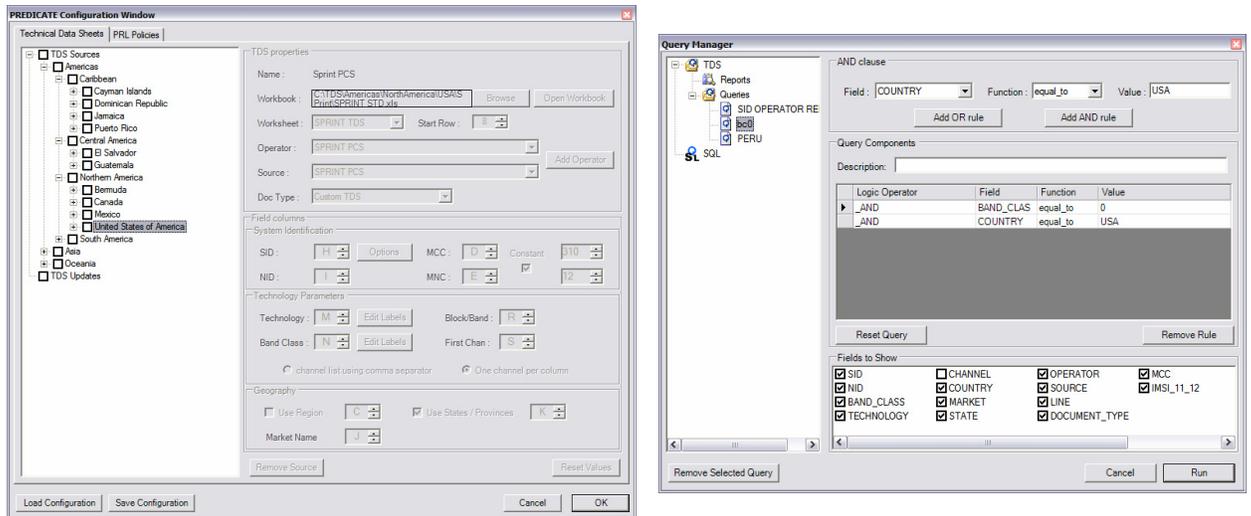
Figure 7-5 PRL Predicate Tool Configuration & Query

7.6 Troubleshooting Checks

7.6.1 Potential Reselection Exits

The combination of technology and preference order specified in a GEO can implicitly introduce reselection exits. Recall the discussion in section 5.3.5, that in some implementations, service on an AMPS system can cause more frequent attempts to seek better service.

A poorly designed GEO can have the side effect of continually exiting normal service to perform reselection, even in cases where there may be no better service available. This can happen in a GEO where attempts to further refine the GEO with geographical priorities are established in a single GEO.

- Example 1: A PRL that has a GEO of a roaming market (say the USA) and the most preferred system as the most frequented market (say Miami) will force the device into reselection anywhere outside of the most preferred coverage even though there is little or no likelihood that the most preferred system can be detected.

- Example 2: A PRL has a GEO with two partners providing coverage in the same market; erroneously marking all systems from the same carrier as 'MORE' instead of 'SAME' has the effect of causing reselection exits to look for the first listed system in the GEO.

A GEO should be regarded as the lowest level of geographic granularity. If more granularity is needed then the GEO should be split into more GEOs. Priorities should be limited to establishing technology (band-class) and roaming partner priorities.

7.6.2 Coverage Holes in GEOs

When all of the SIDs of a carrier are not represented in the PRL and if the PRL is a closed PRL (PREF_ONLY=FALSE) then, potentially, service will not be provided in those missing markets.

7.6.3 Inadvertent Presence of AMPS Systems

Use of the CDMA preferred acquisition record indicates that a device, **on this band,** should, first look for CDMA, and then, if no CDMA pilot is found, look for AMPS service, before **advancing to the next acquisition record**. If this is the desired behavior, then there is no problem, if AMPS systems should not be acquired in roaming markets (e.g. in cases of fraud risks), then the PRL should be written to explicitly select CDMA and AMPS, in the appropriate preference order.

7.6.4 Inclusion of SIDs not Listed in Technical Data Sheets

When SIDs are listed in the PRL that are not in the TDS this could have the effect that the device may select a system for which no roaming agreement is in place and thus the device will fail to successfully register on that system. Unless the system sends the mobile device a *Registration Reject Order,* which many systems do not, the device remains on a system that cannot provide service.

7.6.5 Inconsistent Preference within GEOs

It is always worthwhile to check the consistencies of preferences between technology (band-classes) and roaming partners within GEOs. In some cases this may be

intentional and by design; in which case, the established policy can be referenced. In other cases it may be an indication that further geographic definition is being attempted within the GEO (see earlier); otherwise it may just be a mistake that results in the incorrect roaming partner being selected in some GEOs which could be service and/or revenue affecting.

- Example: In a particular GEO, a PRL declares that in City Market 1, Carrier A is more preferred than Carrier B. In the same GEO, an attempt is made to declare in City Market 2, Carrier B is preferred over Carrier A. This is further geographic refinement that could mean that while in Market 2 on Carrier B, the device will perform reselection exits to acquire the Carrier A system in Market 1.

7.6.6 Duplicate System Records

Having system records listed multiple times in the same GEO with the same acquisition record may have no adverse affect on system selection but does use up valuable real estate in the PRL. Checks should be made to ensure that the appearance of a SID more than once can be fully explained.

7.6.7 Problems of Acquiring a SID on a Non-Partner Network

If the handset acquires a SID that exists in PRL, but for which no roaming agreement is in place, in all likelihood the registration attempt will not succeed. If that serving network does not support the sending of a 'RegistrationRejectOrder' the handset is unaware of the unsuccessful attempt and it remains camped on an unusable network.

8. PRL Testing

The testing of a PRL is an important part of its life since a PRL is literally deployed into every handset detection of errors post-distribution can be expensive. Testing of a PRL falls into three major categories:

- **Static Linkage testing**: An audit that the PRL, as built, reflects the technical data upon which it is predicate: off target (i.e. not on a handset)
- **Trace behavior testing**: A trace through the expected system selection behavior to verify blocked systems and priorities: off target (i.e. not on a handset)
- **Controlled RF (lab) testing**: Use of base station emulation equipment to broadcast actual RF signals and verify PRL behavior in a handset
- **Field testing**: Field testing in target markets to verify a handset exhibits system selection behavior

8.1 Static Linkage Testing

A static linkage test is in effect an audit of the PRL as built to ensure that it reflects the data upon which it is predicated. This testing is performed by comparing the PRL with the TDS information and can include some basic reports such as:

- Basic statistics, number of GEOs
- Market names per GEO to verify that all systems pertain to the GEO
- Number of systems and their relative priorities within a GEO to verify that any reselection that may happen is desirable.

> *An example of the problem that this may reveal is where the most preferred system is only available in one specific location and all other less preferred systems are at some other distinct location. This will force pointless periodic reselection when the user is at any other location than that of the most preferred system even though there is no likelihood of finding the most preferred system.*

- Cross referencing of each system table record (SID/NID) with its associated acquisition table entry (band-class and channel)

PREDICATE™, from QUALCOMM Engineering Services is a tool that performs static linkage testing and auditing on a PRL and the technical data sheet(s) upon which the PRL is based. The tool will match SID, technology and channel information and provide cross referencing to the technical data.

8.2 Trace Behavior Testing

PREDICT™, a tool from QUALCOMM Engineering Services, performs system selection on a PRL by using the information from the technical data sheet(s) upon which the PRL is based. Given a specific location, PREDICT™, will perform system selection in line with the behavior of the default QUALCOMM MSM System Determination shipped by QCT. It will show the channels scanned, the system selected SID, technology and channel information, and provide cross referencing to the technical data.

8.3 RF (Lab) Testing

RF testing is on-target testing (i.e., it is performed with the PRL loaded in one or more handsets). Handsets are tested in a simulated RF environment. A typical set up and flow of a lab test of a PRL is shown in Figure 8-1.

The RF environment is created by use of one or more base station emulators (BSE) configured to a particular technology, band-class, channel and SID/NID combination using the technical data from which the PRL was constructed.
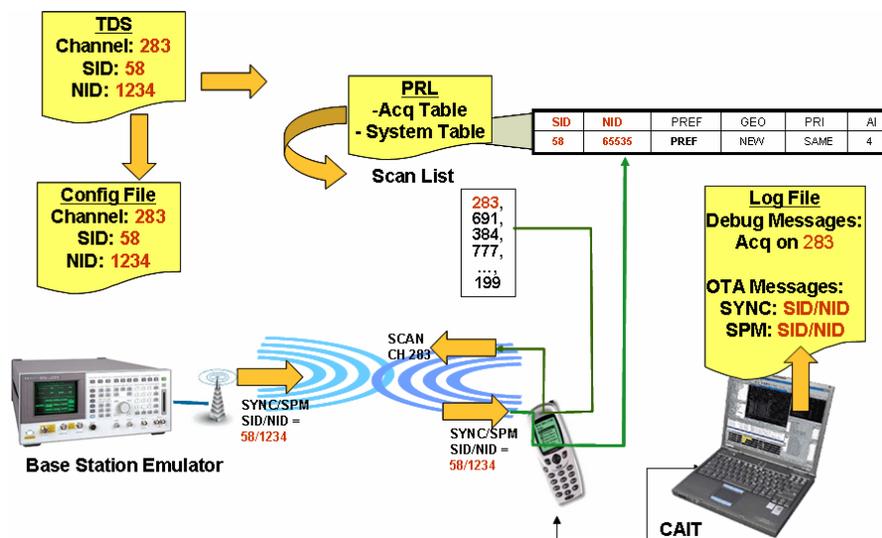
Figure 8-1 PRL Lab Test Environment

The BSE is configured according to the technology, band-class and channel to be simulated (from information in the TDS). The handset is loaded with the PRL under test; the handset is also connected to a logging tool (such as QUALCOMM CDMA Air Interface Tester (CAIT)). The logging tool will show the over-the-air messages indicating the selected network. If CAIT is used and the device is a QUALCOMM MSM-based device that has not had debugging information disabled by the manufacturer, debug messages can be examined to show the system acquisition progress.

8.3.1 BSE Requirements

The base station emulator should support IS-95/2000 and IS-856 (EV-DO) operation and should allow the configuration of overhead channel messages. Ideally it should support multiple sectors of 1x/IS-95 and 1X-EvDO (optional). It should have a radio network simulator capable of operating at 800 MHz and 1900 MHz and radiating sufficient amounts of power to provide a good coverage and be able to demodulate the reverse link (RL) from the mobile station in a good coverage environment. To simulate scenarios such as losing a system an emulator should have an ability to vary the transmitted signal power.

In order to test the PRL and simulate different markets, the BSE should have configurable network settings such as the technology, band-class, channel, the SID/NID and any required overhead messages.

There are a number of suppliers of commercial or base station simulators, examples are the Racal Instruments, Spirent, Agilent Technologies and Anritsu.

8.3.2 PRL Test Scenarios

There are multiple scenarios under which a PRL may be tested. The level of test to be performed would be chosen based on the changes in the PRL being tested. PRL test scenarios include:

- Initial acquisition
- Reselection
- System loss
- System avoidance
- Handset system preferences settings
- No selectable network
- Emergency service on an available system

8.3.2.1 Initial Acquisition

The purpose of an initial acquisition test would be to verify that power-up acquisition is based on the normal scan list. The normal scan list is based on:

- **Recent channels**: Sometimes known as the most recently used (MRU) list or as the recent channel list (RCL).
- **Acquisition Table**: An implicit statement acquisition table is that the order in which channels appear is the order into which they are entered in to the scan list.

Section 5.3.2 describes initial acquisition. The test equipment (BSE) should broadcast on multiple sectors, as appropriate, with combinations of SID and NID and channels of roaming partners in the same market and/or GEO.

This test should verify, for a given radio environment, that service should be provided on the most preferred system available. The results of this test should show that initial acquisition occurred as expected in the following scenarios

- Service on most preferred system in a GEO
- Service on a less preferred system in a GEO
- Service on an available system
- Dual band device
- Acquisition on every preferred system record in the system table
- No service on a negative system

8.3.2.2 Better Service Reselection

The objective of a reselection test is to verify reacquisition of a more preferred system. Section 5.3.5 describes better service reselection, which, when served by a less preferred system, tries to obtain better service based on a reselection scan list of channels of systems in the same GEO. A better service reselection test should configure the test environment to verify that

- Most preferred system acquired on rescan
- More preferred system acquired, when most preferred is not available
- Only available system found on rescan where the PRL permits service on available systems

8.3.2.3 System Loss

The objective of the system loss tests would be to verify reacquisition after network loss. Section 5.3.7 describes system loss reselection based on the system lost scan list. The scan is punctured on a time-based schedule with the system that was lost (it would be important to understand which schedule applied before any verification). A system loss test would, through appropriate configuration of the test environment (based on the TDS information), verify that:

- A lost system is reacquired
- The most preferred system - same GEO, acquired
- Most preferred system - another GEO, acquired
- Less preferred system - another GEO, acquired
- Available system acquired

8.3.2.4 System Avoidance

The objective of such a test would be to verify avoidance of unusable systems. Section 5.3.4 describes an unusable system in terms of system determination. A system avoidance test would, through appropriate configuration of the test environment (based on the TDS information), verify that, when any one of the avoidance conditions occur, there is an avoidance timer which is set (this timer varies between 30 to 60 seconds)

and that the system is avoided. Avoiding a system does not imply that system is re-acquired after avoidance timer expires it just means that it is eligible to be scanned again. The avoidance timer can be understood to be a flag set to skip the channel during the normal scanning process. After the avoidance timer expires, the channel can now be scanned during the next scanning schedule. The following conditions would need to be created to test for system avoidance:

- The supported protocol level does not provide a match to the protocol revision of the handset i.e. a P_REV mismatch. Could occur for Mobile P_Rev Max=5 and base station P_Rev Min=6 (Typical avoidance time = 60 seconds)

- The registration is rejected by the serving system. (Typical avoidance time = 30 seconds)

- The handset exceeds the maximum number of access attempts (probes) without success

- The Sync Channel is acquired but not Paging Channel

- The overhead messages do not provide the handset the information or configuration to operate correctly (i.e. bad overhead messages). For the purposes of testing, a bad overhead message condition can be mimicked by:
  - Sending a global service redirect to a 'non-broadcasting' frequency with the return if fail flag (RIF) set to 'don't come back' (0). (Typical avoidance time = 30 seconds).
  - The setting of the persistence values (PSIST (0-9)) in the Access Parameters Message to a value of 63. (Typical avoidance time = 60 seconds.)

8.3.2.5 Handset Preferences

As section 5.1.1detailed, there are handset preferences that can affect the behavior of the PRL and system selection. A lab test suite may include testing PRL behavior for these settings, as appropriate. Such test may include:

- **Mode preference**: Setting to digital only or automatic. This only affects PRLs with AMPS systems

- **Roam preference**: A setting of 'Home Only' to verify that service is not provided on SIDs that are not defined as HOME SID. (See section 5.3.8.) A setting of 'Automatic' to verify that service is provided on all preferred SIDs.

8.3.2.6 No Selectable Network

As section 5.3.11 describes, when there is no CDMA system present: MS will keep searching for 10 -15 minutes and then go into power-save mode to minimize battery life.

8.4 Field Testing

8.4.1 Drive Testing

In a drive test of the PRL, normally all devices would be idle since system selection is usually only invoked when the phone is idle. A drive route is chosen based on suspected problem areas, experience of issues or reported problems. If there is more than one PRL under test, then the drive route is completed for each PRL under test. Information is logged for the entire drive route using an air interface logging tool such as QUALCOMM CDMA Air Interface Tester (CAIT). A GPS receiver is used to log exact position and for correlation of the logged mobile messages to an exact physical location.

8.4.1.1 Equipment

One of each mobile device under test should be used. Each phone should be connected to a logging set up normally comprising:

- Laptop computers
- GPS receiver
- CAIT (CDMA Air Interface Tool) installed on the laptops
- Appropriate connection cable for mobile device

Generally DC to AC inverter(s) is useful to power laptops and handset chargers. Since this is a problem area where much scanning is to be performed, battery life will be less than normal.

8.4.1.2 Test Overview

There are multiple ways that such a test can be run. One way would be to have all devices with the same PRL and re-drive the same route for each different PRL.

8.4.1.3 Information to be Logged

The following information should be logged:

- Debug messages from the handset are used to monitor system determination actions. Some devices may not support debug messages
- Event messages capture items such as timer expirations, SID changes, NID changes, channel changes
- Signaling messages (sync, paging, access) to show over-the-air messaging
- Receive and transmit power so that the environment can be categorized (e.g., can explain which systems are lost)
- Active set information: Active, Candidate, and Neighbor set pilots along with their Ec/Io

9. The PRL for 1xEV-DO Systems

9.1 What is 1xEV-DO?

CDMA2000 1xEV-DO is an evolution of CDMA2000 and an approved 3G standard for fixed, portable and mobile applications. CDMA2000 1xEV-DO is 'data optimized,' providing a peak data rate of 2.4 Mbps for revision 0 and 3.1 Mbps for revision A and peak reverse rates of 153 kbps and 1.8 Mbps for release 0 and A respectively. IS-856 describes the operation of CDMA2000 1xEV-DO systems.

Understanding some of the basics of a 1xEV-DO network and the mode of operation of the 1xEV-DO device (often called the access terminal (AT)) is necessary to understand how to properly construct a PRL and how that PRL is used by the device. Elements that are necessary are:

- The sector-ID and its use in 1xEV-DO systems (see section 9.1.1)
- The subnet-ID and its use in the PRL and how it relates to sector-ID (see section 9.1.2)
- Hybrid mode 1xEV-DO operation (see section 10.1.1)

9.1.1 Sector-ID in 1xEV-DO

The sector-ID of a 1xEV-DO sector is the name that it broadcasts to identify itself. It is defined to be 128 bits and comprises two major elements:

- Sector identity part: typically the 24 least significant bits uniquely identify the sector
- Subnet identity part: typically the 104 most significant bits identify the subnet

A sector belongs to subnet. One analogy that may help here is that the subnet identity part is similar to the SID in 1x/IS-95 systems and the sector identity part is similar to a NID. However, unlike a NID, the sector identity parts should be chosen to ensure global uniqueness as opposed to the NID being unique only within the SID namespace.

9.1.2 Subnet-ID in 1xEV-DO

A subnet-ID in the PRL is a 128-bit address value formatted according to the IPV6 protocol (not an IPV6 address). See Figure 9-1. IPV6 format comprises eight 16-bit values separated by colons followed by a slash and a length value within the range 0 to

127. It is not necessary to write the leading zeros in an individual field, but there must be at least one numeral in every field.

e.g.
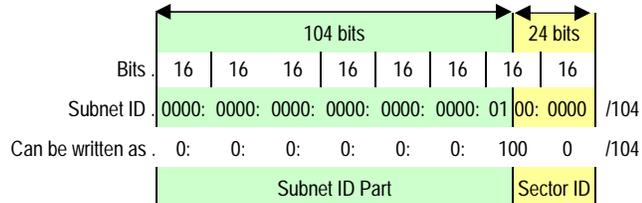
Figure 9-1 Subnet-ID with Subnet and Sector Parts

Just as a SID of zero value meant any SID in 1x, a subnet ID of /0 indicates a wildcard subnet ID and indicates any 1xEV-DO system is selectable (subject to network authorization and authentication).

The length value indicates how much of the subnet-ID is significant. Generally 1xEV-DO systems are only specified in the PRL at the subnet-ID part (equivalent to SID only usage in 1x) and thus the length generally will be 104 bits or less.

9.2 IS-683-C PRL Structure

The PRL in revision C of the standard adds some new structure and meaning. It still contains the three major sections as before (i.e. properties, acquisition table and system table) but additional elements now allow for:

- A new table called the common sub-net table
- A new extended system record that can describe analog, 1x/IS-95 and 1xEV-DO systems
- New grouping and linkage mechanisms that introduce a new level of sub-grouping of 1x/IS-95 and 1xEV-DO systems fully contained within the existing GEO grouping mechanism
- New generic CDMA and 1xEV-DO acquisition records

A representation of the structure is shown in Figure 9-2.
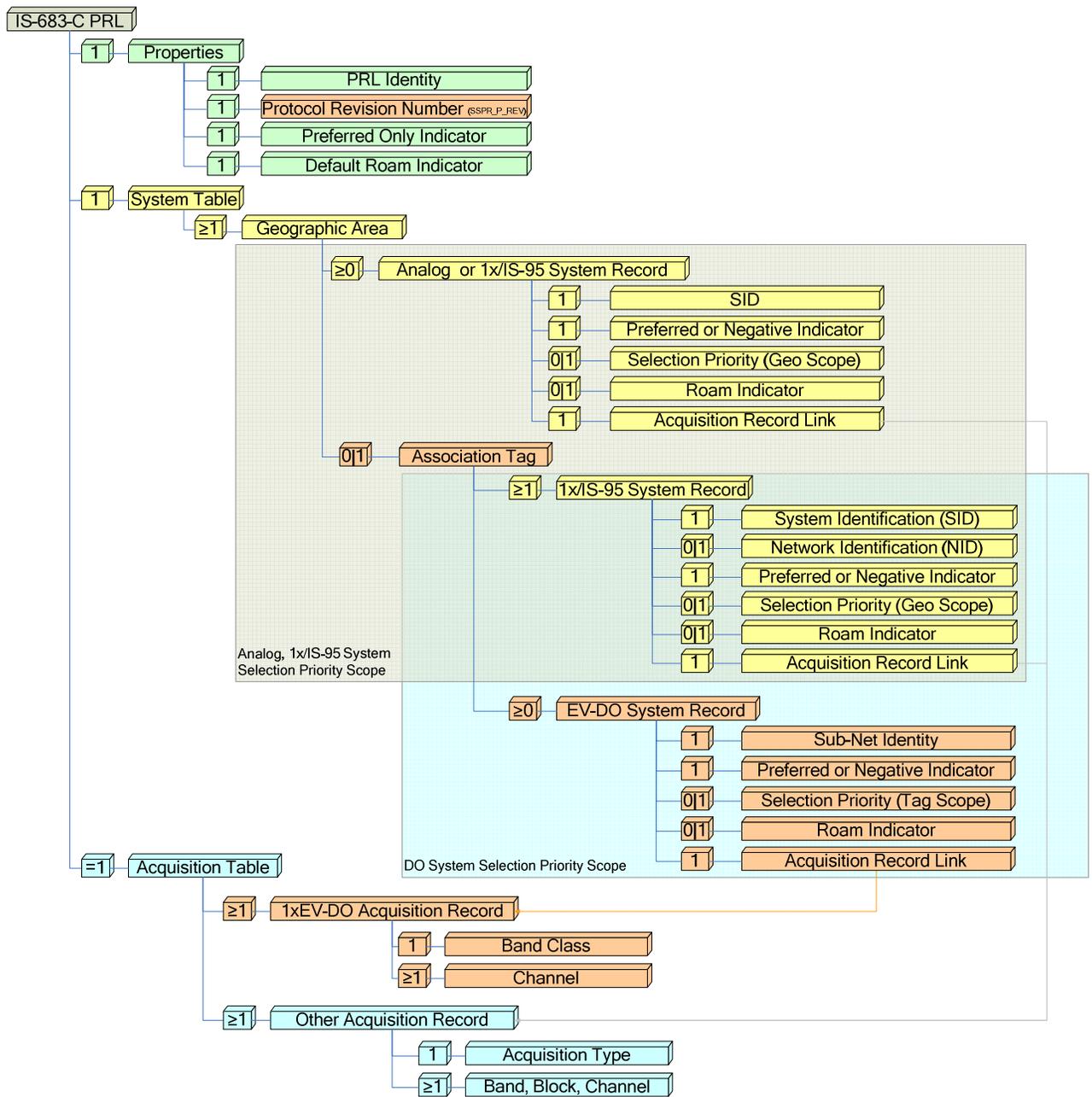
Figure 9-2 A Representation of the IS683C PRL for EVDO

9.2.1 Common Sub-net Table

Section 9.1.2 explains how a 1xEV-DO system is recognized by a [up to] 128-bit subnet identity as opposed to the 15-bit SID for analog and 1x/IS-95 systems. The common subnet identity table provides a mechanism for subnet-ID compression by repeating any common subnet-ID prefix only once in this table.

This is, in effect, a table of subnet-ID prefixes. A 1xEV-DO system record, with a common subnet-ID prefix, would then contain only the unique, least-significant bits of the subnet-ID and refer to an entry in the common subnet table for the most significant bits. The full subnet-ID would be obtained by concatenating the prefix from the common subnet table and the least significant bits from the 1xEV-DO system record.

Although this mechanism is described in the standards and likely present in most implementations of system determination; most of the PRL writing tools that produce IS683C PRLs do not currently perform this optimization.

9.2.2 Grouping of Systems within the Scope of a GEO

1xEV-DO systems are deployed either as adjunct or overlay networks to 1x/IS-95 networks. Detecting a 1x/IS-95 network would not necessarily reveal any information about the presence of a 1xEV-DO network. While both 1x/IS-95 and 1xEV-DO systems can be accessed independently, operational scenarios exist where a mobile device would access both (see section 10.).

1xEV-DO by itself brought about the need for new system record and acquisition record types; however, the need to access both types of network at the same time introduced the need to capture co-location information in the PRL. This collocation scheme can only be applied (i.e. only has meaning) within the context of a geographical area.

The association of systems by GEO is further developed in the IS-683-C PRL with the introduction of the 'Association Tag.' The association tag is used to define a scope within a GEO that can:

- Group together one or more 1x/IS-95 systems
- Group together one or more 1xEV-DO systems
- Indicate that systems in 1xEV-DO group may be present when served by one of the systems in the 1x/IS-95 group

The association tag cannot be used when describing analog systems since a 1xEV-DO system cannot be associated with analog cellular systems (i.e. a mobile device cannot operate on an analog system and a 1xEV-DO system at the same time.

The GEO group, as was described in section 4.5, introduced not only information organization in the PRL but it is also a scope definition within which 1x/IS-95 system priorities are specified and applied. Consequently, the GEO has a direct relationship to system selection and reselection behavior (see section 5.3.5).

The introduction of a second scope context introduces new behavior implications that need to be considered. These will be considered in detail later but can be introduced as:

- 1x/IS-95 and analog system priorities continue to be enforced within the scope of the GEO as before
- 1xEV-DO systems are searched (and, possibly, their priorities are enforced) within the scope of the association tag

There are some conditions that require further explanation of this general rule, i.e. when no 1x/IS-95 system is present or when a device operates only on 1xEV-DO systems. These will be covered later in this section.

9.3 PRL with 1xEV-DO

As before, the PRL still specifies the frequencies and systems that the access terminal is allowed to acquire. The standard has been extended to include support for an IS-856 system record type. The preferred roaming list format has also been extended to include support for defining associations between IS-2000 systems and IS-856 systems. These extensions to the preferred roaming list format are defined in the IS-683C standard. See Figure 9-3.

Figure 9-3 EVDO PRL Properties

9.3.1 High Rate Packet Data (EV-DO) Acquisition Record

In revision C of the standard the Generic HRPD (High Rate Packet Data) became available.

The Generic HRPD acquisition record (Table 9-1) is used to instruct the mobile device is to search for 1xEV-DO service on a specific channel of a specific band-class.

Table 9-1 CDMA Generic Acquisition Record Fields

Acquisition Record Field	Length (bits)
ACQ_TYPE	4
LENGTH	5
LENGTH/2 occurrences of	
BAND_CLASS	5

Up to 16 band-class and channel pairs can be specified in one record. Generally, the order in which the channels are listed is the order that they would be searched. Figure 9-4 shows one particular editor view of the HRPD generic acquisition record. This record is in the extended acquisition record format. This extended format is merely an encoding extension but would be transparent in tools such as PRL editors. Figure 9-4 also shows the actual field names and lengths described in the standard in its extended acquisition record format.

Figure 9-4 HRPD Generic Acquisition Record Editor View

9.3.1.1 Acquisition Type

An editor will generally show a meaningful descriptive term for this, as in the example of Figure 9-4 where it is shown as 'HDR Generic.' In the standards the mechanism to identify a HRPD generic acquisition type record is by setting the actual (decimal) value of'11' for the 'ACQ_TYPE' field.

9.3.2 IS-683-C System Record Structure

The new system record introduced by IS-683-C (the extended system table record) can be conceptually visualized as comprising four parts, namely:

- The record type indicates if the record is a type 0 system record (analog, 1x/IS-95) or a type 1 1xEV-DO system record.
- The System Characterization Block identifies the GEO, preference type, selection priority, roam indicator and the acquisition record that describes the band-class and channels for the system.
- The System Identification Block describes the broadcast identity of the system that is to be recognized. An analog system has only a SID, a 1x/IS-95 system has a SID and optionally a NID and a 1xEV-DO system has a subnet-id.
- The Association Block identifies systems that are co-located (i.e. grouped together inside the GEO scope) for the purposes of hybrid operation.

This representation is shown in Figure 9-2; only the right most nodes of this representation actually represent fields in the system table record.
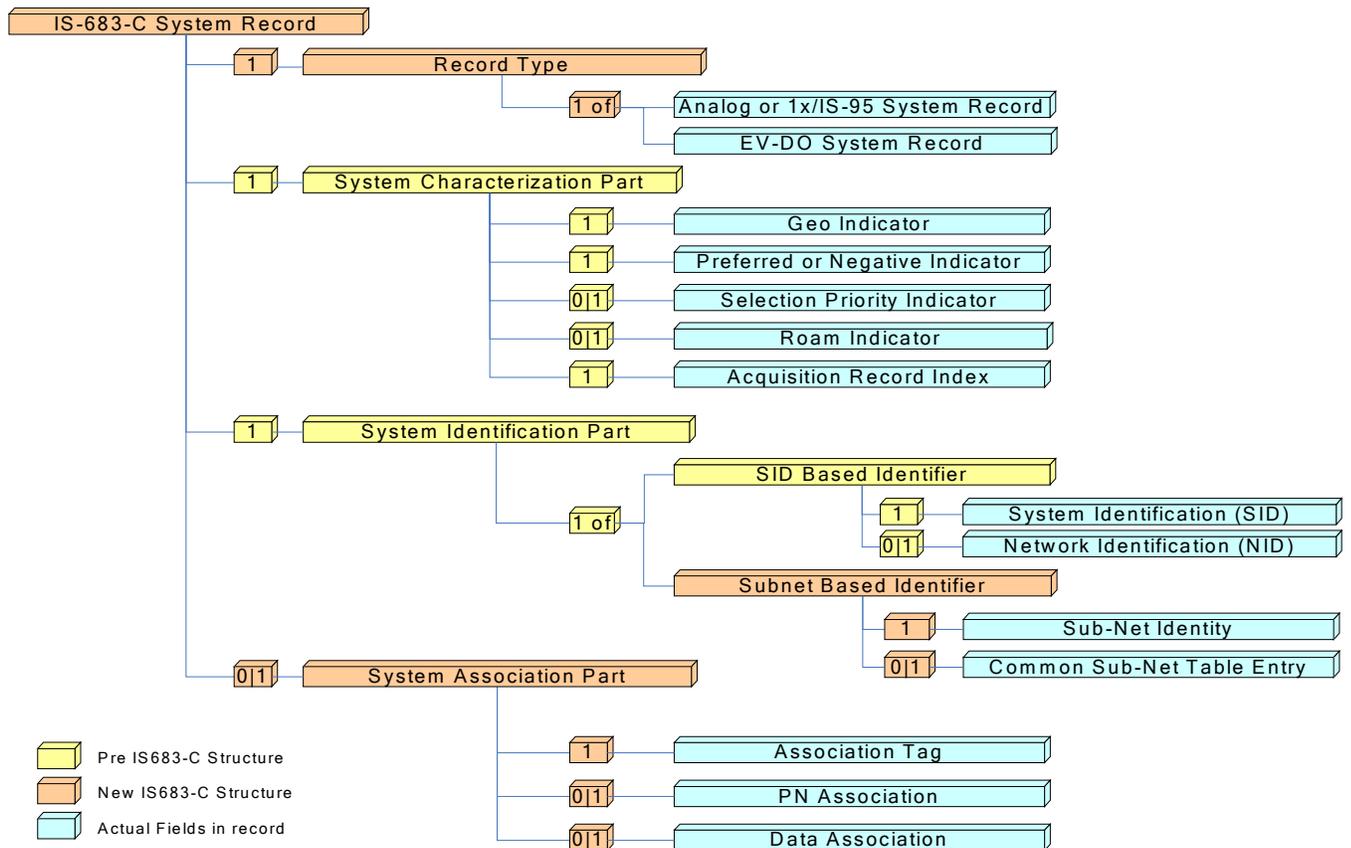
Figure 9-5 The New System Record Structure

9.3.3 High Rate Packet Data (1xEV-DO) System Record

The 1xEV-DO systems that are to be permitted or prohibited are described in a system record of the system table. An editor view of the system table is shown in Figure 9-5. Each line is a system record. The specific fields of a system record are shown in Table 9-2.
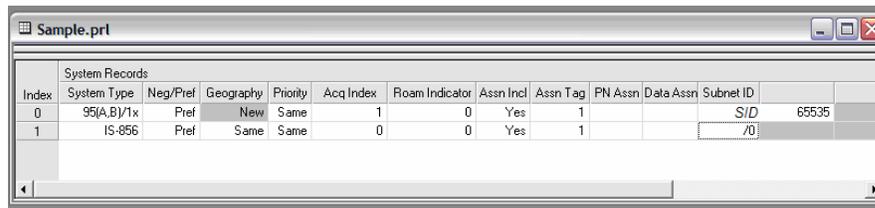
Figure 9-5 Example Editor View of a 1xEV-DO System Record

Table 9-2 EVDO System Record Fields (IS-683 C)

System Record Field	Length (bits)
SYS_RECORD_TYPE	4
PREF_NEG	1
GEO	1
PRI	1
ACQ_INDEX	9
SUBNET_COMMON_INCLUDED	1
SUBNET_LSB_LENGTH	7
SUBNET_LSB	SUBNET_LSB_LENGTH
SUBNET_COMMON_OFFSET	0 or 12
ROAM_IND	0 or 8
ASSOCIATION_INC	1
ASSOCIATION_TAG	0 or 8
PN_ASSOCIATION	0 or 1
DATA_ASSOCIATION	0 or 1

9.3.3.1 System Record Type

System record type indicates if the record is a 1x/IS-95 record (type 0) or a 1xEV-DO record (type 1). The type determines which identification scheme is used in the system identification block.

9.3.3.2 System Characterization Part

This set of information provides the characteristics of the system that are used to perform system selection.

- **Negative/Preferred**: This field has the same meaning as that described in Section 4.5.2, except now it applies to a 1xEV-DO system.

- **Geography**: This field has the same meaning as that described in Section 4.5.2, except now it applies to a 1xEV-DO system.

- ▪ **Priority**: Just as before, only a preferred 1xEV-DO system can have priority. Priority for a 1xEV-DO system is applied within the scope of system identified as being co-located (by way of the association tag). Negative systems are prohibited. The same rules (and cautions) of use apply here as those that were described for priority in Section 4.5.2.
- ▪ **Acquisition Index**: This field is set to the index of the acquisition record that specifies the acquisition parameters for the system associated with this record.
- ▪ **Roam Indicator**: Only preferred systems can have a roam indicator. For negative systems, this field is omitted

9.3.3.3 System Identification Part

The type of the system record determines which type of identity may be used (Table 9-3). For a 1xEV-DO system record (type 1); subnet identification must apply (as opposed to SID/NID identification which applies to 1x/IS-95 systems).

Table 9-3 EVDO System Record Identity Fields

System Record Field	Length (bits)
SUBNET_COMMON_INCLUDED	1
SUBNET_LSB_LENGTH	7
SUBNET_LSB	SUBNET_LSB_LENGTH
SUBNET_COMMON_OFFSET	0 or 12

The subnet-ID can take two forms in the PRL. The first, and most typical, is where the full subnet identity is contained in the system record. The second form is where part of the subnet-ID is in the system record together with information about how to locate the other part from a store known as the common subnet table.

9.3.3.3.1 Full Subnet in System Record

When the full subnet is described all significant bits are contained in the record and no part of the subnet is located elsewhere. It is explicitly stated in the record that the common subnet table is not used. Figure 9-6 shows an example of how the full subnet id would be represented in the identification part of a type 1 system record.
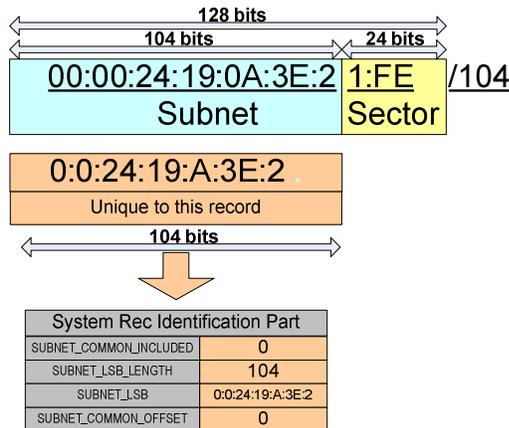
Figure 9-6 Full Subnet Id in System Record

The fields of the identification part of the type 1 system record are:

- SUBNET_COMMON_INCLUDED indicator value of 0 indicates that the common subnet optimization is not being used.
- SUBNET_LSB_LENGTH contains the entire subnet that follows (104 in the example shown).
- SUBNET_LSB is the field that contains all the bits of the subnet
- SUBNET_COMMON_OFFSET is omitted when SUBNET_COMMON_INCLUDED has a value of zero.

9.3.3.3.2 Use of the Common Subnet Table

If the most significant part of the subnet-id is common this can be optimized through the use of the common subnet table (Figure 9-7).
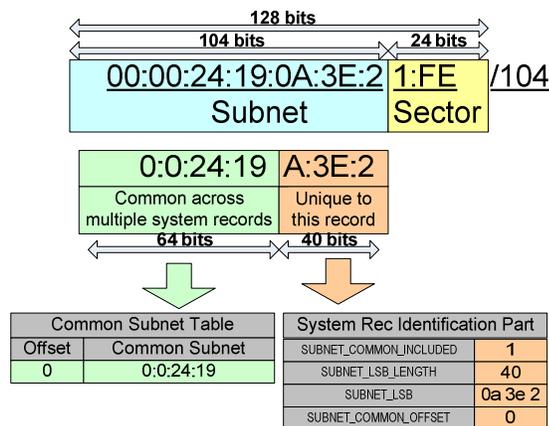
Figure 9-7 Use of Common Subnet Table

This optimization is indicated by the:

- **SUBNET_COMMON_INCLUDED** indicator value of 1 indicates that the common subnet optimization is being used and that a reference to the common subnet table is included.

- **SUBNET_LSB_LENGTH** contains the length of the unique part (the least significant bits) of the subnet that follows.

- **SUBNET_LSB** is the field which contains the least significant bits of the subnet.

- **SUBNET_COMMON_OFFSET** is the vector to the part of the common subnet table that contains the most significant bits of the subnet of this system record (e.g., a value of zero is the beginning of the common subnet table).

9.3.3.4 Association Part

The presence of an association is indicated by the field ASSOCIATION_INC. having a value of 1. There are three associations that comprise the association part of the system record.

The first and most significant in use today, is the ASSOCIATION_TAG. This is an 8-bit number that names the 'association set' to which this system record belongs. The set name only has meaning within the scope of a GEO. System records in the same GEO that have the same association tag are members of the same set. System records in different GEOs that have the same association tag are **not** members of the same set.

The other two associations, while present in the PRL, are not currently used by system selection but their description is included here for completeness. The associations are

- PN association flag identifies systems that have the same PN offset assignment (i.e., collocated).

- Data association flag identifies systems that can reach the same set of PDSNs (i.e., associated).

9.4 Size of the IS-683-C PRL

In IS-683-C it was not just the addition of new records that changed, also the binary packing format of the PRL changed which requires a revisit of some of the basic size understandings.

9.4.1 Acquisition Table Record Sizes

Due to different bit packing and byte alignment introduced in IS-683-C some records increase in size. Record sizes are shown in the table below and the increase over the sizes of the same record in IS-683-A. Note how every record size is a number that is a multiple of 8. See Table 9-4.

Table 9-4 Sizes of IS-683C Acquisition Records for Later Revisions

Acquisition Record Type	Min Size Bits	Bits per extra Element	Max num extra elements	Max Size (bits)	% Increase over IS-683A
Analog	24	-	-	24	400%
CDMA Standard	24	-	-	24	300%
CDMA Preferred	24	-	-	24	300%
CDMA Custom	32	11	31	376	104% - 160%
PCS (Block)	24	3	5	40	160% - 240%
PCS (Custom)	32	11	31	376	104% - 160%
CDMA Generic	32	16	15	272	103% - 128%

9.4.2 System Table Records

Changes in the specification for revision C for the priority bit and the binary packing issue mentioned above produce a considerable increase in system size as shown in Table 9-5.

Table 9-5 System Record Sizes Increases in IS-683C non 1xEV-DO System Records

Association	Record Format	IS-683C Size (bits)	IS-683A Size	Increase
Unassociated	Preferred System no NID	48	37	130%
	Preferred System with NID	64	53	121%
	Negative System with NID	56	44	127%
	Negative System no NID	40	28	143%
Associated	Preferred System no NID	64	37	173%
	Preferred System with NID	80	53	151%
	Negative System with NID	72	44	164%
	Negative System no NID	56	28	200%

Table 9-6 and Table 9-7 show the composition of the new bit packing in the IS-683C records for both CDMA 1x/IS-95 systems and 1xEV-DO systems.

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Table 9-6 Sizes of IS-683C non 1xEV-DO System Records

Type	Record Format	Len + Type	Extra Bit	SID	NID Incl	NID	Pref Neg	Geo	Pri	Acq Index	Roam Ind	Assoc Incl	Assoc Tag	PN Assoc	Data Assoc	Pad	Size (bits)
	Preferred System no NID	9	1	15	2	0	1	1	1	9	8	1	0	0	0	0	48
0	Preferred System with NID	9	1	15	2	16	1	1	1	9	8	1	0	0	0	0	64
0	Negative System with NID	9	1	15	2	16	1	1	1	9	0	1	0	0	0	0	56
0	Negative System no NID	9	1	15	2	0	1	1	1	9	0	1	0	0	0	0	40
1	Preferred System no NID	9	1	15	2	0	1	1	1	9	8	1	8	1	1	6	64
1	Preferred System with NID	9	1	15	2	16	1	1	1	9	8	1	8	1	1	6	80
1	Negative System with NID	9	1	15	2	16	1	1	1	9	0	1	8	1	1	6	72
1	Negative System no NID	9	1	15	2	0	1	1	1	9	0	1	8	1	1	6	56

The size of a 1xEV-DO record varies based upon whether it is associated or not and whether the common subnet table is used. Currently the common subnet optimization is not used. The unassociated 1xEV-DO record describes non-hybrid operation: a mode that is not covered in this paper.

Table 9-7 Sizes of IS-683C 1xEV-DO HRPD System Records

Record Format	Len + Type	Extra Bit	Comm Subnet Incl	Subnet Length	Subnet LSB Min	Subnet LSB Max	Common Offset	Pref Neg	Geo	Pri	Acq Index	Roam Ind	Assoc Incl	Assoc Tag	PN Assoc	Data Assoc	Min Pad	Max Pad	Size (bits) Min	Size (bits) Max
Associated Preferred System no Common Subnet	9	3	1	7	0	128	0	1	1	1	9	8	1	8	1	1	5	5	56	184
Associated Preferred System with Common Subnet	9	3	1	7	0	128	12	1	1	1	9	8	1	8	1	1	1	1	64	192
Associated Negative System no Common Subnet	9	3	1	7	0	128	0	1	1	1	9	0	1	8	1	1	5	5	48	176
Associated Negative System with Common Subnet	9	3	1	7	0	128	12	1	1	1	9	0	1	8	1	1	1	1	56	184
Unassociated Preferred System no Common Subnet	9	3	1	7	0	128	0	1	1	1	9	8	1	0	0	0	7	7	48	176
Unassociated Preferred System with Common Subnet	9	3	1	7	0	128	12	1	1	1	9	8	1	0	0	0	3	3	56	184
Unassociated Negative System no Common Subnet	9	3	1	7	0	128	0	1	1	1	9	0	1	0	0	0	7	7	40	168
Unassociated Negative System with Common Subnet	9	3	1	7	0	128	12	1	1	1	9	0	1	0	0	0	3	3	48	176

10. Hybrid PRL & System Determination

10.1 Hybrid System Determination

Hybrid system determination (Figure 10-1) is that process that the 1xEV-DO device uses in hybrid mode to:

- Identify the best 1x/IS-95 and 1xEV-DO systems based on the device configuration and the conditions at the location
- Acquire the best systems as quickly as possible

For any given environment the charter of any hybrid system determination is to either:

- Try to acquire a specific 1x/IS-95 system
- Stay on the current serving 1x/IS-95 system
- Enter 1x/IS-95 power save mode

AND either:

- Try to acquire a specific 1xEV-DO system
- Stay on the current serving 1xEV-DO system
- Enter 1xEV-DO power save mode
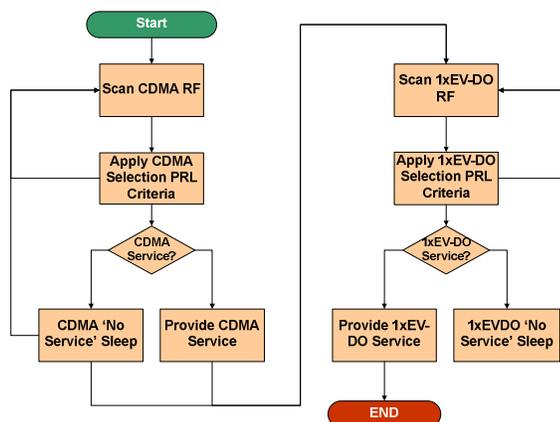
Figure 10-1 Hybrid System Determination Process

Hybrid system determination draws on information from various sources, namely:

- Static, programmable information such as device settings, a list of preferred and forbidden systems, a list of radio access technologies
- Dynamic information such as the system identification information (SID/NID or subnet) broadcast by available CDMA and 1xEV-DO systems, the RF conditions and protocols in use on available CDMA and 1xEV-DO systems
- User activity

For all the same reasons cited in section 5.1, any description here is a general guideline and questions on actual implementation should be directed to device manufacturers. For 1xEV-DO devices in hybrid mode using the preferred roaming list, the PRL provides the data upon which system determination operates. Hybrid system determination, as shown in Figure 10-1 can be understood to have two distinct phases: CDMA system determination followed by 1xEV-DO system determination.

Each phase has two stages:

- Scanning to find a system
- Applying system selection criteria to the system that has been found

When dual system (i.e. 1x/IS-95 and 1xEV-DO) operation is enabled, 1x/IS-95 system acquisition always occurs first. In some implementations, 1xEV-DO may not be acquired unless a 1x/IS-95 system is found first; while, in others acquisition procedures may allow 1xEV-DO acquisition after the 1x/IS-95 acquisition fails. In the situation where a 1x/IS-95 system is acquired, the 1xEV-DO search would be limited to the associated 1xEV- DO systems in PRL.

Although, in reality, the two stages of each phase are very closely coupled, for the purposes of explanation, each will be described separately.

10.1.1 Device Settings & Modes of Operation

Just as for 1x/IS-95 devices there are settings on a 1xEV-DO device that will affect system selection behavior. Additionally, there are additional permutations introduced by having a 1x/IS-95 mode and a 1xEV-DO mode.

A 1xEV-DO device can be configured for single system or dual system operation. In single system configurations it can operate on a 1x/IS-95 system or a 1xEV-DO system. In dual system operation mode (often referred to as hybrid mode) it is able to operate on both 1x/IS-95 and 1xEV-DO systems, concurrently.

The type of system that the terminal is configured to access is controlled by the preference mode as was the case for the standard 1x/IS-95 device. If the preference mode permits, dual system mode is controlled by the 'Hybrid Mode' setting.

10.1.2 Preference Mode

Earlier discussions showed that there is a preference mode setting that controls the types of systems upon which a device can operate (see section 5.1.1). The same setting

exists for 1xEV-DO terminals, except now there are more variables, since, in effect, 1xEV-DO is a new mode and there are more combinations.

10.1.3 Hybrid Preference Mode

Hybrid preference mode is a setting that governs if the 1xEV-DO device is permitted to operate in hybrid mode. Table 10-1 shows that there are only two preference mode settings when hybrid preference mode setting is considered: digital only and automatic.

Table 10-1 1xEV-DO Device Preference Modes

Preference Mode	PRL can contain system types			Can Operate on			Can be in Dual System (Hybrid) Mode
	1x/IS-95	1xEV-DO	Analog	1x/IS-95	1xEV-DO	Analog	
Digital only	✓	✓	✓*	✓	✓	✓	✓
Analog only	✓*	✓*	✓	✗	✗	✓	✗
Automatic (determine mode based on PRL)	✓	✗	✗	✓	✗	✓	✗
	✗	✓	✗	✗	✓	✗	✗
	✓	✓	✓	✓	✓	✓	✓
1X only	✓	✓*	✓	✓	✗	✗	✗
1xEV-DO only	✓*	✓	✓*	✗	✓	✗	✗
1X and analog only	✓	✓*	✓	✓	✗	✓	✗
* ignored if present							

10.1.4 Single System (Non Hybrid) Mode

In a single system mode of operation, a 1xEV-DO device is capable of functioning on either a 1x/IS-95 or a 1xEV-DO system. It cannot operate on both systems simultaneously.

10.1.4.1 1xEV-DO-only Mode

In 1xEV-DO only mode, the search for systems is limited to the IS-856 acquisition entries in the PRL and any other records would be ignored. As the name suggests, in this mode of operation, the device may only support 1xEV-DO operation and, therefore, is unlikely to support voice calls, SMS or automatic PRL updates which are supported only on a 1x/IS-95 system.

A device can be configured to operate in 1xEV-DO-only mode in one of two ways. The first one is by setting preference mode to 1xEV-DO only. The setting of the hybrid preference mode, in this case, is inconsequential. Any analog or 1x/IS-95 systems in the PRL would be ignored. The second way is to set the preference mode to automatic and load a PRL on the device that only describes 1xEV-DO systems (the setting of the hybrid preference mode, in this case, again is inconsequential).

10.1.4.2 CDMA 1x-only Mode

In CDMA-only mode the DO device reverts to exhibit only the behavior of a standard 1x/IS-95 device. It will operate on a 1x or IS-95 system as directed by the PRL.

A device can be configured to operate in 1x-only mode in one of two ways. The first one is by setting preference mode to 1x/IS-95 only. The setting of the hybrid preference mode, in this case, is meaningless. Any 1xEV-DO systems in the PRL would be ignored. The second way is to set the preference mode to automatic and load a PRL on the device that only describes 1x/IS-95 systems. The setting of the hybrid preference mode, in this case, again is inconsequential.

10.1.5 Dual System (Hybrid) Mode

A hybrid access device supports services on 1x/IS-95 and 1xEV-DO with handoff of a packet data session between 1x/95 and 1xEV-DO. The hybrid device is able to register and receive pages on 1x/95 and 1xEV-DO.

A device can be configured to operate in dual system (hybrid) mode in one of two ways. The first one is by setting preference mode to digital only, setting of the hybrid preference mode to 'enabled' and a PRL describing 1x/IS95 and 1xEV-DO systems appropriately. The second way is to set the preference mode to automatic, setting of the hybrid preference mode to 'enabled' and loading a PRL on the device that describes both 1x/IS-95 and 1xEV-DO systems.

Typically, when preference mode is set to anything other than 'automatic' or 'digital only, the hybrid preference setting may be ignored. When preference mode is set to 'automatic' or 'digital only, and the hybrid preference setting is set to off, it is an attempt to configure the DO device to acquire the 1x/IS-95 or 1xEV-DO systems, but not both. Typically, this mode of operation is not supported.

10.2 Hybrid System Scanning

Section 5.2 describes the scanning to find 1x/IS-95; this section deals with the scanning for 1xEV-DO service. The concepts are similar for 1xEV-DO with some subtle changes.

10.2.1 Recent Channel or Most Recently Used List

As was described in 5.2.2, mobile devices implementing system determination using the preferred roaming list (PRL) typically maintain a most recently used (MRU) table. Typically in a 1xEV-DO device there is still just one MRU table except that now its space is allocated between remembering the 1x/IS-95 systems and the 1xEV-DO systems that have provided service. The MRU table does not record any association information.

The number of total entries in a hybrid mobile device's MRU list is implementation-dependent but a typical number may be 12. The allocation split between 1x/IS-95 and 1xEV-DO systems is also implementation-dependent but a typical split may be 11/12 entries for 1x/IS-95 and 1/12 entries for 1xEV-DO.

10.2.2 Types of 1xEV-DO Scan List

Just like for 1x/IS-95 operation, the 1xEV-DO device builds a scan list dynamically. The building of scan lists, their names and their use is not standardized and is left to the implementation; therefore, how the scan list is constructed would be a function of the particular vendor's implementation of system determination. That said, in general, scan lists would be formed from:

- 1xEV-DO channels from the most recently used table
- 1xEV-DO channels from the acquisition table in the PRL

There are different types of scan lists that can be built to acquire 1xEV-DO which would be used by different scans. The types of scan lists for hybrid mode can include:

- Collocated scan list
- All 1xEV-DO Channels Scan List
- 1xEV-DO System Lost Scan List
- 1xEV-DO Better Service Reselection Scan List

10.2.2.1 Collocated Scan List

The *Collocated Scan List* is constructed when the:

- Device has successfully acquired 1x/IS-95 service
- Acquired 1x/IS-95 system has been associated with one or more 1xEV-DO system

This scan list contains channels of the most recently acquired 1xEV-DO systems in the MRU table followed by all 1xEV-DO channels described in the acquisition records of any 1xEV-DO systems with the same association tag (only within the same GEO) as the serving 1x/IS-95 system. The order of the 1xEV-DO frequencies in the scan list may be derived from the order in which the acquisition records are referenced by the order of the 1xEV-DO system records in the system table. As with all scan lists, duplicates are removed as are any channels that are outside of the permitted band classes of the band preference setting.

10.2.2.2 1xEV-DO system Lost Scan List

The *1xEV-DO System Lost Scan List* would be constructed when 1xEV-DO service is lost. This scan list contains an ordered list of 1xEV-DO channels comprising:

- The channel of the 1xEV-DO system that has just been lost
- Channels of the 1xEV-DO MRU table
- All 1xEV-DO channels described in the acquisition records of any 1xEV-DO systems with the same association tag (only within the same GEO) as the serving 1x/IS-95 system

The exact placement of the channels of the *Lost 1xEV-DO* System in this scan list is a direct function of the system lost policies (sometimes called the 1xEV-DO system loss

reacquisition schedule) that are built into the hybrid system determination. These policies are often specified by a network operator as part of their handset requirements and, therefore, may vary for devices from different operators. A common 1xEV-DO reacquisition schedule is one which places the lost system only at the head of the scan list and performs no further interspersing.

Duplicates are removed as are any channels that are outside of the permitted band classes of the band preference setting.

10.2.2.3 All Collocated 1xEV-DO Scan List

The *All Collocated 1xEV-DO Scan List* would be constructed, in hybrid mode, when attempt to acquire 1x/IS-95 service fails. Under such conditions there is no association information available to guide the 1xEV-DO search. This scan list contains any 1xEV-DO channels in the MRU table followed by all 1xEV-DO channels referenced by the 1xEV-DO system records that have membership of any association set (i.e. have an association tag defined). Typically, the order of the 1xEV-DO channels in the scan list is derived from the order in which the referencing system records appear in the system table (from top to bottom).

10.2.3 How Long does it Take to scan?

Hybrid mode 1xEV-DO devices typically optimize the acquisition-search through the use of the collocated 1xEV-DO channels. As before, the question of 'how long does it take the phone to scan?' arises often, which is difficult to quantify because it depends on many things over which system selection has no responsibility; not least search algorithms, the speed of the searcher and also on the type of scan being performed. In general there are four types of scans for 1xEV-DO; a *full scan*, a *deep* scan, a *shallow scan* and a *micro scan.* The number of 1xEV-DO channels that can be searched in time interval depends on searcher capabilities of the device.

10.2.3.1 1xEV-DO Full Scan

The 1xEV-DO full scan can acquire a 1xEV-DO signal as low as -15dB E_c/I_o and is normally a combination of a deep and shallow scan. Depending on the device (implementation and processor speeds, etc) a 1xEV-DO full scan can takes as long as 1000 milliseconds.

10.2.3.2 1xEV-DO Deep Scan

The 1xEV-DO deep scan is able to acquire a CDMA signal as low as -15dB E_c/I_o. Again, the speed of a 1xEV-DO deep scan is device- and implementation-dependent; typically it takes around 500 milliseconds.

10.2.3.3 1xEV-DO Shallow Scan

The 1xEV-DO shallow scan is able to acquire a 1xEV-DO signal as low as -13dB E_c/I_o. Again, the speed of a 1xEV-DO shallow scan is device- and implementation-dependent. Typically it takes around 500 milliseconds.

10.2.3.4 1xEV-DO Micro Scan

This type of scan is one that looks for any energy on the 1xEV-DO channel. If the measured energy is stronger than a predefined value (typically -95 dBm), then a 1xEV-DO full scan may be performed. The time for a 1xEV-DO micro scan is device- and implementation-dependent and may take between 60 and 100 milliseconds.

10.3 Hybrid System Selection

The hybrid device attempts to perform 1x/IS-95 system determination first. Once the best available 1x/IS-95 system has been selected an attempt is made to acquire the best available 1xEV-DO system, as is depicted in Figure 10-2. Generally, the hybrid device will attempt to acquire a 1xEV-DO system only once a 1x/IS-95 system has been acquired and then, only one that is in the same association set scope as the serving 1x/IS-95 system in the PRL shows a generalized example of the components that any hybrid system determination implementation would have to exhibit.
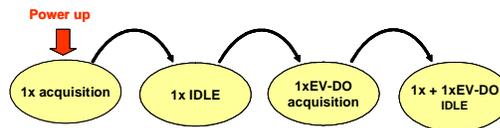
Figure 10-2 Hybrid Mode System Selection

.
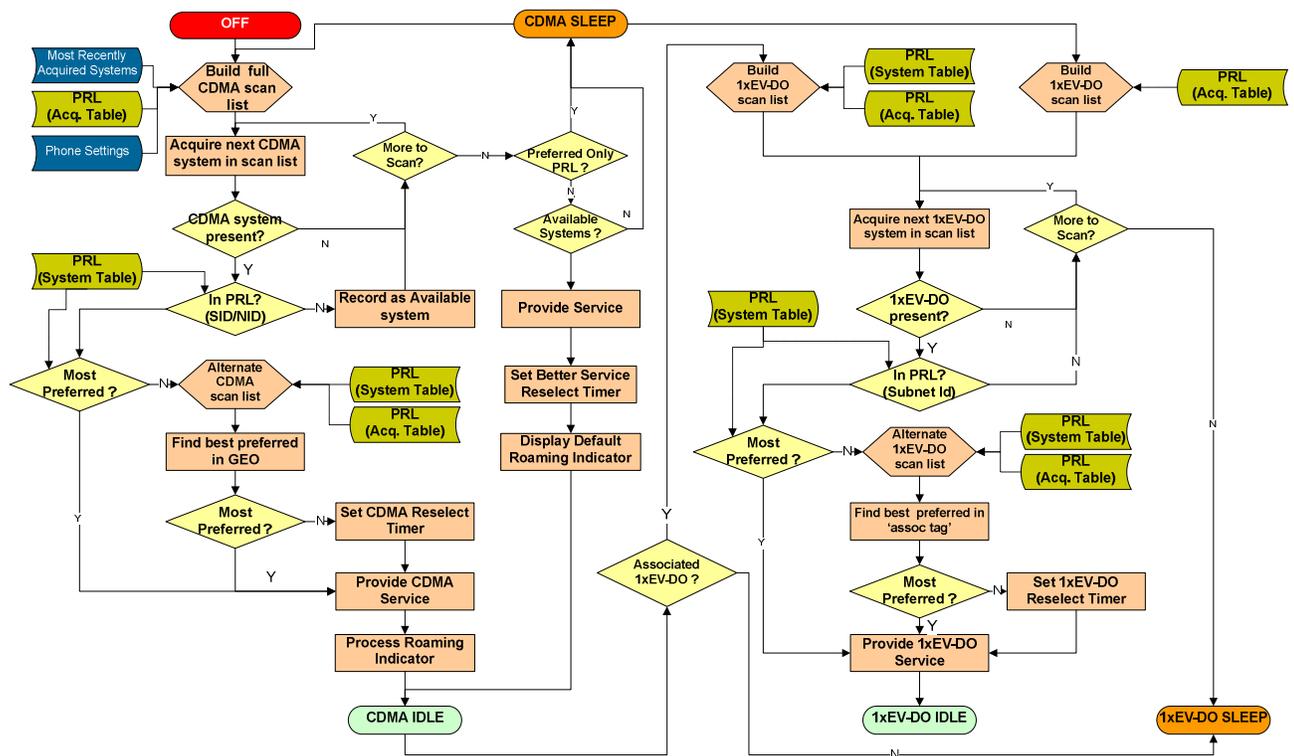
Figure 10-3 Example Hybrid System Selection

10.3.1 Initial System Selection

On initialization, the hybrid device searches for an available 1x/IS-95 system and attempts to acquire it first (as described by section 5.3.2). During this time the radio interface is dedicated to 1x/IS-95 system acquisition. In 1x/IS-95 initial system selection the state of the environment was simply described as the presence of a usable system or not. In hybrid operation, during initialization, the combination of the states of both the 1x/IS-95 and 1xEV-DO environments now yield one of four possible environment conditions that may exist:

- Both 1x/IS-95 and 1xEV-DO systems are available
- 1x/IS-95 systems are available and no 1xEV-DO systems are available
- No 1x/IS-95 systems are available and 1xEV-DO systems are available
- Neither 1x/IS-95 nor 1xEV-DO systems are available

10.3.1.1 Both 1x/IS-95 and 1xEV-DO Systems Available

Where both 1x/IS-95 and 1xEV-DO are available the hybrid device acquires 1x/IS-95 first and, once idle on 1x/IS-95, it attempts to acquire a 1xEV-DO system in the association set using channels of the *Collocated Scan List* (see section 10.2.2.1).

If a PRL-listed 1xEV-DO system is acquired that is the most desirable system in the association set, then service is provided on that system and no further 1xEV-DO scanning is performed until the system is lost. If the device acquires a PRL-listed 1xEV-DO system that is not the most desirable system in its association tag scope, then, dependent on the implementation, the device may attempt to acquire a more preferred 1xEV-DO system.

Once both systems are acquired the hybrid device enters idle mode operation on both the 1x/IS-95 system and the 1xEV-DO system.

10.3.1.2 Only 1xEV-DO Systems Available (No 1x/IS-95)

If no PRL listed 1x/IS-95 system is available then, depending in the implementation, the hybrid device may attempt to search for a 1xEV-DO system.

There are some implementations that dedicate radio resources to acquire 1x/IS-95 and do not attempt any 1xEV-DO acquisition until a 1x/IS-95 system is acquired.

Other implementations may allow a hybrid device to operate on 1xEV-DO in the absence of a 1x/IS-95 system. The 1x/IS-95 part of the device remains in 1x/IS-95 power save mode while the 1xEV-DO system is operational. Where supported, 1xEV-DO acquisition, in the absence of 1x/IS-95 is performed using the *All Collocated 1xEV-DO Scan List* (described in section 10.2.2.3). Also, while on 1xEV-DO service there can be periodic attempts to search for 1x/IS-95 service.

10.3.1.3 Only 1x/IS-95 Systems Available (No 1xEV-DO)

Having acquired 1x/IS-95, 1xEV-DO acquisition commences using the *Collocated Scan List.* If this fails to yield any 1xEV-DO system then the hybrid device enters 1xEV-DO power-save mode. Depending on the implementation, repeated attempts to acquire a 1xEV-DO system may be performed periodically. The period may be fixed or one of increasing intervals in order to optimize power consumption. An example of such a telescoping schedule may be for 2, 4, 10, 30 and 60 seconds.

10.3.2 Hybrid System Reselection

Since the hybrid device introduces two modes of operation there are also two modes of reselection.

- 1x/IS-95 System Reselection
- 1xEV-DO System Reselection

In each case, if the PRL indicates that the current serving system is not the most preferred system available in the priority scope (GEO for 1x/IS-95 and Geo plus Association Tag for 1xEV-DO), and then the device may periodically attempt to acquire a more preferred system. Again having two distinct modes means that there are more situations to consider:

- 1x/IS-95 Reselection while idle on 1xEV-DO

- 1x/IS-95 Reselection while connected on 1xEV-DO
- 1xEV-DO Reselection while idle on 1x/IS-95
- 1xEV-DO Reselection while connected on 1x/IS-95

10.3.2.1 1x/IS-95 Reselection while Idle on 1xEV-DO

If the hybrid device is served by a *less preferred* 1x/IS-95 system then 1x/IS-95 reselection will occur (as described by 5.3.5). Acquisition of a different 1x/IS-95 system may result in 1xEV-DO reacquisition as outlined in section 10.3.1.1 . This may result in staying on the same serving 1xEV-DO system or selecting another as dictated by the association tag scope and priorities. Whenever the hybrid device acquires a new 1x/IS-95 system, and the new 1x/IS-95 system is not associated, in the PRL, with the current serving 1xEV-DO system; then the device would normally try to acquire an 1xEV-DO system that is associated with the new 1x/IS-95 system.

10.3.2.2 1x/IS-95 Reselection while Connected on 1xEV-DO

If the hybrid device is connected on 1xEV-DO while served by a *less preferred* 1x/IS-95 system then, subject to the implementation, 1x/IS-95 reselection may be prohibited until the 1xEV-DO session is ended.

10.3.2.3 1xEV-DO Reselection while Idle on 1x/IS-95

If the hybrid device is served by a *less preferred* 1xEV-DO system then, dependent on the implementation, 1xEV-DO reselection may occur to attempt to acquire a higher priority 1xEV-DO system.

10.3.2.4 Reselection on a Less Preferred 1x/IS-95 System

10.3.3 1xEV-DO Better Service Reselection

A mobile device may acquire service on a 'less-preferred 1xEV-DO system[12], which is any 1xEV-DO system that is not the most preferred within the scope of the association tag. Depending on the implementation, '1xEV-DO *Better Service Reselection*' may occur (often just simply referred to as DO reselection). A Better Service Reselection policy is based on the following mechanisms:

- A reselection period to wait before trying for better service
- A reselection timer
- The better system scan list
- A better service scan

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[12] Table 2-1 describes preferred, less preferred and most preferred systems

10.3.3.1 Reselection Timer & Reselection Period

The mobile device has a timer that is set running when service is offered on any less preferred system. The timer runs for a period of time, known as the reselection period, after which, the hybrid device again attempts to acquire the most preferred 1xEV-DO system in the scope of the association set. The 1xEV-DO reselection period depends on the implementation and may actually be infinity. A 1xEV-DO reselection period of 'infinity' effectively means that after initial selection of the best available 1xEV-DO system, subject to the stated preferences, no further reselection would be performed. An infinite reselection time effectively means that the 1xEV-DO system selection is not performed until 1x/IS-95 reselection occurs.

10.3.3.2 1xEV-DO Better Service Scan

Expiration of the 1xEV-DO reselection timer causes the device to search for more preferred 1xEV-DO systems in the same association set. If 1xEV-DO reselection acquires the most preferred 1xEV-DO system, then, service is provided and the 1xEV-DO reselection timer is not set, i.e. no more reselection will occur.

If a more preferred, but not the most preferred, 1xEV-DO system is acquired then service is provided and the 1xEV-DO reselection timer is reset. Better service reselection will continue once the timer expires.

10.3.4 System Lost

If service is lost, on the 1x/IS-95 or 1xEV-DO systems, the hybrid device would normally either attempt to re-acquire the lost system or attempt to acquire another system in accordance with the preferred roaming list. With the hybrid device system lost further qualification is required to determine what should happen. There are three basic pieces of information that are required to understand what the next steps should be:

- Which system is lost
- The relevant system loss scan list
- A relevant system loss service scan

When a mobile device has declared that it has lost a system[13] it invokes its system lost reselection policy. The device implements this policy by use of the following mechanisms:

- A system loss reacquisition schedule
- The system loss scan list
- A system loss service scan

---

[13] The signal level that a mobile device declares that is loses a system is implementation dependent. A CDMA system is normally unusable at E_c/I_o of -16dB.

Section 5.2.3 describes how the system lost scan list consists of channels from the lost system, channels corresponding to preferred systems in the same geographic region as the lost system, channels from the MRU table, and channels from the acquisition table. The system loss reselection is similar to the better service reselection except for the earlier noted changes in how the scan list is constructed.

Table 10-2 Hybrid Device System Lost Permutations

Device State		Service Lost on		Resultant System Determination action	
1x/IS-95	**1xEV-DO**	**1x/IS-95**	**1xEV-DO**	**1x/IS-95**	**1xEV-DO**
Idle	Idle	Y	N	1x/IS-95 system lost reselection	1xEV-DO acquisition may also occur in line with PRL
		N	Y		1xEV-DO system lost reselection
	Connected	N	Y	No action	Session is handed down to 1x & 1xEV-DO acquisition when idle on 1x
		Y	N	No action until 1xEV-DO idle.	Session in connected state continues while service is available.
Connected	Idle	Y	N	1x/IS-95 system lost reselection	1xEV-DO acquisition may also occur in line with PRL
		N	Y	No action	No 1xEV-DO reselection until idle on 1x/IS-95, then 1xEV-DO system lost reselection.

The 'schedule' of attempts to reacquire the system, that has just been lost, is set and driven by the construction of the system lost scan list. As in better service reselection, if a system is acquired and it is less-preferred, then better service reselection will be performed. It is worth noting that often the system determination will search through the GEO first.

10.3.4.1 1x/IS-95 lost & 1xEV-DO Idle

If, while idle on both 1xEV-DO and 1x/IS-95, the 1x/IS-95 system is lost, then the hybrid device attempts to reacquire 1x/IS-95 as described in section 5.3.7.

Once idle on 1x/IS-95, 1xEV-DO acquisition is performed in line with the description outlined in section 10.3.1. This may result in staying on the same serving 1xEV-DO system or selecting another one as dictated by the association tag scope and priorities.

10.3.4.2 1x/IS-95 Idle & 1xEV-DO System Lost while Idle

When idle on both 1xEV-DO and 1x/IS-95, the 1xEV-DO system is lost and the hybrid device attempts to reacquire an 1xEV-DO system using the *collocated scan list* as described in section 10.3.1.3 . If, after repeated attempts to acquire a co-located 1xEV-DO system, no 1xEV-DO system is acquired then the hybrid device enters 1xEV-DO power save mode.

10.3.4.3 1xEV-DO System Lost while in Connected State

If the hybrid device is in a 1xEV-DO connected state and moves to a location where there is no 1xEV-DO coverage, data session handoff to 1x/IS-95 system takes place.

10.3.4.4 1xEV-DO Connected & 1x/IS-95 Lost

In some implementations there may be no attempt to acquire 1x/IS-95 service while 1xEV-DO is in the connected state. Other implementations may permit 1x/IS-95 acquisition but enforce some form of throttling scheme so as not to starve the connected 1xEV-DO session of radio resources. A common throttling scheme is to return to the 1xEV-DO session for a telescoping period of time while 1x/IS-95 system is unavailable and 1xEV-DO is connected.

10.3.5 Avoidance of Unusable Systems

A device may encounter a 1xEV-DO system upon which it cannot provide service. A device can declare a 1xEV-DO system to be unusable for a number of reasons, some of which are:

- Protocol mismatch
- 1xEV-DO redirection
- Access denied
- Session abort
- Connection deny - general/network busy
- HDR connection deny - authentication failure
- Maximum access probes

Most implementations will avoid 1xEV-DO systems considered to be unusable; although, for exactly how long, is implementation dependent. Depending on the actual condition causing the avoidance, typical time to 1xEV-DO avoidance times can range from 30 seconds to 10 minutes. This avoidance time is often referred to as the avoidance timer. Just as for 1x/IS-95, avoiding a 1xEV-DO system does not imply that system is re-acquired after avoidance timer expires, it just means that it is eligible to be scanned again. During the avoidance time the channel is omitted from the 1xEV-DO scanning process. When the avoidance timer expires, the channel reenters the next scanning schedule.

10.3.5.1.1 Max-Access Probe Exit Scan

When an access attempt fails with maximum number of permitted access probes[14], the mobile device would normally use a maximum access probe exit scan list for

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[14] Access probe is a term used to collectively mean a system access message, sent on the access channel, and the specific power level with which it is sent. If the mobile device does not get a response, it sends subsequent access probes (same message at increased power levels);

reacquisition. This list is similar to a power up scan but lacks the channel on which the access attempt failed.

10.3.6 Matching System Table Described Systems

Once a system is acquired, it must be identified in the system table so as to locate the GEO within which the device is currently operating. Furthermore, once located the system's criteria, on validity and preference to provide service, must be applied. Identifying a system record in the system table is often referred to as matching. Exactly how an acquired system is matched, against the system table, is determined by the matching policies, which, can vary widely across implementations. Nonetheless, all will exhibit general behavior in terms of:

- Index keys into the system table
- Wildcards in system's description
- Band-class and channel matching

10.3.6.1.1 Index Key into the System Table

A 1xEV-DO system is matched in the system table by a composite index of the system's broadcast identity together with the description of the frequency on which the system is located. The component key fields of the index, for a 1xEV-DO system, are:

- Subnet identity
- Channel and band-class

Earlier discussion showed that these component elements can have non-unique values. In section 4.5.2 we saw that a PRL subnet identity value of 0 is designated a wildcard value. A PRL wildcard value for subnet identity will match any broadcast subnet identity.

The presence of a non-unique subnet identity means that matching criteria are required in order to match an acquired system to a particular system entry in the PRL's system table. In most implementations, the over-riding rule tends to be that the finest granularity of match is the one used (i.e. most unambiguous).

- Scope must match: the acquired 1xEV-DO system must be in the same GEO and a member of the same association set as the serving 1x/IS-95 system. (Where no 1x/IS-95 system has been acquired then membership of any association set)
- Least ambiguous subnet identity

10.3.7 Applying Priorities in Selecting a System

Having located a system within its GEO; SD must decide whether to stay on the acquired system or whether to continue to look for a better one. Exactly what these

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often described as 'raising its voice until it is heard.' There are a predefined maximum number of probes a device can send and a maximum power it can use.

criteria are and how they are applied can vary widely across implementations; however, they can include:

- Priority
- Roaming preference

10.3.7.1.1 Roaming Preferences

In many implementations the roaming indicator of a 1xEV-DO system record is ignored for system selection. In some, the roaming preference setting may act as a system table filter that reduces the systems available for selection. If the roaming preference has a setting of 'Home Only' then any system in the system table with a roaming indicator other than '*Roaming Indicator Off*' becomes unavailable for selection.

10.3.7.1.2 Priority

Priority is normally the primary distinguishing factor for system selection within an association set and it is the major indicator of whether a system is most preferred or not. Remember that the scope of priority for 1xEV-DO is limited to within the association tag set. The prime objective is to get to the most preferred system. The same priority can be applied to multiple systems and, therefore, situations arise where priority does not distinguish between systems. In most cases, this is perfectly fine and means that any one is as equally selectable as the other; however, there are situations where priority alone may not be enough, as when two systems have the same preference and different roaming indications.

10.3.7.1.3 Equal Priority, Different Roaming Indicator

Where the roaming indicator is used in 1xEV-DO system selection, then typically, where two systems in the same association tag are compared and the only discernable difference is the roaming indicator, then a system will likely be more preferred if it is not roaming.

10.3.8 No Selectable 1xEV-DO System

When the 1xEV-DO scan list is exhausted and 1xEV-DO service cannot be provided, hybrid system selection, typically, would enter 1xEV-DO power-save mode to preserve stand-by time (the exact behavior is implementation and, potentially, operator specification dependent). 1xEV-DO power save mode may involve a wake-up schedule to look for service with lengthening sleep intervals A hybrid device will exit 1xEV-DO power save mode periodically to search for 1xEV-DO service. Some points to bear in mind:

- The length of time of the initial search period is implementation-dependent.
- The length of time the hybrid device sleeps (1xEV-DO) between searches may lengthen by some expansion factor as subsequent searches do not find service. Any increasing sleep window behavior and the expansion factor is implementation-dependent.

- The length of time the hybrid device searches during wake up times may decrease by some compression factor as subsequent searches fail to find service. Any decreasing search window behavior and the compression factor is implementation-dependent.
- Often any user intervention, such as a key press, can reset the power save cycle and recommence with the search window reset to the initial search time.

Some or all of these behaviors may, in fact, be included in an operators' handsets specification.

11. 1xEV-DO PRL Production

11.1 Designing an 1xEV-DO PRL

As before for 1xEV-DO, the coverage plan is important. There is an added complication in that the 1xEV-DO network coverage is generally a subset of the 1x/IS-95 coverage and, of course, 1xEV-DO systems cannot be associated with analog systems. This can result in a situation of pockets of 1xEV-DO coverage.

A single IS-856 system span can be shared by multiple 1x/IS-95 systems which may be an important PRL design consideration.

11.1.1 *Subnet Access Restrictions*

It is possible to restrict users to particular subnet areas through appropriate use of the subnet id entry. It is a good idea to consider if the sub-net is to be a criterion for 1xEV-DO system access; if not, then a wildcard subnet id (/0) can be used. However, as with any wildcard use, it requires careful consideration of any potential side-effects.

11.1.2 Geographical Areas

As before, the number of geographical regions is an important design consideration and, in the case of a 1xEV-DO overlay, understanding the current geographical area design to represent the existing 1x/IS-95 network is important. A useful first step would be to identify which of these geographical regions would have 1xEV-DO service available.

11.1.3 Associating 1xEV-DO with 1x/95 Systems

Within a GEO a further scope can be defined in the *association set*. It is the use of the association tag that puts systems in an association set. A 1x/IS-95 system and a 1xEV-DO system with the same association tag value identifies them as belonging o the same association set. Multiple IS-856 systems, distinguished by channels or subnets, can be associated.

In designing associations that are necessary the following questions need to be answered:

- Which 1x/IS-95 systems (SID/NIDs or channels) have associated 1xEV-DO systems?
- Which 1xEV-DO systems are to be more preferred than the others?

- Is 1xEV-DO service provided while roaming?
- Is packet data roaming supported by roaming partner allowed?

11.2 How to Write an 1xEV-DO PRL

To describe 1xEV-DO systems in a PRL requires that a PRL of type IS-683C is used. In whichever tools that are being used (RL Editor or Excel or otherwise), it is important to ensure that the PRL will be formatted as IS-683C. The other header information described earlier in this paper is the same, i.e. Preferred Only and the PRL ID.

11.2.1 Creating an 1xEV-DO Acquisition Record

Creating a 1xEV-DO acquisition record is similar to creating acquisition records in IS683A/B PRLs except that now the acquisition type field should be set to HDR channels.

This type of record channel information is entered in pairs of:

- Band-class
- Channel number within the specified band

Up to 15 additional band-class/channel number pairs, can be entered as needed.

11.2.2 Creating an 1xEV-DO System Record

Creating a 1xEV-DO system record is similar to creating system records in IS683A/B PRLs. The following key differences exist:

- The system type field should be set to *Type 1 (*IS-856 or HRPD)
- Subnet is used instead of SID and NID
- The association must be set between this record and the appropriate 1x/IS-95 record

The following are the major steps for building a 1xEV-DO system record in the PRL for hybrid operation:

- Set system type to IS-856
- Enter fields as in IS-683A
- Specify if the system is preferred or prohibited (Neg/Pref)
- Identify the GEO
- Establish the priority
- Identify the appropriate acquisition table index
- Decide on the state of the roam indicator
- Enter subnet ID in 'Subnet ID' field. Enter as an IPv6 address text string representation of x:x:x:x:x:x:x:x/len where the xs are the hexadecimal values of the eight 16-bit pieces of the 128-bit address. *Len* is the length of the subnet ID,

which must be in the range of 0-127. To specify a wildcard subnet ID, set len to 0 (for example: 0:0:0:0:0:0:0:0/0).The shorthand notation /0 can also be used to specify the wildcard subnet ID.

11.2.3 Associating an 1xEV-DO with a CDMA System

To establish membership of an association set then the *Association Included* field must be set to *Yes*, and then the name of the set must be entered as a number between 0-255 in the *Assn Tag* field.

To associate a 1xEV-DO system with a 1x/IS-95 system, the same association tag value has to be entered for both systems. The association set only has scope within a GEO and therefore, only systems that are within the same GEO with the same association tag belong to the same association set. *PN Association* and *Data Association* fields are not currently used and are normally left blank.

A.1 Trouble-shooting Checks

Upon creating a PPP session with a PDSN, IS-683-C compliant 1x/IS-95 and 1xEV-DO devices will either attempt to access SIP or MIP depending on an IS-683-C defined configurable parameter (3.5.8.2-1). The parameter can be set to one of three modes:

- MIP-only
- MIP with SIP fallback
- SIP-only

The behavior of MIP with SIP fallback is to attempt to access mobile IP service, but to attempt to access SIP service upon failure to acquire MIP.

For both MIP-only and SIP-only modes, the device will terminate the PPP session if it is unable to acquire the respective service. Therefore, in cases where MIP is not available on a PDSN, a MIP-only configuration will prevent the device for acquiring service. Similarly, if a PDSN refuses to supply SIP service to a SIP-only configured device, the device will terminate its PPP session.

This particular parameter may not be configurable via OTASP and may have to be programmed prior to customer delivery or at a customer service center for in service devices.

An operator that has set this parameter to MIP-only precludes access to 1xEV-DO service in a roaming partner network that only has SIP, irrespective of the contents of the PRL.

12. PRL Enhancements

12.1 Problem of Tracking SIDs

A broadcast SID normally covers the area of a city, large town or a state. The network ID can further divide a SID area as necessary. A national wireless network can comprise tens or hundreds of SIDS. When international roaming is required a PRL becomes significantly larger due to the need to include the roaming partners' SIDs. This means that more memory is required in the handset or RUIM and can also mean longer over-the-air download times for a PRL. Changes in the use of SIDs in the roaming partner's networks' must be tracked and can result in a modification to the PRL, which must be redistributed to all affected handsets. If memory is an issue then an operator may have to choose which markets in a roaming partner's network are most important to them and only include those that can result in reduced coverage.

Also, any changes in broadcast SIDs as a result of network expansion or SID consolidation mean that a roaming partner must modify their PRL if they want to take advantage of the changed coverage.

Being able to describe the roaming partner's network at the 'network level' as opposed to the SID level would remove this issue from PRL management.

Networks with hundreds of SIDs are not uncommon. Figure 4-14 shows 1 KB of system table is required to add 220 preferred SIDs. If NIDs or negative system are required, then the number of effective SIDs per KB starts to go down.

12.2 PRL Enhancements

The PRL enhancement, as described by the CDG Reference Document #86, describes how CDMA networks can, for the purposes of system selection, identify themselves and be recognized at the 'network level.' Through appropriate use of current broadcast information in the extended system parameters a network can identify itself in terms of its mobile country code (MCC) and mobile network code (MNC) or 'IMSI_11_12' as it is referred to in the CDMA standards.

A specially encoded entry, known as an MCC/MNC system table record, in the existing form of the PRL allows the description of a network by its MCC and MNC (or IMSI_11_12) by use of a reserved SID and the NID to hold an encoded form of the MCC and MNC.

The system determination function of the handset is extended to now allow system selection using a MCC/MNC (IMSI_11_12) scheme.

The PRL enhancements are fully backward compatible. A PRL containing an MCC/MNC system table record can be loaded into any handset whether or not it supports the enhanced system selection. Since the MCC/MNS system record has the same form of existing system records the presence of an MCC/MNC (IMSI_11_12) entry in the PRL will not 'break' any existing handset system determination or existing PRL management mechanisms.

12.3 Identifying a CDMA System at the Network Level

To understand how a CDMA network can identify itself at the network let's look again at CDMA network identification. We have already established that the CDMA system broadcasts in system its system identification (SID) and network identification (NID).

There are two other identification parameters that every CDMA system broadcasts in the extended system parameters message, namely the mobile country code (MCC) and the IMSI_11_12 (also known as the mobile network code (MNC)). See Figure 12-1.

Figure 12-1 CDMA Network Identification

12.3.1 Granularity of a Network Description

In GSM, the description level of granularity, for the purposes of selecting a network, is the public land mobile network (PLMN) identity. A PLMN ID is the MCC and the MNC. One description describes a complete carrier's network or part thereof where a carrier has more than one MNC.

In CDMA, the currently used description level of granularity, for the purposes of selecting a network, is the SID/NID pair, which is one description of a particular market within the carrier's network as chosen by the carrier. This provides very good control for the carrier of how to describe the network and hence select a network particularly when there are multiple networks present. However, the cost of only using this level of detail in a multiple-carrier home market is that roaming partners must also describe the network at this level of detail and hence they must know and track all their partners' SID/NID definitions and incorporate them into their PRL.

However, the CDMA networks have the inherent ability to allow their operators to describe their network both ways and both can be used simultaneously. System selection implementations always match at the finer level of granularity. Therefore,

combining the MCC/MNC and SID/NID levels of granularity presents a host of options to the CDMA operator, for example:

- Using the granularity of SID/NID for its own users and domestic roaming partners
- Using the MCC + MNC(IMSI_11_12) granularity so roaming partner PRLs do not have to contain all the SID/NID information

12.4 PRL Enhancements: How They Work

With the PRL enhancements the PRL has the ability to describe a system by SID/NID or MCC/MNC, or both. The MCC and MNC are encoded into the existing SID and NID fields such that full backward compatibility is achieved. See Figure 12-2.
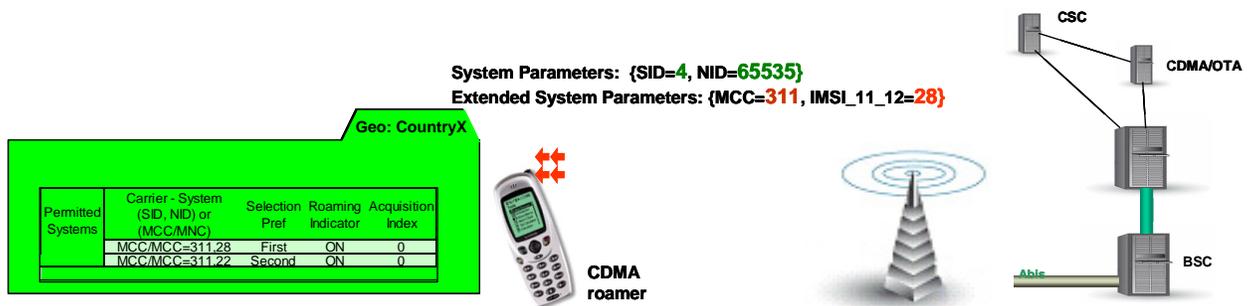
Figure 12-2 PRL Enhancement Operation

12.4.1 Handset

Enhanced system determination software in the mobile device is required to use the MCC/MNC system record. With this enhanced system determination, the device is able to identify an MCC/MNC system record and uses the MCC and MNC information from the extended system parameters message to perform PRL matching. See Figure 12-3.

If system determination is not updated, the encoding of the MCC/MNC type entries is such that full backward compatibility is supported. To a device with standard system selection software which is loaded with a PRL containing MCC/MNC type entries; these entries will appear as normal SID/NID entries. Since those SIDs are reserved and never broadcast the entries will never match.

Since the two special SIDs used in the PRL encoding are reserved and not allocated to any carrier for broadcast, those entries will never trigger a match and thus have no effect on system selection.

Pref/ Neg	GEO	Pri	SID (15 bits)	NID (16 bits)	Roam Ind	Acq Index
			00 0011 1110 0010 0000	**1001 1011 1001 1011**		
			15904	39835		

Decimal	15904	15905
	Special SID for 0	Special SID for 1

Left bit0	0	1001 1011 1001 1011	Right 16 bits
	SID part	NID part	
	0 1001 1011 1001 1011		(17 bits)
	MCC and MNC concatenated		

(10 bits)	01 0011 0111	001 1011	(7 bits)
(3 digits)	311	27	(2 digits)
	MCC	MNC	
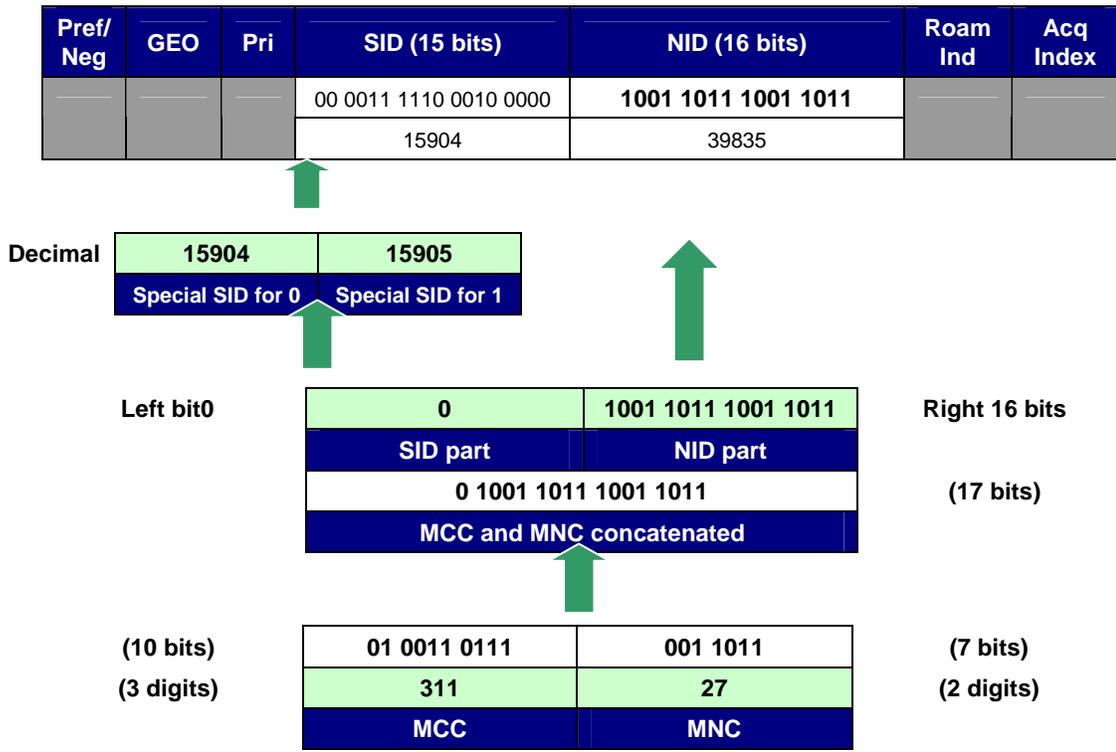
Figure 12-3 PRL Enhancement Encoding Example

12.4.1.1 System Selection

System selection software in the device must be upgraded to understand the system record described in terms of MCC, IMSI_11_12 and act upon it. Existing handsets and existing system selection implementations will not be 'broken' by encountering an 'enhanced PRL' entry. Any new format MCC, IMSI_11_12 records will be ignored by existing system selection implementations.

This newer system determination has been available in all QUALCOMM MSM 6xxx series since April 2004. Operators wishing to use this functionality must assure that their handset specifications communicate this desire to their vendors.

12.4.2 Network

The CDMA 2000 (revisions 0 and A) air interfaces currently require the broadcast of a 2-digit MNC (IMSI_11_12) and a 3-digit MCC in the 'Extended Systems Parameters' message. Since these are mandatory parameters of this message, each CDMA system must, and currently does, broadcast a value in these fields. These current values may be the manufacturer default, if it has not been set by the operator, or they may be the wildcard values for MCC and IMSI_11_12 (see section B.1.4).

For the PRL enhancements to function, the network must be configured to broadcast the real values allocated to the operator.

12.4.3 Standards Affected by PRL Enhancements

The PRL enhancement does not modify any CDMA standard. It describes a uniform method for populating and using existing data elements currently in use. It does not impose any requirements on the use or not of full-IMSI in the core network (ANSI-41).

12.5 Steps for Implementation of PRL Enhancements
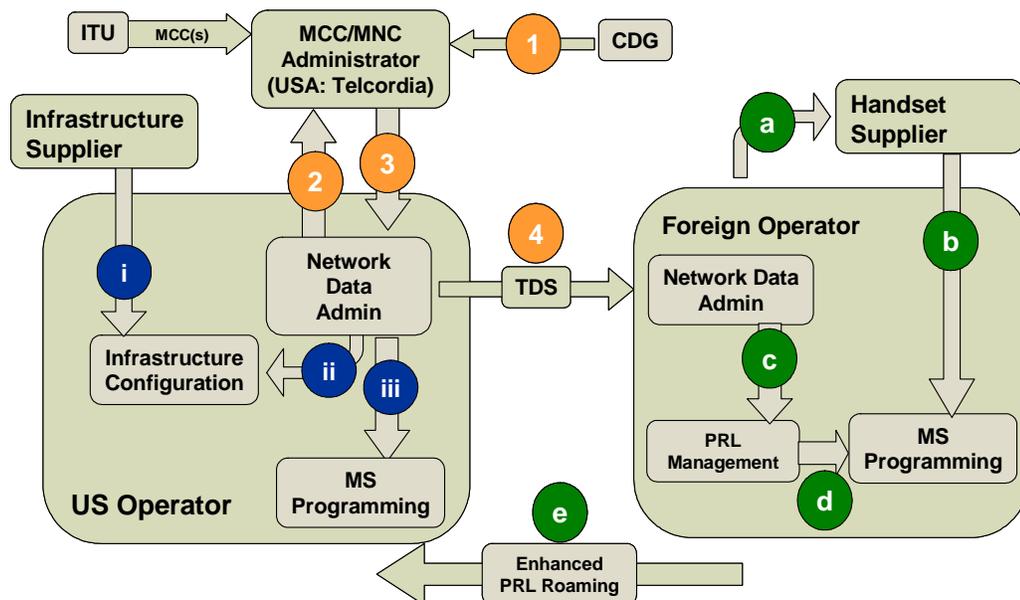
Figure 12-4 Implementation Process for PRL Enhancements

12.5.1 Broadcasting Operator

- **Obtaining MNCP**: The first stage in implementing the PRL enhancements is to obtain the valid MCC and IMSI_11_12 for their network(s) from the national administrator or regulator for mobile network codes.
- **Network config**: Configuring infrastructure and verifying the broadcast of valid MCC and IMSI_11_12 values. This may require consultation with the infrastructure vendor to enable access or capability.
- **Handset config**: Configuring handsets to have the new MCC and MNC configuration to ensure maximum efficiency of addressing on the paging and access channels.
- **Publication**: Declaring as part of the technical data exchange the MCC and MNC being broadcast by the network.

12.5.2 Inbound Roaming Operator

Once an operator has obtained and started to broadcast valid MCC and IMSI_11_12, then it is imperative to inform roaming partners of these values in Technical Data Sheet (TDS) exchange so that inbound roamers can start to utilize the PRL enhancements.

- **Mobile Device**: Specifying the PRL Enhancement behavior in handset specifications to ensure that the enhanced system determination capability is included.
- **PRL Development**: Building and distributing new PRLs with the more streamlined MCC/MNC entries.
- **PRL Distribution**: Loading of the enhanced PRL onto devices.

12.6 PRL Enhancements Impact on Infrastructure

The radio access network part of the infrastructure must support IMSI aspects as per existing standards and implementations. The MCC and IMSI_11_12 are already broadcast by CDMA operators. They are mandatory parameters in the *Extended Systems Parameters Message*. The MCC is assigned by ITU E.212 (see section 1.1.5). The IMSI_11_12 is allocated to each operator. (See section 1.1.6.)

The most important factor is that operators must be able to configure systems to broadcast their own MCC and IMSI_11_12. They currently may be broadcasting the current wildcard values (standards reserved values for MCC and IMSI_11_12) or some manufacturer defaults. It is critically important to note that the PRL enhancement requires **no migration to full IMSI in the ANSI-41 Core Network.** However, not all carriers have had formal national assignments of IMSI_11_12.

12.6.1 Impact on Access Channel Messaging

Section B.2 describes the addressing mechanisms on the access channel. Depending on network settings and how the devices MCC and IMSI_11_12 are programmed, how handsets are programmed will determine the form and length of mobile identity (including the IMSI_M/MIN) that is sent on the paging channel (10, 12, 13 or 15 digits).

12.6.2 Effect on Paging Channel Messaging

Section B.4 describes the addressing mechanisms on the paging channel. Depending on how handsets are programmed will determine the length of the IMSI_M (MIN) that is sent on the paging channel (10, 12, 13 or 15 digits).

It is recommended that the MCCp and IMSI_11_12p (programmed in the mobile station) are set to match the broadcasted MCC and IMSI_11_12 from the *Extended System Parameters Overhead Message* of the home network.

12.7 PRL Enhancement Benefits

The PRL enhancements provide a more efficient means to describe a network in a PRL and mean that a roaming partner has less need or interest in knowledge of the use of SIDs and NIDs within a visited network (from a PRL perspective). A national CDMA network may have a large number of SIDs (tens or hundreds) and can be replaced by a single system table entry per acquisition record required.

The PRL enhancements require no changes to existing standards, merely that existing messages/fields be populated with appropriate data. There is no need for full IMSI support to be available in the core network (ANSI-41) for PRL enhancements to function.

The major factor is that the enhancement allows for reduction in size of PRLs and therefore permits international roaming partners to describe a greater number of roaming networks in the same PRL memory space. More efficient use of memory is made in the handset of RUIM thereby enabling reduced PRL download times (OTA). PRL maintenance is made easier since it easier to ensure foreign partners' information is current.

12.8 Mobile Network Code Convention

12.8.1.1 USA MNC Assignment

Current US IMSI assignment guidelines call for the assignment of a 3-digit MCC and a 3-digit MNC. These guidelines are administered by the US IMSI Administrator on behalf of the IMSI Oversight Council. The current US IMSI Administrator is Telcordia Technologies.

All currently deployed CDMA equipment is constrained to operate on broadcasting a 2-digit MNC, as is the case in all deployed GSM networks. The CDG has, on behalf of the CDMA industry in the US, obtained the same waiver to these guidelines that is currently applied to GSM networks, which will ensure that all US CDMA operators will obtain mobile network codes in the form XX0. These MNCs are allocated on a next-available scheme where the next available may be a reclaimed MNC being placed back into operation. The USA has seven country codes allocated to it which are also administered by the US IMSI Administrator, so the assigned MNC may be in any one of these country codes, which are 310 through 316.

Similar MNC usage conventions may need to be adopted in other countries that are allocating 3-digit MNCs.

13. Acronyms and Abbreviations

Acronym / Abbreviation	Description
1xEV-DO	CDMA2000 evolution, data optimized
1x/IS-95	CDMA2000 evolution for voice and medium rate data
1xRTT	3G wireless technology based on the CDMA platform. The 1x in 1xRTT refers to 1x the number of 1.25MHz channels. The RTT in 1xRTT stands for Radio Transmission Technology
3G	Third-generation wireless system
3GPP2	Third Generation Partnership Project 2
AC	Alternating Current
AMPS	Advanced mobile phone system
ANSI	American National Standards Institute
ANSI-41	A worldwide network signaling standard used in CDMA systems
AT	Access terminal
AVRU	Automated voice response unit
BIDS	Billing identification (ID) numbers
BTA	Basic trading area
BSE	Base station emulators
BTS	Base transceiver station
CAIT	QUALCOMM CDMA air interface tester
CCITT	Consultative Committee on International Telegraphy and Telephony. Now replaced by ITU-T
CCLM	CDMA channel list message
CDG	CDMA Development Group
CDMA	Code division multiple access
CDMA-2000	A family of air interface standards evolved from IS-95. The family includes evolutionary steps such as 1X, EV-DO, EV-DO Rev A, etc.

Acronym / Abbreviation	Description
CSC	Customer service center
DC	Direct Current
DO	Data optimized (as in EV-DO)
Ec/Io	Energy per chip divided by energy of interference
EIA	Electronics Industry Association
E-PRL/EPRL	Enhanced Preferred Roaming List (PRL)
ECAM	Extended channel assignment message
ERI	Extended roaming indicator
ESN	Electronic serial number
EV	Evolution
EV-DO	Evolution data optimized
FCC	Federal Communications Commission
GEO	Geographical area
GRSA	Geographic region service areas
GSM	Global system for mobility
GSRM	Global system redirection message
HDR	High data rate
HLR	Home Location Register
HNI	Home network identity
HRPD	High rate packet data
HSPD	High speed packet data
ID	Identification
IFAST	International Forum on ANSI-41 Technology
IMSI	International mobile subscriber identity
IMSI_11_12	IMSI bits 11 and 12
IMSI_M	MIN-based IMSI
IMSI_O	Operational IMSI
IMSI_S	Short IMSI
IMSI_T	True IMSI
IMT	International Mobile Telecommunications

Acronym / Abbreviation	Description
ITU	International Telecommunications Union
IS-683	Over-the-air service provisioning of mobile stations in spread spectrum systems. This standard covers provisioning of system selection for preferred roaming parameters in addition to other topics. Obsolete version.
IS-683-A	Update to IS-683. Equivalent to 3GPP2 standard C.S0023. 3GPP2 version published December, 1999.
IS-683-B	Update to IS-683-A, with the addition of Preferred User Zone List. Equivalent to 3GPP2 standard C.S0023-A. 3GPP2 version published December, 2001.
IS-683-C	Update to IS-683-B. Equivalent to 3GPP2 standard C.S0023-B. 3GPP2 version published October, 2002.
IS-683-D	Update to IS-683-C. Equivalent to 3GPP2 standard C.S0023-C. 3GPP2 version published October, 2004.
IS-725-A	OTASP and OTAPA. This document contains modifications and additions to TIA/EIA-41 Revision D that are required to support the Over-The-Air Service Provisioning (OTASP) and Parameter Administration (OTAPA) features.
IS-95	Original CDMA air interface specification. Superseded by CDMA2000 specifications.
JTACS	Japanese Total Access Communications System
MCC	Mobile country code
MCCp	Mobile Country Code (programmed)
MIN	Mobile identification number
MIP	Mobile IP
MNC	Mobile network code
MNCp	Mobile Network Code (IMSI_11_12) programmed
MRU	Most recently used
MS	Mobile station
MSC	Mobile switching center
MSID	Mobile station ID
MSIN	MS Identification Number
MSM	Mobile station modem
MTA	Major trading area
NID	Network identification (number)

Acronym / Abbreviation	Description
NMSI	National MS identity
NV	Non-volatile
NV-RAM	Non-volatile random access memory (RAM)
OTA	Over the air
OTAF	Over the air function
OTAPA	Over the air parameter administration
OTASP	Over the air service provisioning
PDSN	Packet data serving node
PCS	Personal communications services
PLMN-Id	Public land mobile network identity
PN	Pseudo noise, typically used to refer to a random number
PRI	Product release information
PRL	Preferred roaming list
PSIST	Persistence parameter setting
QCT	Qualcomm CDMA Technology. The Qualcomm business unit which supplies chips for terminals and base stations.
RAM	Random Access Memory
RCL	Recent channel list
RF	Radio frequency
RIF	Return if fail
RL	Reverse link
RUIM/R-UIM	Removable user identity module
SD	System determination
SID	System identification
SIP	IETF session initiation protocol
SMS	Short messaging service
SPASM	Subscriber parameter administration security mechanism
SSPR	System selection for preferred roaming
SW	Software
TDS	Technical data sheet

Acronym / Abbreviation	Description
TIA	Telecommunications Industry Association
TLDN	Temporary local directory number
TSB	Telecommunications Standardization Body
UIM	User identity module
UTK	User identity module toolkit
UMTS	Universal Mobile Telecommunications System
VLR	Visitor location register
VRU	Voice response unit

A. PRL & the RUIM

There are often questions on how the PRL can be managed in a network where handsets are RUIM based. This section provides a brief overview of the RUIM memory map and how it can be changed.[15]

A.1 RUIM Memory Map

The majority of RUIMs are 32KB/64KB in size, and memory allocated is often operator specific. However, the conservative memory usage map given may be used for reference:

Table A-1 RUIM Memory Map Example

PRL File Size in KB		4		6		8	
Card Size / Element		32	64	32	64	32	64
ADN File		8					
SMS File		4					
EPRL File		2					
General RUIM Data		3					
Additional Overhead		2					
Free Memory		9	41	7	39	5	37

A.2 Memory Management on Deployed RUIMs

It is possible to remotely manage the RUIM over the air by using an OTA platform. OTA functions may include the ability to remotely update RUIM files. Subscription data is loaded on the RUIM instead of on the handset. A new RUIM should only be necessary when the operator wants to introduce new applications/services not currently supported by existing RUIMs deployed in the field due to functionality or memory constraints. A new RUIM data map may require more memory than is available on current cards. An OTA platform can update RUIMs with new files or applications using available card

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[15] Information provided by GEMPLUS

memory. Furthermore, these files/applications can be extended, deleted, and re-allocated to optimize a card's memory.

A.3 Extending the PRL on a Deployed RUIM

Most of the file structure and application data/code can be modified. Certain key data files may not be updated due to access condition restrictions, defined during card personalization. An OTA platform is necessary to modify these files post-issuance. For example, a deployed 32KB RUIM with only 1KB allocated for the PRL can be modified for a larger PRL, if free memory is unavailable. Outdated or unused files/applications can be deleted to free memory for a larger PRL file. If memory is available, the file may be extended to increase its size. On deployed RUIMs, an OTA platform is required to perform these updates.

A.4 PRL and E-PRL on the RUIM

C.S0023-B (aka IS-683-C) defines two PRL storage locations on the RUIM, one called PRL and one called EPRL. The EPRL file location is intended to store the extended IS-683-C format PRL and the PRL location stores the IS-683-A and -B versions. The reason that two were defined is because the PRL and EPRL formats are not compatible, that is, a non E-PRL device could not accept an EPRL.

The expected behavior would have be that the revision A/B PRL be in the PRL location and the revision C PRL (EPRL) be in the EPRL location The device would read from the appropriate location based on its capabilities. This may not be widely supported yet.

A.5 Concatenated PRL

Some operators, with a deployed base of C.S0023-0 compliant cards, stipulated that existing cards work for 1xEV-DO (which requires an EPRL). C.S0023-0 was around before 1xEV-DO and the IS-683-A/B PRLs were not designed to support 1xEV-DO.

This gave rise to something known as the concatenated PRL which is able to concatenate a PRL and EPRL into the PRL location. (Effectively two PRLs in one space, - the rev A PRL with its checksum, and a concatenated PRL with a new checksum.) This doesn't require C.S0023-B card to support DO. This is a work around for the existing card.

B. PRL Enhancements & Overhead Messaging

A common question on the PRL enhancements is how it affects the access and paging addressing and whether these values need to be programmed into the handset. This appendix provides some background information to describe these aspects from the handset perspective and shows how access and paging works with and without the PRL enhancements.

B.1 IMSI in the Mobile Device

The IMSI consists of up to 15 numerical characters (0-9) (Figure B-1). The MCC is the first 3 digits of the IMSI. The National MS Identity (NMSI) is formed by the remaining digits. The NMSI comprises the MNC and MSIN.

The MCC is the 3-digit, ITU-specified code identifying the home country as applied to mobile networks; some countries have more than one MCC (e.g. the USA has 310-316). The MCC is described in the CCITT Recommendation E.212.
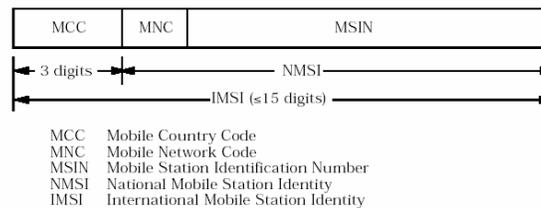
Figure B-1 IMSI Structure

When an IMSI has 12 or more digits IMSI_11_12 denotes the 11th and 12th digits of the IMSI. When an IMSI has fewer than 12 digits it is padded with leading zeros to 12 digits. IMSI_11_12 is the 11th and 12th digits of the resulting number.

When reading about IMSI use over the air there the class of an IMSI is often mentioned. It can be one of two classes: 0 or 1. .A <u>Class 0 IMSI</u> is 15 digits in length and a <u>Class 1 IMSI</u> is less than 15 digits[16]. Class 1 IMSIs are not often encountered in CDMA.

IMSI_S (sometimes referred to as the short IMSI) is a 10-digit (34-bit) number derived from the IMSI[17]. The 10-digit IMSI_S consists of two parts as shown in Figure B-2. IMSI_S2 the most significant 3- digit part (10 bits) and IMSI_S1 the remaining 7-digit part (24 bits).

MCC	MNC	MSIN		

	IMSI_S2	IMSI_S1		
IMSI_S Digits →	First 3 Digits	Second 3 Digits	Thousands Digit	Last 3 Digits
	XXX	XXX	X	XXX
Bits →	10	10	4	10
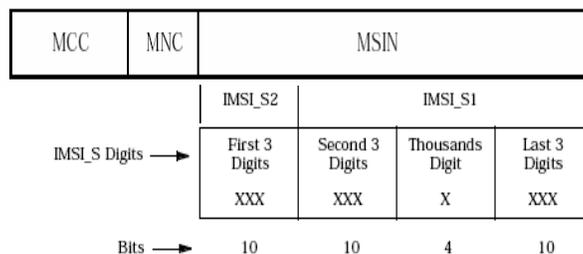
Figure B-2 IMSI_S

From the handset perspective there are **two** IMSIs but **three** IMSI labels; the following sections identify the IMSI terms used.

B.1.1 MIN Based IMSI (IMSI_M)

A MIN-based IMSI is actual IMSI value. It contains a MIN in the right-most 10 digits of the NMSI. If there is no IMSI_M assigned to the mobile then its storage location contains a 10-digit value representing the four least-significant digits of the ESN with leading zeros.

B.1.2 True IMSI (IMSI_T)

A true IMSI is another actual and distinct IMSI value. It is not associated with the MIN and can have any number as the NMSI. If there is no IMSI_T assigned to the mobile then its storage location contains a 10-digit value representing the four least-significant digits of the ESN with leading zeros.

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16 The National MS Identity (NMSI) is less than 12 digits in length). If the MS has a class 1 IMSI, it also has an IMSI_ADDR_NUM which is a number whose value is equal to the number of digits in the NMSI minus four.

17 For an IMSI with ten or more digits has IMSI_S is equal to the last ten digits. An IMSI has fewer than ten digits, the least significant digits of IMSI_S are equal to the IMSI and zeros are added to the most significant side to obtain a total of ten digits.

B.1.3 Operational IMSI (IMSI_O)

This is not another IMSI value but rather a selection of one of the previous two. It is a label that is given to the IMSI value that the MS actually uses. The operational IMSI (IMSI_O) can be the IMSI_M or the IMSI_T. The choice of which IMSI gets the IMSI_O designation is a decision based on the IMSI values that are provisioned into the mobile device and also whether or not the Network supports true IMSI or not (IMSI_T_SUPPORTED field of the extended system parameters message). Table B-1 shows how this choice is made.

Table B-1 Operational IMSI Selection

Forming the Operational IMSI (IMSI_O)			
True IMSI Supported	**MS has an IMSI_T**	**MS has an IMIS_M**	**IMIS_O uses**
No	No	No	-
	No	Yes	IMSI_M
	Yes		
	Yes	No	**Not Specified**
Yes	No	No	-
		Yes	IMSI_M
	Yes	No	IMSI_T
Note: IMSI_O cannot be formed from IMSI_T when the network does not support true IMSI and no IMSI_M is assigned.			

B.1.4 Special or Wildcard MCC & IMSI_11_12

The MS stores the networks MCC/MNC identity (values of MCC & IMSI_11_12 received in the extended system parameters message). A special set of wildcard values can be transmitted by the network (only when IMSI_T is not supported by the network). These wildcard values are:

- MCC received over the air of all 1s i.e. '1111111111' or 1023
- The IMSI_11_12 received over the air of all 1s i.e. '1111111' or 127

Receiving the wildcard values indicates to the mobile that it must assume that the values of the MCC and IMSI_11_12 provisioned in IMSI_M are also those of the network. See Table B-2.

Table B-2 How the Mobile Decides which MCC and IMSI_11_12 to Use

Storing the Network's MCC & ISMI_11_12			
MCC Received	IMSI_11_12 Received	MCC Stored	IMSI_11_12 Stored
All 1s (1023)	All 1s (127)	IMSI_M_MCC	IMSI_M_11_12
NNN*	nn**	NNN*	nn*
*NNN is any valid MCC 000 – 999 **nn is any valid 00 – 99			

B.2 Mobile Identity Sent to Network (Access Channel)

The way the mobile identifies itself on the access channel by something called the Mobile Station ID (MSID). The MSID can be conceptually understood as being formed from:

- ▪ **MSID Type**: Which indicates the identities that have been used and,
- ▪ **Identities**: As described in the type. These identities can be combinations of the ESN, the short form of the operational IMSI and the long form of the operational IMSI.

The network tells the mobile which identities it wants to be contained in the MSID by sending out the preferred MSID type in the overhead messages (PREF_MSID_TYPE parameter in the Extended System Parameters Message). The mobile device must choose the best way to comply with the networks preference. The only time that the mobile will not be ably to comply is where no IMSI is present and it must use ESN alone since that is all it has. The mobile tells the network which MSID type it is using (MSID_TYPE parameter in access channel messages).

Table B-3 clearly shows which identities to use when the appropriate preferences are declared by the network. The identities relevant to the MSID type are shown in brackets.

Table B-3 Access Addressing

IMSI & Mobile Station Id Parameter				
Network Supports True IMSI?	IMSI_0 is Formed From?	Network Prefers	MS Will Use	Applies to Band Class
Don't Care	None	XX (Don't Care)	001 (ESN)	ALL
No	IMSI_M	00 (IMSI_S & ESN)	000 (IMSI_M_S and ESN)	0 only
		10 (IMSI)	010 (IMSI_M)	ALL
		11 (IMSI and ESN)	011 (IMSI_M and ESN)	
Yes	IMSI_M	10 (IMSI)	010 (IMSI_M)	
		11 (IMSI and ESN)	011 (IMSI_T and ESN)	
	IMSI_T	10 (IMSI)	010 (IMSI-T)	
		11 (IMSI and ESN)	011 (IMSI_T and ESN)	

B.2.1 Does the Mobile have to Send the MCC and IMSI_11_12 All the Time?

When an IMSI is used as part of the MSID, whether a mobile device needs to transmit the MCC and IMSI_11_12 components as part of the MSID is determined by how the network's MCC and IMSI_11_12 compare to the programmed MCC and IMSI_11_12 of the mobile device.

When either the MCC or IMSI_11_12 values (of the network and those of the mobile device) match, then that matching value need not be sent over the air as part of the MSID. This efficiency is only applicable to a 15-digit IMSI (i.e. class 0 IMSI).

However, since either or both of the MCC and IMSI_11_12 may not now be present in the IMSI part of the MSID then the combination that is sent must be declared. This is done by declaring the type of class 0 IMSI that is being used as part of the MSID (IMSI_Class_0_Type field in the MSID). Table B-4 shows the comparisons that are made and the resultant values that are sent over the air.

Table B-4 Components of IMSI Sent on Access Channel

CLASS of IMSI_O	MCC and IMSI_11_12 Comparison		MSID Used on the Access Channel			
	Network MCCs = IMSI_O_MCC	Network IMSI_11_12 = IMSI_O_11_12	IMSI Class 0 Type	MCC	IMSI_11_12	IMSI_S
0	Yes	Yes	00	-	-	IMSI_O_S
	Yes	No	01	-	IMSI_O_11_12	IMSI_O_S
	No	Yes	10	IMSI_O_1MCCs	-	IMSI_O_S
	No	No	11	IMSI_O_1MCCs	IMSI_O_11_12	IMSI_O_S

B.2.2 Access Addressing with MCC and IMSI_11_12 Wildcards

Understanding how the mobile device selects the address to use on the access message, the example in Figure B-3 shows how a mobile identifies itself when accessing a network that broadcasts the wildcards values of MCC and IMSI_11_12.
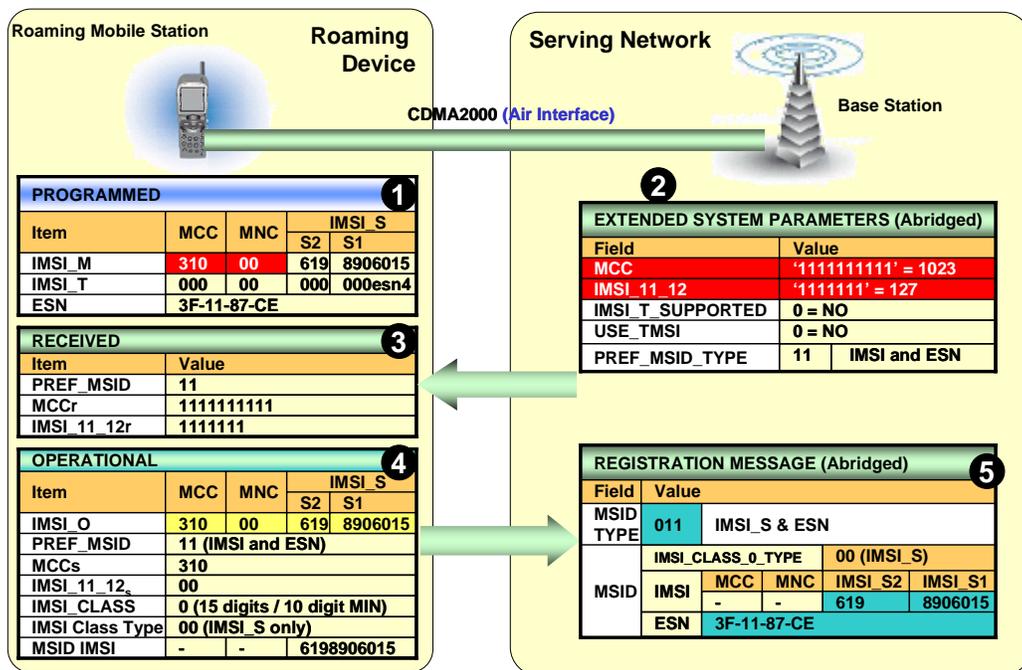
Figure B-3 Mobile Accessing a Network with MCC and MNC Wildcards

1. This case shows a mobile with only an IMSI_M programmed and with the MCC and IMSI_11_12 set to 310 and 00, respectively.

2. The network is broadcasting wildcard values of MCC and IMSI_11_12 (i.e. all bits set to 1). This network is declaring no support for true IMSI or temporary IMSI. This network would like mobiles to identify themselves using IMSI and ESN.

3. The mobile stores the network's MCC and IMSI_11_12 values and the preferred mobile station identity type.

4. The wildcard values also tell the mobile to assume that the network has the MCC and IMSI_11_12 values of 310 and 00. The mobile has an IMSI_M programmed. It is able to comply with the networks request to use the IMSI and ESN as MSID and sets its MSID_TYPE accordingly. Since the MCC and IMSI_11_12 wildcards were used the network and handset MCC and IMSI_11_12 are assumed to be equal therefore do not need to be sent over the air the IMSI_CLASS_0_TYPE is set to '00' (IMSI_S only).

5. The MSID that is sent over the air to the base station has an MSID_TYPE indicating that an ESN and IMSI follow, of which only the last 10 digits need to be sent, i.e. IMSI_O_S, which is effectively the MIN.

B.2.3 Access Addressing with Network MCC & MNC Different from Handset

Once the wildcard values broadcast by the network change then existing handsets that are programmed with anything other than the new broadcast values will have to use the full 15 digits as shown in Figure B-4.
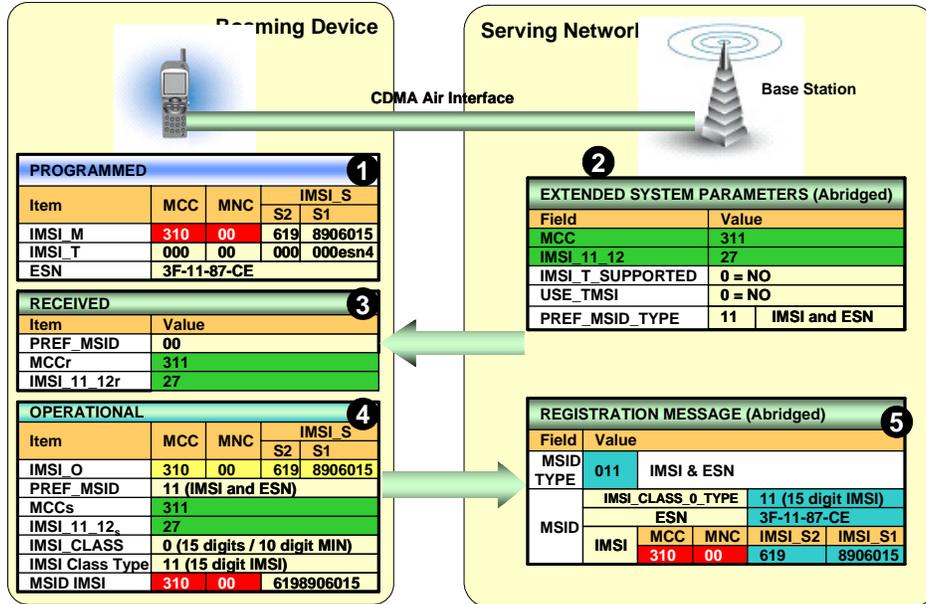
Figure B-4 Mobile Accessing a Network with a Different MCC and IMSI_11_12

1. This case shows a mobile with only an IMSI_M programmed and with the MCC and IMSI_11_12 set to 310 and 00, respectively.

2. The network is broadcasting real values of MCC and IMSI_11_12 of 311 and 27 respectively. This network is declaring no support for true IMSI or temporary IMSI. This network would like mobiles to identify themselves using IMSI and ESN.

3. The mobile stores the network's MCC and IMSI_11_12 values and the preferred mobile station identity type.

4. The network has the MCC and IMSI_11_12 values of 311, 27 while the mobile has 310 and 00. The mobile has a programmed IMSI_M and is able to comply with the networks request to use the IMSI and ESN as MSID. Since the network MCC and IMSI_11_12 and handset MCC and IMSI_11_12 are different, they do need to be sent over the air the IMSI_CLASS_0_TYPE is set to '11' (MCC+IMSI11_12+IMSI_S).

5. The MSID that is sent over the air to the base station has an MSID_TYPE indicating that an ESN and IMSI follow, which means that all 15 digits of the IMSI need to be sent, i.e. IMSI_O_MCC, IMSI_O_11_12 and IMSI_O_S.

B.2.4 Access Addressing with Network MCC & MNC Same as Handset

Once the wildcard values broadcast by the network change then existing handsets that are programmed with anything other than the new broadcast values will have to use the full 15 digits as shown in Figure B-5.
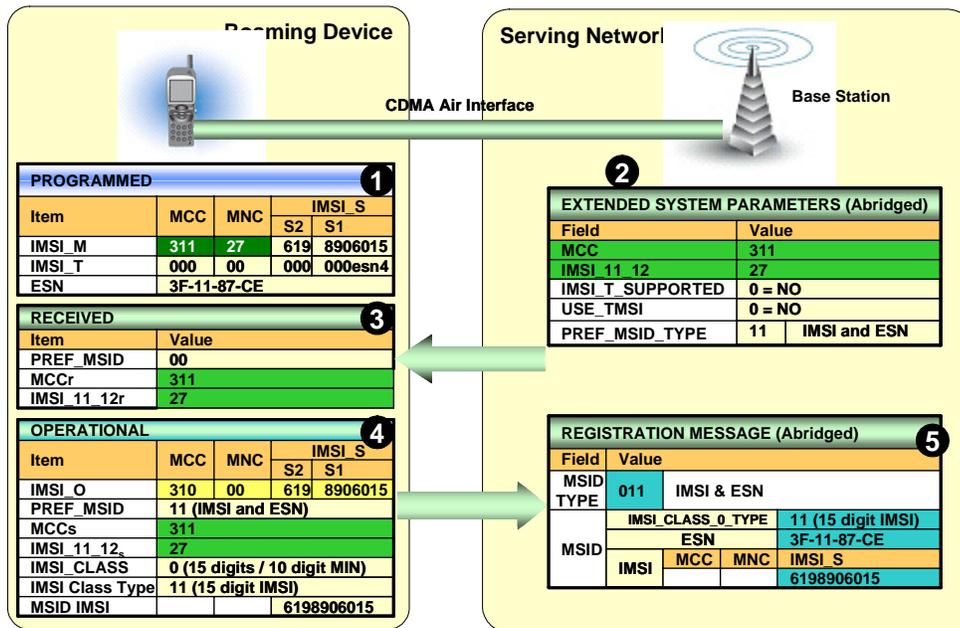
Figure B-5 Mobile Accessing a Network with the Same MCC and IMSI_11_12

1. This case shows a mobile with only an IMSI_M programmed and with the MCC and IMSI_11_12 set to 311 and 27, respectively.

2. This network broadcasts values of MCC and IMSI_11_12 of 311 and 27, respectively. This network is declaring no support for true IMSI or temporary IMSI. This network would like mobiles to identify themselves using IMSI and ESN.

3. The mobile stores the network's MCC and IMSI_11_12 values and the preferred mobile station identity type.

4. The MCC and IMSI_11_12 values of the network and handset are identical. The mobile has an IMSI_M programmed. It is able to comply with the networks request to use the IMSI and ESN as MSID and sets its MSID_TYPE accordingly. Since the MCC and IMSI_11_12 are equal they do not need to be sent over the air. IMSI_CLASS_0_TYPE is set to '00' (IMSI_S only).

5. The MSID that is sent over the air to the base station has an MSID_TYPE indicating that an ESN and IMSI follow, of which only the last 10 digits need to be sent (i.e. IMSI_O_S).

B.2.5 Access Addressing with Network MNC & Handset MNC Different

When the network broadcasts either an MCC or IMSI_11_12 (MNC) that is the same as the IMSI programmed in the handset, then the coincident value need not be sent. The example shown in Figure B-6 shows the access channel efficiencies that occur when the broadcast MCC is the same as the programmed MCC and the IMSI_11_12 values are different.
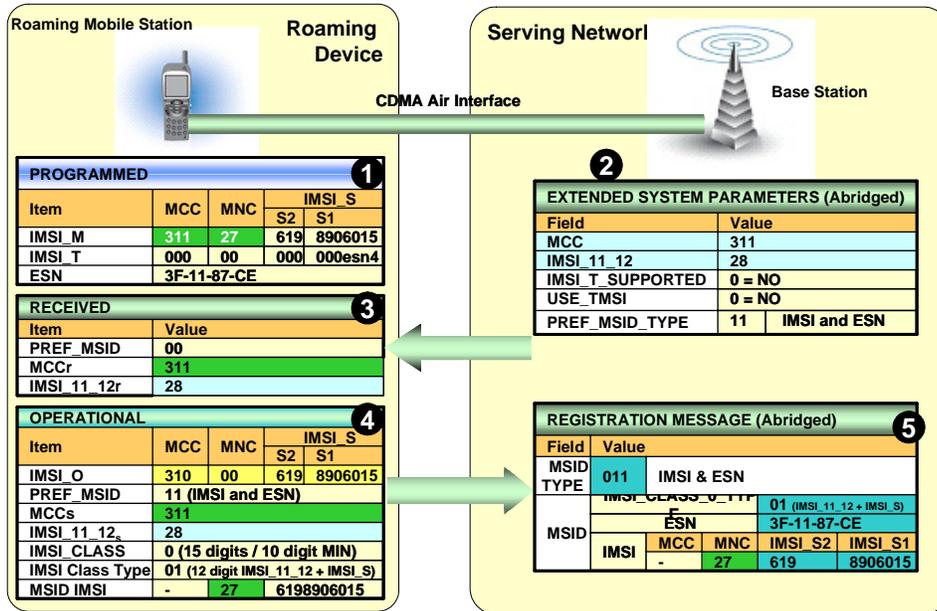
Figure B-6 Mobile Accessing a Network with Same MCC and Different IMS_11_12

1. This case shows a mobile with only an IMSI_M programmed and with the MCC and IMSI_11_12 set to 311 and 27, respectively.

2. This network broadcasts values of MCC and IMSI_11_12 of 311 and 28 respectively. This network is declaring no support for true IMSI or temporary IMSI. This network requests that mobiles identify themselves using IMSI and ESN.

3. The mobile stores the network's MCC and IMSI_11_12 values and the preferred mobile station identity type.

4. The MCC values of the network and handset are identical. The IMSI_11_12 values of the network and the IMSI_O are different. The mobile has an IMSI_M programmed. It is able to comply with the networks request to use the IMSI and ESN as MSID and sets its MSID_TYPE accordingly. Since the MCC values are equal they do not need to be sent over the air. IMSI_CLASS_0_TYPE is set to '01' (IMSI_11_12 and IMSI_S).

5. The MSID that is sent over the air to the base station is has an MSID_TYPE indicating that an ESN and IMSI follow, of which only the last 12 digits need to be sent, i.e. IMSI_O_11_12 and IMSI_O_S.

B.3 Access Address Stored in the Network

Once the registration message is received by the MSC then it must perform a registration based on the mobile identity. However, unless the core network is operating on ANSI-41 revision E or with IS-751 additions, communications with the HLR are limited to a mobile identification of 10 digits.

The PRL enhancements do not require or suggest that full IMSI support be implemented in the ANSI-41 network. They have been designed such that no standards changes are required. The use of MCC and IMSI_11_12 values in the Radio Access Network is stipulated by IS-95 and TIA/EIA-2000 CDMA standards.

The VLR has the responsibility of storing the values of MCC and IMSI_11_12 used in the access address of the radio network. Although these values are not propagated in ANSI-41, they are stored at the VLR, as can be seen in Figure B-7.
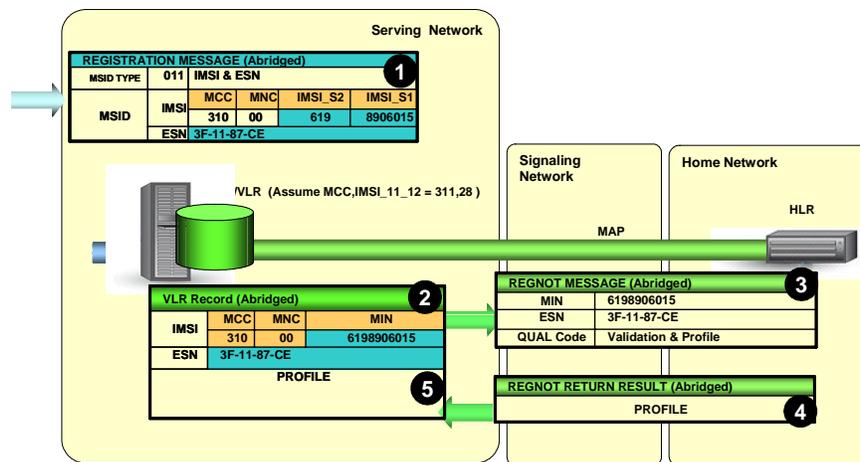
Figure B-7 Core Network Address Components.

1. The registration message arrives at the MSC, in this case the MCC and IMS_11_12 values of the registering handset are different from the 311, 27 values of the network.
2. The MSC records the ESN and IMSI values received from the radio access network.
3. This VLR is ANSI-41D and is limited to using a 10-digit IMSI_S in all messages to the HLR – the registration notification is sent with the IMSI_S value and ESN.
4. The HLR validates and authorizes the registration and return to the VLR the profile for the identified mobile station identity.
5. The profile is stored in the VLR and service is provided in accordance with the profile.

B.4 Page Addressing

To communicate with a particular mobile the network 'pages' it on the paging channel, in a PAGING Message, using the appropriate form of address.

The paging message contains page records for one or more mobile devices. The form of address in a page record is stipulated by two pieces of information:

- The page class
- The page sub-class

B.4.1 Page Class

The page class that is used to page a mobile is a function of the type of address the mobile used to register and the type of page message as is shown in Table B-5. Most commonly, page class '00' is encountered.

Table B-5 Different Classes for a Page

Page Class on Paging Channel	
Page Class	Type of Page Address
00	Device registered with a class 0 IMSI
01	Device registered with a class 1 IMSI
10	Pane using a TMSI
11	Announcing a broadcast message

B.4.2 Page Sub-Class

The page sub-class defines the information that is included in the page record to use for matching. Since Class 0 IMSI are the most prevalent in CDMA networks, we only consider the page sub-classes of page class '00.' In effect, the page sub class delivers the same efficiencies on the paging channel that section B.2.1 described for the access channel, except that the comparisons are based on the values 'programmed' in the network and the mobile devices' stored values in the network (from the registration).

The page sub-class describes four distinct formats of the page record. These formats vary only based on the inclusion of the MCC and IMSI_11_12 components of the IMSI; as is shown in Table B-6.

Table B-6 Page Records Based on MCC & IMSI_11_12 Equality (page sub-class)

IMSI Used in Registration (stored by Serving System)			Page Record Contents on the Paging Channel					Record Format Number
Class	Same MCC as Serving System	Same IMSI _11_12 as Serving System	Page Class	Page Sub-Class	MCC (7 bits)	IMSI_11_12 (10 bits)	IMSI_S (34 bits)	
0	Yes	Yes	00	00	(not sent)	(not sent)	IMSI_S	0
	Yes	No		01	(not sent)	IMSI_11_12	IMSI_S	1
	No	Yes		10	IMSI_MCC	(not sent)	IMSI_S	2
	No	No		11	IMSI_MCC	IMSI_11_12	IMSI_S	3

B.4.3 Page Matching

When an IMSI is used as part of the MSID, whether a mobile device needs to transmit the MCC and IMSI_11_12 components as part of the MSID is determined by how the network's MCC and IMSI_11_12 compare to the programmed MCC and IMSI_11_12 of the mobile device. See Table B-7.

Table B-7 Page Sub-class Definitions for a Class-0 IMSI

IMSI Used in Registration (stored by Serving System)					Page Record Contents on the Paging Channel				
Class of IMSI_O	MCC		IMSI_11_12		Page Class	Page Sub-Class	MCC (7 bits)	IMSI_11_12 (10 bits)	IMSI_S (34 bits)
	MCCr (Serving System)	IMSI_O_MCC	IMSI_11_12r (Serving System)	IMSI_O_11_12					
0	Equal		Equal		00	00			=IMSI_S
	Equal		Don't Care			01		=IMSI_11_12	=IMSI_S
	Don't Care		Equal			10	=IMSI_MCC		=IMSI_S
	Don't Care		Don't Care			11	=IMSI_MCC	=IMSI_11_12	=IMSI_S

B.4.4 Paging a Mobile in a Network with MCC and IMSI_11_12 Wildcards

Armed with the rules of the page message addressing; the example shows how a mobile is paged when registered on a network that broadcasts the wildcards values of MCC and IMSI_11_12 (Figure B-8).
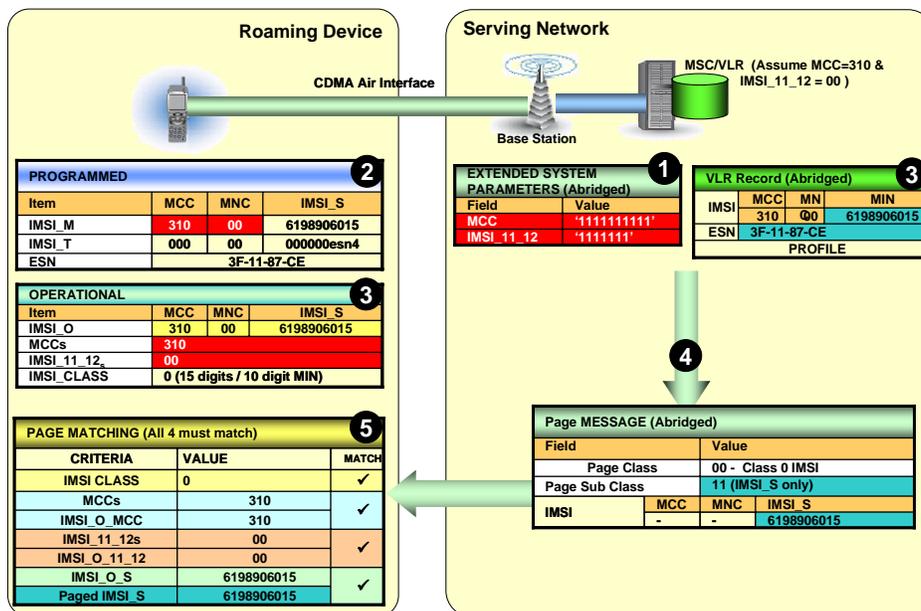
Figure B-8 Page Matching - Network Broadcasts Wildcard MCC & IMSI_11_12

1. The network broadcasts wildcard values of MCC and IMS_11_12 instructing the mobile device to assume that the broadcast values match the programmed values.

2. The mobile device has a class 0 IMSI, and MCC and programmed IMSI_11_12 values of 310 and 00, respectively.

3. The mobile device registers with just the IMSI_S (see section B.1). The MSC records the ESN and IMSI values arriving from the radio access network. In this case it is assumed that the network assumes itself to be 310, 00.

4. The MSC (call delivery or similar) requires that the mobile be paged. A page message is constructed; since MCC and IMSI_11_12 are deemed equal the page record contains only the 10-digit IMSI_S.

5. The mobile device performs its page matching for a page record of this format:
   - The IMSI must be a class 0 IMSI
   - The network MCC (MCCs) must be the same as the IMSI_O_MCC
   - The network IMSI_11_12 values of the network and of IMSI_O must match
   - The paged IMSI_S must equal IMSI_O_S

B.4.5 Paging a Mobile in a Network Broadcasting Different MCC and IMSI_11_12

Figure B-9 shows how a mobile is paged when registered on a network that broadcasts values of MCC and IMSI_11_12.
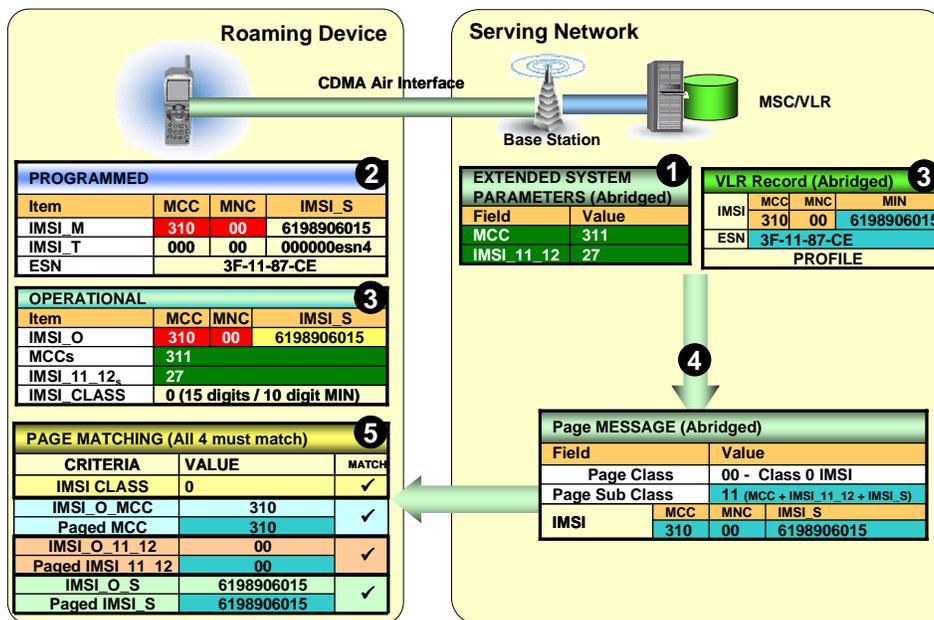
Figure B-9 Page Matching - Network and Mobile MCC & IMSI_11_12 are Different

1. The network broadcasts values of MCC and IMS_11_12 of 311 and 27, respectively.
2. The mobile device has a class 0 IMSI, and MCC and programmed IMSI_11_12 values of 310 and 00, respectively.
3. The mobile device registers with a 15 digit IMSI (see sectionB.2.3). The MSC records the ESN and IMSI values arriving from the radio access network. In this case the mobile device has an MCC and IMSI_11_12 of 310, 00.
4. The MSC requires that the mobile be paged. A page message is constructed; since MCC and IMSI_11_12 are different the page record contains the 15-digit IMSI.
5. The mobile device performs its page matching for a page record of this format:
    -   The IMSI must be a class 0 IMSI
    -   The page record MCC must be the same as the IMSI_O_MCC
    -   The IMSI_11_12 values of the page record and of IMSI_O must match
    -   The page record IMSI_S must equal IMSI_O_S

B.4.6 Paging a Mobile in a Network Broadcasting Different MCC and IMSI_11_12

Figure B-10 shows how a mobile is paged when registered on a network that has the same values of MCC and IMSI_11_12.
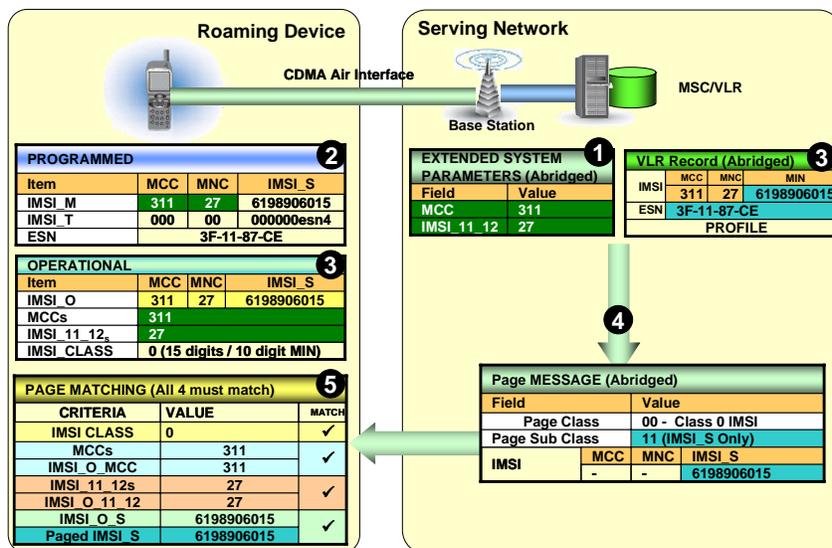
Figure B-10 Page Matching – Network & Mobile Have Same MCC & IMSI_11_12

1. The network broadcasts values of MCC and IMS_11_12 of 311 and 27, respectively.

2. The mobile device has a class 0 IMSI, and MCC and programmed IMSI_11_12 values are 311 and 27, respectively.

3. The mobile device registers with a 10-digit IMSI (see section B.2.4). The MSC records the ESN and IMSI values arriving from the radio access network. In this case the mobile device has an MCC and IMSI_11_12 of 311, 27; the same as the network.

4. The MSC requires that the mobile be paged. A page message is constructed. Since MCC and IMSI_11_12 are the same, the page record contains the 10-digit IMSI.

5. The mobile device performs its page matching for a page record of this format:
   - The IMSI must be a class 0 IMSI
   - The MCC values of the network (MCCs) and the IMSI_O must match
   - The IMSI_11_12 values of the network (IMSI_11_12s) and of IMSI_O must match
   - The IMSI_S values of the page record and IMSI_O must match

B.4.7 Access Addressing with Network MNC & Handset MNC Different

When the network broadcasts either an MCC or IMSI_11_12 (MNC) that is the same as the IMSI programmed in the handset then the coincident value need not be included in the page record. The example shown in Figure B-11 shows the paging channel efficiencies that occur when the broadcast MCC is the same as the programmed MCC and the IMSI_11_12 values are different.
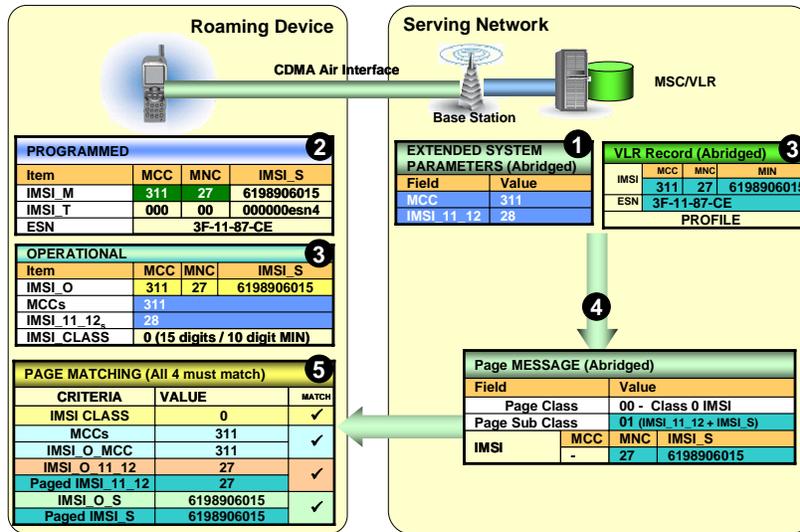
Figure B-11 Page Matching - Network & Mobile MCC the Same - IMSI_11_12 Different

1. The network broadcasts values of MCC and IMS_11_12 of 311 and 28, respectively.

2. The mobile device has a class 0 IMSI, and MCC and programmed IMSI_11_12 values are 311 and 27, respectively.

3. The mobile device registers with a 12-digit IMSI (see section B.2.5). The MSC records the ESN and IMSI values arriving from the radio access network. In this case the mobile device has an MCC and IMSI_11_12 of 311, 28.

4. The MSC requires that the mobile be paged. A page message is constructed; since the MCC values are the same and IMSI_11_12 values are different the page record contains 12 digits of the IMSI.

5. The mobile device performs its page matching for a page record of this format:
   - The IMSI must be a class 0 IMSI
   - The MCC values of the network (MCCs) and the IMSI_O must match
   - The IMSI_11_12 values of the page record and of IMSI_O must match
   - The IMSI_S values of the page record and IMSI_O must match

C. Band-Class 0 and 1 Channels (US)

Table C-1 Frequencies and Channel Numbers for Band-Classes 0 and 1

Band-class	Band/Block	Reverse Link Frequency Range (MHz) Lower	Upper	Forward Link Frequency Range (MHz) Lower	Upper	Valid for CDMA	Channel Number Range Lower	Upper	Channel Band-width (MHz)	Number of Channels
0	A''	824.040	824.670	869.040	869.670	FALSE	991	1012	0.030	22
	A''	824.700	825.000	869.700	870.000	TRUE	1013	1023	0.030	11
	A	825.030	834.330	870.030	879.330	TRUE	1	311	0.030	311
	A	834.360	834.990	879.360	879.990	FALSE	312	333	0.030	22
	B	835.020	835.650	880.020	880.650	FALSE	334	355	0.030	22
	B	835.680	844.320	880.680	889.320	TRUE	356	644	0.030	289
	B	844.350	844.980	889.350	889.980	FALSE	645	666	0.030	22
	A'	845.010	845.640	890.010	890.640	FALSE	667	688	0.030	22
	A'	845.670	845.820	890.670	890.820	TRUE	689	694	0.030	6
	A'	845.850	846.480	890.850	891.480	FALSE	695	716	0.030	22
	B'	846.510	847.140	891.510	892.140	FALSE	717	738	0.030	22
	B'	847.170	848.310	892.170	893.310	TRUE	739	777	0.030	39
	B'	848.340	848.970	893.340	893.970	FALSE	778	799	0.030	22
1	A	1850.000	1851.200	1930.000	1931.200	FALSE	0	24	0.050	25
	A	1851.250	1863.750	1931.250	1943.750	TRUE	25	275	0.050	251
	A	1863.800	1864.950	1943.800	1944.950	CONDITIONAL	276	299	0.050	24
	D	1865.000	1866.200	1945.000	1946.200	CONDITIONAL	300	324	0.050	25
	D	1866.250	1868.750	1946.250	1948.750	TRUE	325	375	0.050	51
	D	1868.800	1869.950	1948.800	1949.950	CONDITIONAL	376	399	0.050	24
	B	1870.000	1871.200	1950.000	1951.200	CONDITIONAL	400	424	0.050	25
	B	1871.250	1883.750	1951.250	1963.750	TRUE	425	675	0.050	251
	B	1883.800	1884.950	1963.800	1964.950	CONDITIONAL	676	699	0.050	24
	E	1885.000	1886.200	1965.000	1966.200	CONDITIONAL	700	724	0.050	25
	E	1886.250	1888.750	1966.250	1968.750	TRUE	725	775	0.050	51
	E	1888.800	1889.950	1968.800	1969.950	CONDITIONAL	776	799	0.050	24
	F	1890.000	1891.200	1970.000	1971.200	CONDITIONAL	800	824	0.050	25
	F	1891.250	1893.750	1971.250	1973.750	TRUE	825	875	0.050	51
	F	1893.800	1894.950	1973.800	1974.950	CONDITIONAL	876	899	0.050	24
	C	1895.000	1896.200	1975.000	1976.200	CONDITIONAL	900	924	0.050	25
	C	1896.250	1908.750	1976.250	1988.750	TRUE	925	1175	0.050	251
	C	1908.800	1909.950	1988.800	1989.950	FALSE	1176	1199	0.050	24