# HOW TO EVALUATE FIELD TEST PERFORMANCE OF A CDMA2000 HANDSET

by

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# ABSTRACT

With the ever-increasing demand of high-speed wireless data from the mobile users in North America, a wide range of Third Generation (3G) Code Division Multiple Access 2000 (CDMA2000) mobile phones will be launched. It is important that all CDMA2000 mobile stations go through a well defined, complete, and thorough test before launching out into the market. One critical test activity for this purpose is field test.

The goal of this project is to discuss the importance of field test activities, to demonstrate the evaluation of CDMA2000 mobile phone field performance, to implement four field test cases for verifying the CDMA2000 voice service, and, finally, to execute the field test cases. We analyze the four field test cases, and illustrate the methodology of test case design for the research and development (R&D) field test.

In this project, we introduce the CDMA technology and the added benefits provided by the 3G CDMA2000. We discuss the testing methodology within a software engineering model, and differentiate the field test from other testing activities. We also show that field test is an important and high priority task in R&D projects. It is mandatory to include field test in any handset development project. We elaborate on the details of field test activities, which include test planning, test tools application, test sites selection, test case design, and test results analysis. We illustrate the typical field test analysis required for the R&D

field test. In particular, the R&D field test results confirm that the message flow complies with the IS-2000.5 Rev.0 Upper Layer (L3) Signaling Standard [1].

# DEDICATION

This project is dedicated to my coworkers and supervisors who have worked with me for the past few years, to the companies that I have worked for and their sponsorship of my Master degree, and to my family and friends who have encouraged me for pursuing my degree.

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# ACRONYMS AND ABBREVIATIONS

| Term | Definition |
|---|---|
| 1X | 1XRTT |
| 1XRTT | Single Carrier Radio Transmission Technology |
| 1XEV | Single Carrier Evolution |
| 1XEV-DO | Single Carrier Evolution for Data Only |
| 1XEV-DV | Single Carrier Evolution for Data and Voice |
| 2G | Second Generation |
| 3G | Third Generation |
| 3GPP2 | Third Generation Partnership Project 2 |
| AC | Authentication Center |
| AMPS | Advanced Mobile Phone System |
| BS | Base Station |
| BSC | Base Station Controller |
| BTS | Base Station Transceiver |
| CAIT | CDMA Air Interface Tester |
| CDG | CDMA Development Group |
| CDMA | Code Division Multiple Access |
| CDPD | Cellular Digital Packet Data |
| CTIA | Cellular Telecommunications and Internet Association |
| DTMF | Dual-Tone Multi-Frequency |
| Ec/Io | Energy of desired pilot alone / Total energy received |
| EHDM | Extended Handoff Direction Message |
| EMS | Enhanced Message Service |
| ESN | Electronic Serial Number |
| EVRC | Enhanced Variable Rate Codec |
| E911 | Emergency 911 |
| FER | Frame Error Rate |
| GHDM | General Handoff Direction Message |
| GPS | Global Positioning System |
| HLR | Home Location Register |
| HSPD | High Speed Packet Data |
| IMT-2000 | International Mobile Telephony 2000 |
| ITU | International Telecommunications Union |
| IWF | Inter Working Function |
| JTACS | Japanese Total Access Communications System |
| LAC | Link Access Control |
| MAC | Medium Access Control |
| MAHO | Mobile Assisted Handoff |
| MMS | Multimedia Service |
| MO | Mobile Originated |

| Term | Definition |
|---|---|
| MS | Mobile Station |
| MSC | Mobile Switching Center |
| MT | Mobile Terminated |
| NMT | Nordic Mobile Telephone |
| OTA | Over the Air |
| PCS | Personal Communication System |
| PDSN | Public Data Switching Network |
| PIM | Personal Information Management |
| PN | Pseudo Noise |
| PPP | Point to Point Protocol |
| PRL | Preferred Roaming List |
| PSMM | Pilot Strength Measurement Message |
| PSTN | Public Switched Telephone Network |
| QoS | Quality of Service |
| R&D | Research and Development |
| RF | Radio Frequency |
| R-UIM | Removable-User Identity Module |
| SMS | Short Message Service |
| SS7 | System Signaling 7 |
| TACS | Total Access Communications System |
| TCP/IP | Transport Control Protocol/Internet Protocol |
| Tx | Transmit |
| UDM | Universal Diagnostics Monitor |
| UHDM | Universal Handoff Direction Message |
| UI | User Interface |
| VLR | Visitor Location Register |
| V&V | Verification & Validation |
| xHTML | Extended Hyper Text Markup Language |

# 1. INTRODUCTION

According to a 3G wireless market report by the Philips Group, the number of 3G wireless subscribers is expected to grow from 1.7 million in 2002 to around 38 million in 2007 [2]. The percentage of 3G subscribers relative to total wireless subscribers is expected to grow from 1.3% in 2002 to 23% in 2007 [2].

3G services aim to provide high data rates with mobility. As the mobile users increase their demand of wireless data, deploying 3G services is high on the priority list for all major carriers. In North America, CDMA2000 will be the leading 3G technology. Most major carriers are already upgrading their network infrastructure to support CDMA2000 protocol, and promote the new 3G features. CDMA2000 1X was the world's first 3G network commercially deployed in October 2000 [3]. A wide range of CDMA2000 1X mobile handsets is expected to be launched as the 3G market continues to grow. Before the deployment of the handset to the market, a series of field tests has to be performed. The field tests include R&D field test, CDG stage 3 test, and acceptance test at the carriers' sites.

In this project, our objective is to analyze the field test activities of a CDMA2000 1X mobile phone. They include the understanding of the deployed technologies, the planning of field test, the goals of field test, the selection of field test engineers, the usage of field test tools, the searching for suitable test sites, the design of field test cases, and the analysis of field test results.

In this project, we show the importance of field test within a software engineering project. In order to demonstrate the design of field test cases, we have created four R&D field test cases to test the voice service of CDMA2000. We use one of the latest CDMA2000 1X handsets, Samsung N400, to conduct our field test. Using the Spirent diagnostic monitor test tool, we gather the detailed logs of the CDMA messages over the air interface for both forward and reverse links. In particular, we study in details the R&D field test cases for CDG stage 3 test, and the message flow defined in IS-2000.5 Rev.0 Upper Layer (L3) Signaling Standard [1].

This project is organized as follows. In Chapter 2, we introduce the CDMA technology and describe the evolution from the 2$^{nd}$ Generation CDMAOne to the 3$^{rd}$ Generation CDMA2000 technology. In Chapter 3, we introduce the testing methodology, the W-model, and the field test in the W-model. Chapter 4 provides the overview of field test for a CDMA2000 1X mobile phone. We discuss detailed test activities from test planning to test execution. In Chapter 5, we illustrate the field test cases for CDMA2000 voice services, and conduct the actual field test using the live network. We also perform a detailed analysis of the test results. In Chapter 6, we conclude the result of this project, summarize our project activities, and state our achievements. The Appendices include typical field test cases in the laboratory and in the field, and common test tools used for CDMA2000 testing, and the detailed soft handoff analysis.

# 2. CDMA TECHNOLOGIES

CDMA is known as spread spectrum or Code Division Multiple Access. It is based on the idea that all mobile phones can use the same spectrum, and that the conversations can be kept separate through the use of individual codes. User's signal within the cell is made to sound like noise or interference to every other user. Each individual mobile can recognize the digitally coded call intended for its own user.

## 2.1 CDMAOne

IS-95 CDMA systems are marketed under the name CDMAOne. The US carriers first launch IS-95 CDMA in the 1990s. Its technology provides the basic voice services, as well as integrated voice mail and SMS services. Limited data services (< 64 kbps) are supported by IS-95B, the later release of IS-95. However, most carriers in North America only support the older version of IS-95, named IS-95A. In this chapter, we present some background to IS-95.

### 2.1.1 IS-95 based 2G network

The network architecture for IS-95-based wireless network is shown in Figure 1. Voice calls are routed through the Mobile Switching Center

(MSC). However, for limited circuit data services, the MSC and Base Station Controller (BSC) connect to an Inter Working Function (IWF).

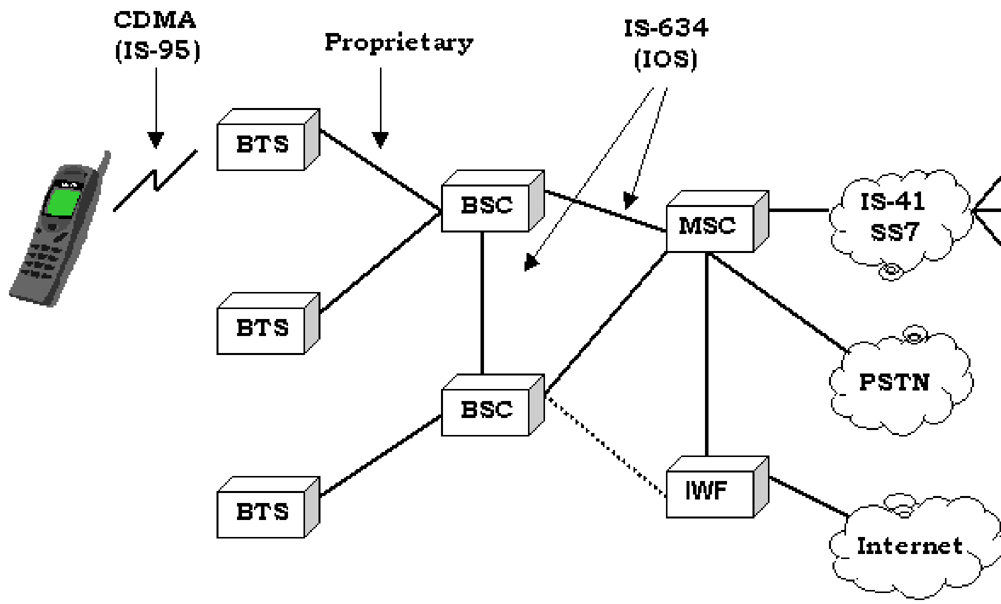



Figure 1: IS-95 based 2G network components, with limited data services provided via IWF [4].

### 2.1.2 2G services

Services provided by 2G networks are:

- Voice service
- Supplementary services: 3-way calling, call transfer, flexible alerting, conference call, voice privacy, message waiting, call forwarding, and call waiting
- Short Message Service (SMS)
- Analog fax, circuit switched data support.

### 2.1.3 2G limitations

Voice was the primary service for IS-95, even though it only supports low-rate data services. As the demand for data over the Public Switched Telephone Network (PSTN) continues to grow, wireless users' demand for Internet access and data services will grow with it.

There are several limitations in the existing IS-95 network that needs to provide the features to match the increasing demand for high-speed Internet access. For instance, there are limitations regarding bandwidth, data services, packet data, and multimedia services.

IS-95 systems can provide a maximum data rate of 115.2 kbps, although 14.4 kbps is the maximum rate supported in most carrier networks [5]. IS-95 is primarily designed for voice services. In North America, most systems use IS-95A and only support data rates up to 14.4 kbps. Services, such as high-speed Internet access, are not feasible using IS-95 technology. Data services provided by IS-95 are using the circuit switched approach, which is not an efficient method for providing the data services. Lastly, multimedia services require concurrent streams for delivering voice, video, and data packets. IS-95 systems do not support protocols necessary for these services.

## 2.2 CDMA2000

CDMA2000 is the 3rd Generation solution based on IS-95. The air interface of CDMA2000 is called IS-2000 [3]. It is an evolution of an existing wireless standard. The network components of CDMA2000-based 3G network are shown in Figure 2. CDMA2000 supports 3G services as defined by the International Telecommunications Union (ITU) for International Mobile Telephony 2000 (IMT-2000). 3G networks will deliver wireless services with better performance, greater cost-effectiveness, and significantly more content [6]. The goal is access to any service, anywhere, anytime from one terminal [3].

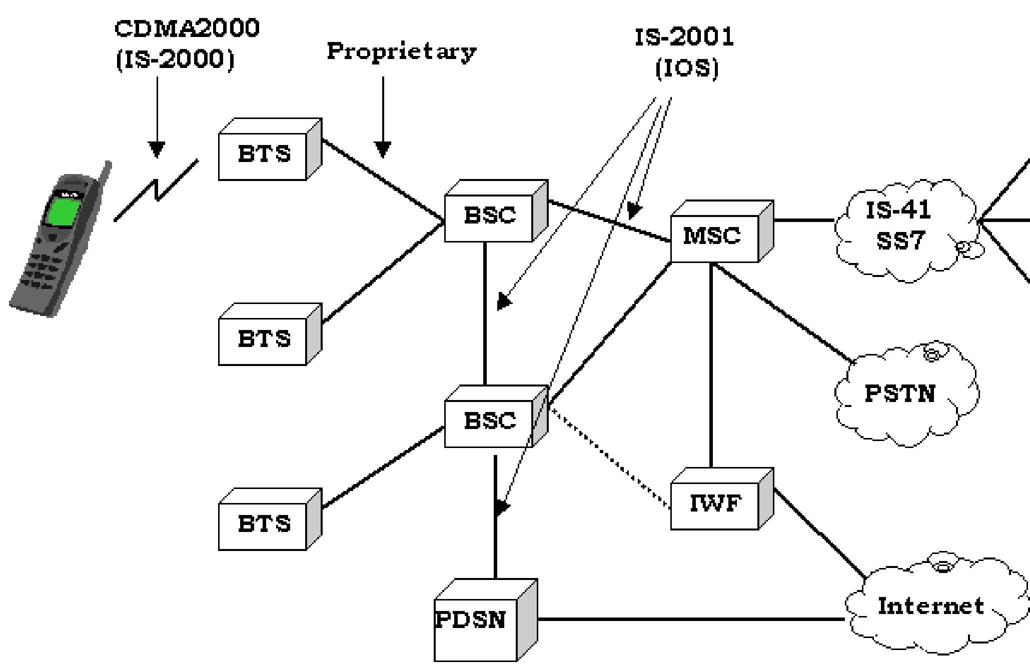



Figure 2: CDMA2000-based 3G network, with high-speed Internet service provided through the Public Data Switching Network (PDSN) component [4].

One key requirement of CDMA2000 is to be backward compatible with the existing, widely deployed IS-95 systems. In addition, it should provide an upgrade path to the next generation wireless system. CDMA2000 provides various features and enhancements, including:

- Smooth evolution from existing IS-95-based systems.
- Support for packet data services with data rates of 144 kbps to 2 Mbps.
- Various techniques are introduced to improve the system capacity for voice calls such as transmit diversity, fast forward power control, reverse pilot channel, and new coding schemes.
- Support Quick Paging Channel to improve the battery life of mobile stations (MS).
- Reduction of the system access collision and support sending short data bursts on a common channel. Support soft-slope algorithm to reduce the required amount of handoffs.
- Support for multiple concurrent services with Quality of Service (QoS) management capability. For example, it supports concurrent voice and High Speed Packet Data (HSPD) services.
- Support bandwidth on demand. Depending on the amount of data to be transmitted, either the mobile phone or network could request the bandwidth allocation as required. This is useful for the support of multimedia services that usually have intermittent and bursty characteristics.
- Support for global roaming through Removable User Identity Module (R-UIM).

CDMA2000 represents a family of technologies that includes CDMA2000 Single Carrier Radio Transmission Technology (1XRTT) and CDMA2000 Single Carrier Evolution (1xEV). CDMA2000 1XRTT, also known as 1X, doubles the voice capacity of CDMAOne networks. It delivers peak packet data speeds of 307 kbps in mobile environments.

CDMA2000 1xEV includes CDMA2000 Single Carrier Evolution for Data Only (1xEV-DO) and CDMA2000 Single Carrier Evolution for Data and Voice (1xEV-DV). The world's first 3G commercial system, which is a CDMA2000 1X system, was launched by Korea SK Telecom in October 2000.

## 2.3 3G handsets

3G handsets range from a simple phone to a multi-purpose communicator capable of handling multiple voice, data, and video services in parallel. Some of the features available in a 3G handset are:

- Messaging services: SMS, Enhanced Message Service (EMS), Multimedia Service (MMS), email, instant message, remote synchronization.
- Browser: Extended Hyper Markup Language (xHTML), video streaming.
- Digital imaging: picture message, photo, and video capture.

- Global Positioning System (GPS) and location services: Emergency 911 (E911), location-based directories, person/child locator, and asset tracking.
- Bluetooth: Personal Area Network, handsfree, wireless data modem.
- Java: entertainment, games.
- Media: music sharing, sampling.
- Others: Personal Information Management (PIM), wallet.

In this project, we select to use the Samsung N400 CDMA2000 1X handset as the test unit. The major difference between this phone and a regular IS-95 CDMA phone is the support of 1X voice service and High Speed Packet Data (HSPD). To end users, this allows faster Internet access and better experience in data service. This changes the existing user pattern, which emanates from voice service only.

From a typical user point of view, it is not obvious that there are changes in the voice service between the existing IS-95 and IS-2000. However, there are changes in the message handling in voice service provided by IS-2000 that still require detailed verification and validation. In this project, we focus on the verification of voice services provided by IS-2000.

# 3. VERIFICATION AND VALIDATION

Testing activities are generally divided into two entities: verification and validation processes. Term "Verification" is used to describe the activities examining intermediate products of the development phases, mostly inspecting or reviewing specification documents and code. Term "Validation" is used for inspecting the end product, and it is performed by executing the software. In general, testing includes both verification and validation activities [7].

There are various software engineering models such as Waterfall model and Dotted-U model [7]. The usage depends very much on the type of the project and the size of the organization. One widely employed presentation of the software engineering model is the V-model [8], which is extended to W-model [8]. The W-model is used to clarify the importance of verification process and its activities. System design and testing have their own independent paths, although testing activities rely on work done in the development phase first. The W-model [8] is shown in Figure 3.

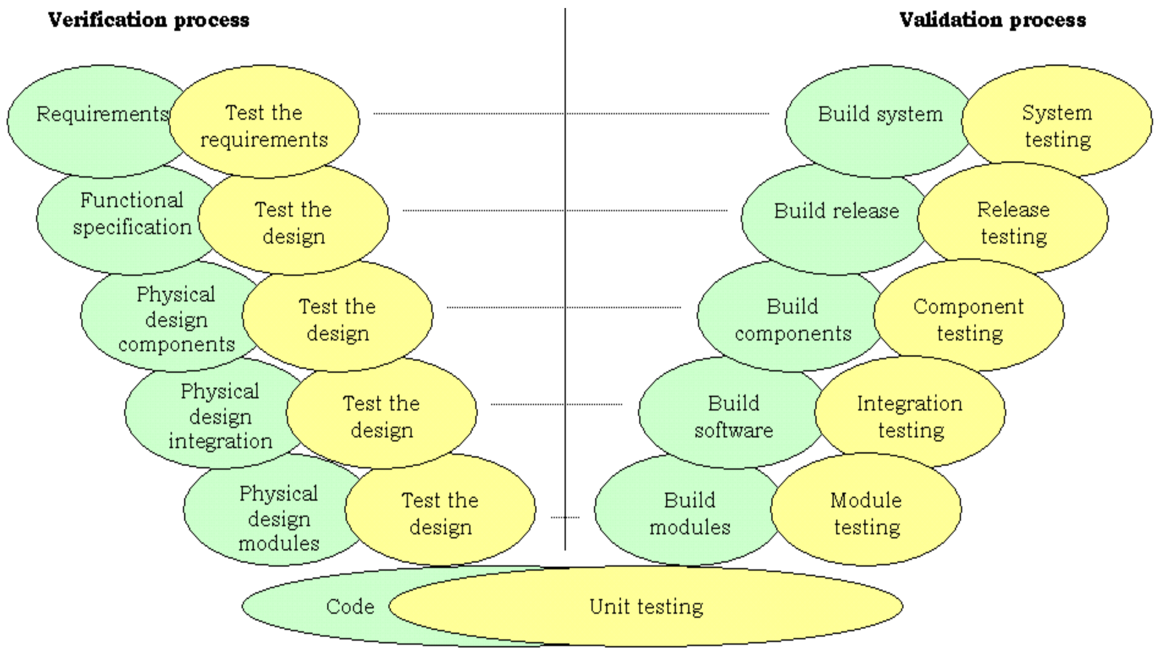



Figure 3: W-model provides a new and improved approach for testing throughout the development cycle [8].

## 3.1 Verification process implementation

Verification test planning activities should start in the early phase of the project. There is no need for requirement specifications to be ready before starting verification activity planning. As soon as the first requirement is written, testing could begin [7].

In general, the development group, rather than the testing group, designs and manages the verification activities. However, it is important that members of a test group also attend verification activities, since some testability issues in specifications are easily ignored by the development group.

### 3.1.1 Test the requirements

Requirements are high-level specifications. Test group participates in the review process of the requirement specifications and focus in the testability of the requirements. Four remarks on requirements based testing are:

- No testing is possible without stated requirements.
- A software product satisfies its stated requirements.
- All test cases trace to one or more stated requirements, and vice versa.
- Requirements state in testable terms.

### 3.1.2 Test the functional design

Functional design specification describes the functionality of a software release. It is not only the foundation for software development, but is also the base for functional testing. It is very important that testers dealing with releases also attend the review process of functional design because these deliverables may include many errors.

### 3.1.3 Test the internal design

Testing the internal design requires special skills from a “Blackbox Tester”. These activities are supported in a more mature test environment, and they involve testers in the internal review process.

Testers are required to review the error reports, and read the software code. Further, they should understand on how the program functions and be aware of the project's informal information system.

## 3.2 Validation process implementation

There are six validation levels, as defined in Figure 3. We describe here the test responsibilities of each level.

### 3.2.1 Unit testing: level 0

Unit test focuses on the smallest possible software entity, which provides a single functionality. It is a single functional test that involves code coverage test, and static test. Typically, designer with competence in the code itself conducts this test.

### 3.2.2 Module testing: level 1

Module test involves integrating level 0 entities to provide a basic functionality. It includes integration tests within software applications and servers. The focuses are on parameter test, value test, inter-working test, and error verification. Designer with competence in module interface and design specification conducts this test.

### 3.2.3 Integration testing: level 2

Integration test involves integrating level 1 entity to provide a complete subset of functionality that can be treated independently. It includes integration tests within software applications and servers. The focus of the test is to search for errors in message test, parameter test, external interfaces test, inter-working test, and memory leakage test. Designer with competence in architecture and design specification is best fit to conduct this test.

### 3.2.4 Component testing: level 3

Component test involves integrating level 2 entity in order to provide a complete set of functionality that can be seen by user. It is the feature test of component focusing on normal feature test, inter-working test, error verification, and memory leakage. User Interface (UI) tester with competence in specific features conducts this test.

### 3.2.5 Release testing: level 4

Release test involves integrating level 3 entity to provide the functionality testing of UI software release. This involves elementary test, basic release test, feature test, inter-working test, and memory leakage test. Release tester with overall competence in features and releases conducts this test.

### 3.2.6 System testing: level 5

System test involves integrating level 4 entity to provide a complete product testing. This involves type approval, interoperability test, and field test. System tester with competence in system architecture and design conducts this test.

## 3.3 Field test in W-model

To optimize the test effort, different testing levels can be divided into two control levels. Design team is responsible for the levels 0-2 testing, and test team is responsible for the levels 3-5 testing. The main interest of the test team is the high level testing (levels 3-5). Design team is responsible for planning and executing low level testing. Nevertheless, it is important to have common understanding over the responsibilities of different levels, start criteria, and exit criteria.

As defined in the W-model shown in Figure 3, field test of a CDMA mobile station is a design validation activity. In a practical development project of a CDMA2000 mobile phone, field test covers the needs of different testing levels. In general, this covers the test activities from levels 3 to 5. For instance, the field test of a new feature, such as Mobile IP, is treated as a combination of level 3, level 4, and level 5 tests. Since the field test uses the mobile station in conjunction with the live network, most of the activities involve end-to-end system testing.

# 4. FIELD TEST ACTIVITIES

Various types of tests are to be performed on the mobile phone, and field test is one of the major activities. Carrier networks are not the same everywhere. The purpose of field test is to find errors using various networks and to prevent after-sales-faults. Field test is the customer's voice to the product. When planning for a mobile phone field test, the following points are considered.

- What is field test?
- Why is field test necessary?
- When should we conduct field test?
- Who should conduct field test?
- How should we conduct field test?
- Where could we conduct field test?

We describe here the details of each point.

## 4.1 Purpose of field test (what and why?)

The term "field test" is widely used in various disciplines. In general, it is a type of testing that will make use of the real live environment and simulate the use cases of the real users. Field test in the world of wireless communication can be grouped into two major categories. One is the field test from the network infrastructure side, and the other is the field test from the mobile terminal side. In this project, we focus on field test of the mobile terminal.

The purpose of field test is:

- To understand the behavior of the phone in a real live network instead of a simulated network environment in the lab.
- To verify features and behavior not supported by a simulator.
- To provide a quality product by ensuring it is completely interoperable with different infrastructures, by ensuring its robustness in good and adverse field conditions, and by benchmarking with respect to a reference phone.
- To ensure that the phone works according to the end user expectations based on the product user manual, product tailored field test specifications, and product requirement.
- To prepare the product to go through the acceptance test defined by the customers or carriers.
- To verify and identify all the product errors, both hardware and software, in the real live network before the product is launched to the customer.
- To conduct various types of tests in the field, including software feature test, protocol test, Radio Frequency (RF) test, interoperability test, system test, and stress test.

## 4.2 Time phase for field test (when?)

Field test should be well planned into phases depending on the maturity of the mobile phone under development. Due to the tight schedule of the development cycle of the product, test should start as soon as features are ready and stable. Companies can no longer afford to have the entire implementation completed before actual testing can start. Hence, testing activities have to be carefully planned together with the development team. When the mobile software and hardware reach a certain maturity level, R&D field test can start as defined in Table 1. Field test can be expensive to a development project. Therefore, well-planned entrance criteria should be met before actual field test starts. In general, this takes place after the execution of most in-lab protocol test and software application test, and that a certain maturity level is reached.

| **Step** | **Test activity** |
|---|---|
| 1 | Lab testing. Sample test cases are shown in Appendix B "Sample of field test cases". |
| 2 | Regression cycle for bug fixes, new feature testing, and basic call statistics testing. |
| 3 | Local field test - network testing. Sample test cases are shown in Appendix B "Sample of field test cases". |
| 4 | Remote field test – testing with different infrastructures or networks. |

Table 1: R&D field test can be divided into four steps: in-lab test, feature test, local field test, and remote field test.

## 4.3 Field test engineers (who?)

In general, field test engineers need to be well trained. They are familiar with the CDMA protocol and the behavior of the network. At the same time, these engineers are familiar with the mobile phone to be tested.

They are familiar with application software test and protocol software test. They also need to verify the physical layer in baseband and the Radio Frequency (RF) performance within the network. Ultimately, each field test engineer is an experienced system engineer who can tackle any problem within the end-to-end mobile test environment.

## 4.4 Focus of field test (how?)

Like any other testing activities, field test needs a well planned schedule, a high level field test plan, detailed area-specific field test plans, and field test specifications. We need to plan for test equipments and tools, and to consider the development of automated test tools.

There are several phases of field test in an R&D project. In general, they can be divided into two major phases: R&D field test (performance test) and pre-acceptance field test (compliance test).

### 4.4.1 R&D field test

In the R&D field test phase, most effort is devoted on testing the performance of the device and verifying the new features introduced to it. Since it is difficult to make hardware and RF design changes in the later phase of a project, the R&D field test will focus in testing the baseband functionality and the RF performance. Next, we focus in the protocol software test. In field test, we are interested to test the air interface protocol of CDMA. The details are shown in Figure 4. Particularly, the target is the layer 3, which is covered by the IS-2000.5-0: Upper Layer Signaling standard [1]. As the carriers require many CDMA certifications before the acceptance of a product and many of these certifications are done in the third party laboratories, it is crucial to verify the readiness of protocol software in the early phase of the development.

During the R&D field test, we test and compare the performance of the mobile directly against the best performing competitor phones recommended by the carriers. This gives a baseline for accessing the performance of the product, since the reference phones have been recognized to be good performers. Another focus of performance test is the robustness of the product by stressing the phone and by attempting to make the phone fails. In performance test, our focus is not to test the normal scenario. Our focus is to test the worst-case scenarios (pilot pollution, low signal strength). In summary, the objective of R&D field test is to break the software and detect most of the critical problems as early as possible.

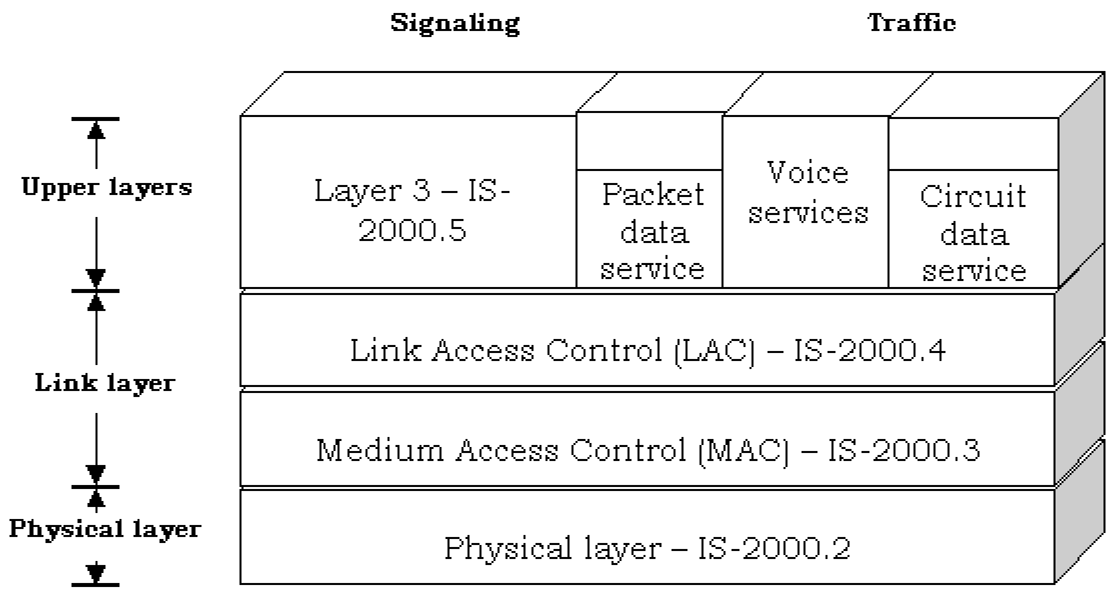



Figure 4: CDMA2000 protocol layers include physical, link, and upper layer. Field test focuses on the upper layer, namely the layer 3 – IS-2000.5 [9].

### 4.4.2 Pre-acceptance field test

The next major phase of field test is the pre-acceptance. Within this phase, we design most tests to validate the compliance to the standards and the features supported by the carriers. The purpose of compliance test is to ensure the product functionality to be fully validated before the start of product acceptance test with the customers. On a feature-by-feature basis, we test the product for the compliance (SMS, email). Our test cases follow several industrial standards, including CDG stage 3 test standard. For IS-2000, the standard is the CDG64 [10].

In North America, the CDMA technology is regulated by two International committees: the Third Generation Partnership Project 2 (3GPP2) [11] and the CDMA Development Group (CDG) [3]. The CDMA Development Group provides the standard for testing new mobile phone. There are several test phases defined by CDG. They are CDG stage 1, CDG stage 2, and CDG stage 3. All these test stages are highly recommended by the CDG for testing the CDMA mobile system, and they are widely adopted by the CDMA carriers. CDG stage 1 deals with the Cellular Telecommunications and Internet Association (CTIA) IS-98D test [12]. CDG stage 2 focuses on interoperability testing between mobile station and base station in the laboratory environment. CDG stage 3 is designated to address the field test related to the launch of the new CDMA mobile phones.

CDG stage 3 demonstrates interoperability between mobile station and base station in a field environment, often on a live commercial network. We conduct most of the test over the air. In the North America CDMA market, it is common that CDG stage 3 is performed as part of the acceptance test for new mobile stations. Mobile station manufacturers perform field tests using components of CDG stage 3 in the early phase of the product development cycle. Some components of CDG stage 3 are also adapted for overall network system performance test. In this project, we conducted a subset of R&D test cases, which is closely related to the CDG stage 3 test cases.

## 4.5 Choosing test sites for field test (where?)

It is obvious that field test is conducted in the field, as its name suggests. Even though we plan most of the field test activities in the office, most of the test executions really take place in the field. Therefore, the selection of test sites is an important topic.

Several major factors determine how we choose the suitable field test area. In general, they are:

- Target market and carrier
- Network infrastructure
- Frequency band
- Protocol in use
- Test cities
- Drive routes and test sites.

Besides of all these major factors, we should also consider all the other factors that change our test environment, such as the temperature, humidity, etc.

### 4.5.1 Target market and carrier

CDMA is a world wide standard, and there are numerous carriers in different countries supporting it. Since most of the CDMA products (mobile phones) are carrier specific, we plan the field test to target the supported carrier. Currently, the largest market for CDMA is in North America (United States and Canada). In Canada, Telus Mobility and Bell Mobility are the two major carriers supporting CDMA. In this project, we used the Telus Mobility network to communicate with our CDMA2000 1X handset.

### 4.5.2 Network infrastructure

Various vendors are developing network infrastructure for the CDMA network. Most of these vendors are well known in the market, and are actively involved in the CDMA standard committee. For instance, some of the most common vendors are Nortel, Lucent, Motorola, Ericsson, and Samsung. Although the standards are well defined, the interpretation of standards could be different, and the features supported by these infrastructures could vary.

It is important to validate the mobile unit in all the supported infrastructures available in the target carrier's network. Hence, the network infrastructure used and its supported features are important information for field test. Usually, the carrier contact gathers the network infrastructure information. In Vancouver, Canada, Telus Mobility is using the Nortel infrastructure.

### 4.5.3 Band selection

Section 2.7.4.13 Band Class Information of the IS-2000.5-0 standard [13] defines a list of bands used for CDMA.

| **Band class** | **Description** |
|---|---|
| 0 | 800 MHz cellular band |
| 1 | 1.8 to 2.0 GHz PCS band |
| 2 | 872 to 960 MHz TACS band |
| 3 | 832 to 925 MHz JTACS band |
| 4 | 1.75 to 1.87 GHz Korean PCS band |
| 5 | 450 MHz NMT band |
| 6 | 2 GHz IMT-2000 band |
| 7 | 700 MHz band |
| 8 | 1800 MHz band |
| 9 | 900 MHz band |
| 10 | Secondary 800 MHz band selection |

Table 2: Band class information is defined by the IS-2000 standards. Band classes 0 and 1 are used in North America.

In North America, band classes 0 and 1 are the most common bands used. They are referred as cellular and Personal Cellular System (PCS) bands, respectively. In this project, we conducted all the test cases in band class 1 (PCS band).

### 4.5.4 Protocol in use

In North America, most CDMA carriers are upgrading their network infrastructure from IS-95A to IS-2000 Release 0. Since network upgrade does not happen at once, IS-2000 mobile phone has to be backward compatible with IS-95A. This would allow seamless and undisrupted services. Table 3 illustrates the protocol revision table for CDMA. Our test phone, Samsung N400, is using protocol revision 6, that is IS-2000 Release 0.

| **Protocol revision (MOB_P_REV)** | **Band class 0 (cellular band)** | **Band class 1 (PCS band)** |
|---|---|---|
| 1 | IS-95 | J-STD-008C |
| 2 | IS-95A | N/A |
| 3 | TSB7/IS95A | N/A |
| 4 | IS-95B phase I | IS-95B phase I |
| 5 | IS-95B phase II | IS-95B phase II |
| 6 | IS-2000 | IS-2000 |
| 7 | IS-2000A | IS-2000A |

Table 3: Protocol revision table lists the revision used for different band classes.

### 4.5.5 Test cities

Carriers often have preferences and suggestions in which cities the field test is to be performed. For example, Telus Mobility usually suggests Toronto and Vancouver as their test cities for product acceptance. Therefore, many field tests in Canada, including R&D field test and pre-acceptance field test, are conducted in these two cities. Besides of testing in the carrier-suggested cities, field test engineers also test in the cities for the carrier's roaming partners. Since we use the mobile phone in different places in North America, the phone can roam to other carriers' networks. Preferred Roaming List (PRL) stores the carrier's roaming cities information. In this case, it is important to consider the cities in the PRL.

The CDMA coverage map is an important information for field test planning. It provides information to the field test engineer to determine the field test sites for each test case. For example, Figure 5 shows the Bell Mobility coverage map for the Greater Vancouver [14]. Figure 6 shows the coverage map for British Columbia and Alberta in Canada [15]. In Figure 7, the cell site map for Greater Toronto is shown [16].

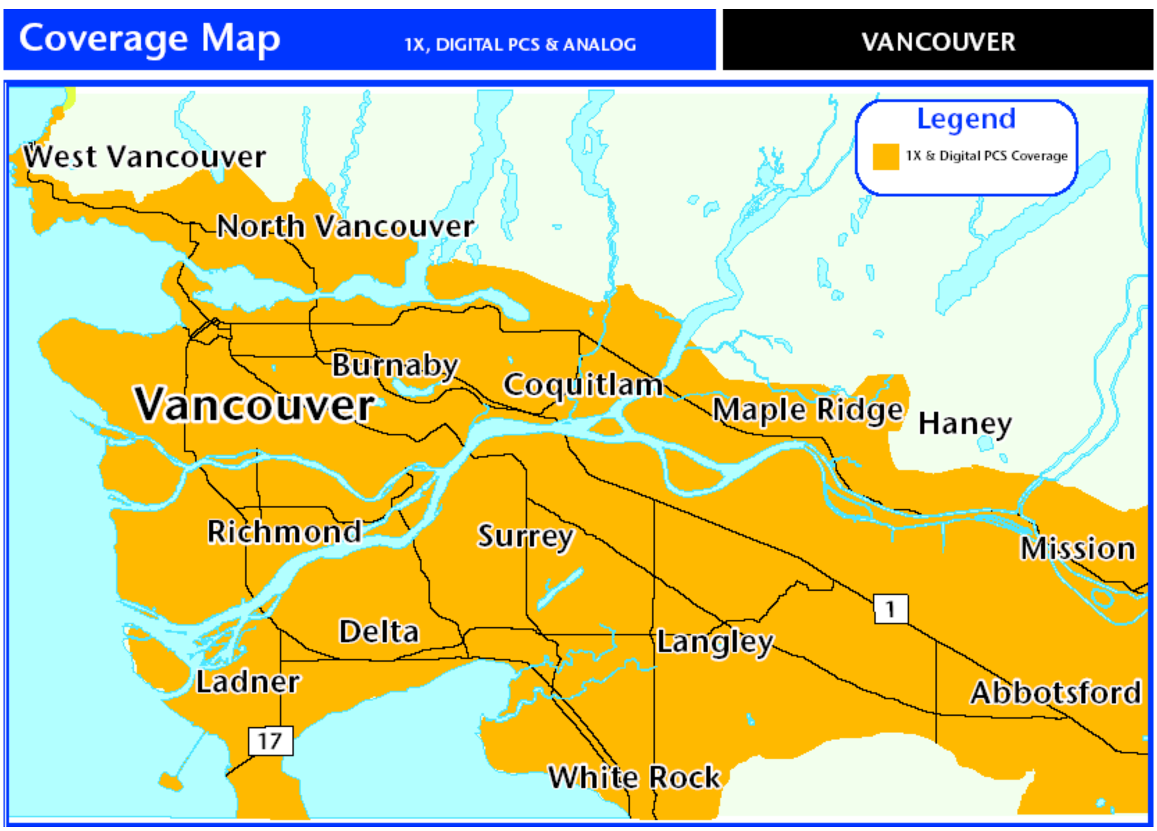





Figure 5: Bell Mobility 1X and digital PCS coverage map for the Greater Vancouver region (orange) [14].

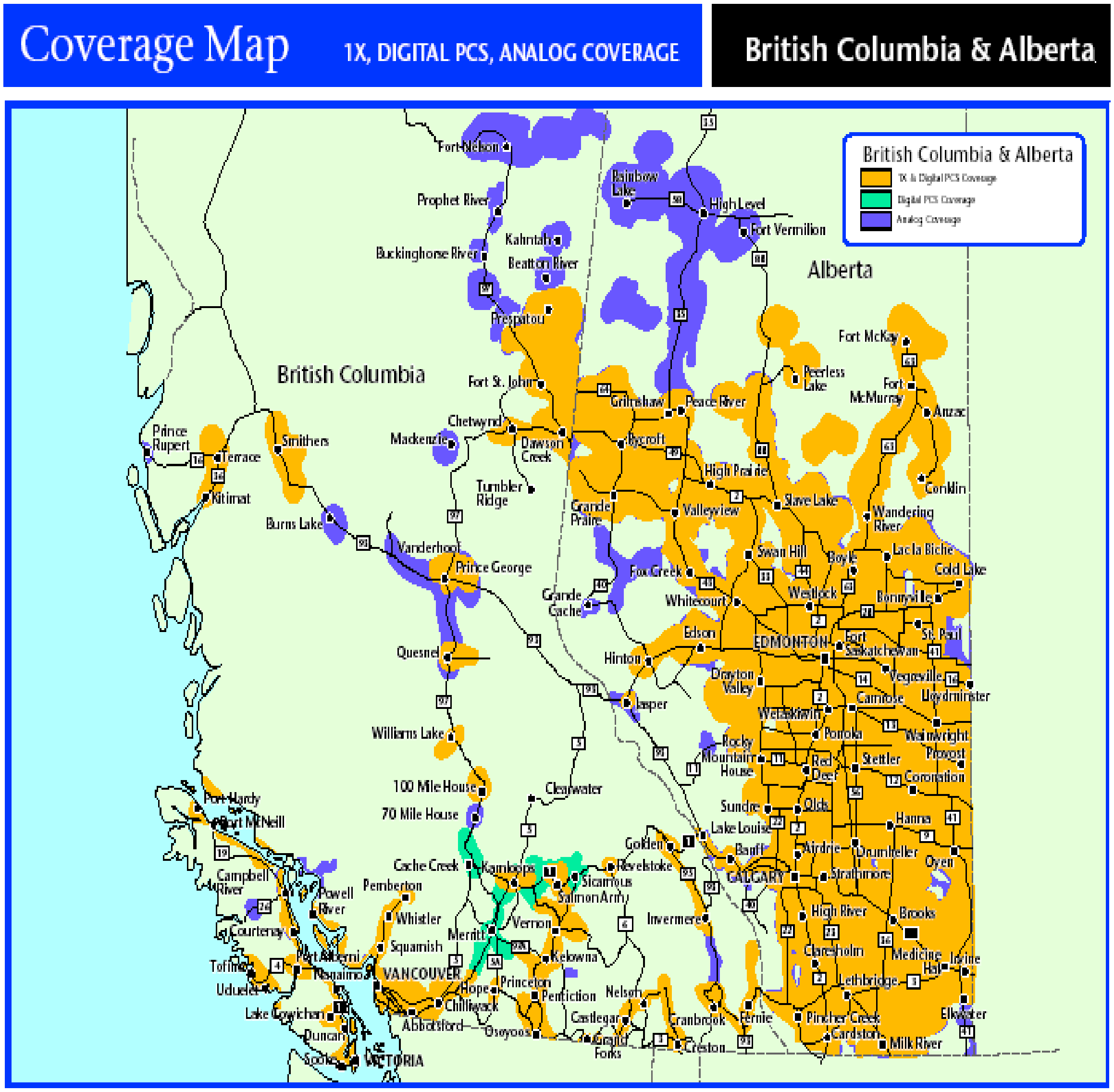





Figure 6: Bell Mobility network coverage map for British Columbia and Alberta, showing the analog coverage (blue), digital PCS coverage (green), and 1X and digital PCS coverage (orange) [15].


Figure 7: Cell site map of Telus Mobility for downtown Toronto provided by Steve's Southern Ontario Cell Phone Page [16].

### 4.5.6 Selection of drive routes

The selection of each drive route requires an understanding of the applicable network features. In normal practice, carriers define the drive routes to be used. Drive routes for each selected city are documented in advance, before the actual field tests are performed. Drive route is prepared to include handoffs and various vehicle speeds to obtain a total drive time of a few hours. Field test engineers characterize each drive route by using a diagnostic monitor. This includes identifying the frequencies, pseudo noise (PN) offsets, registration periods, and boundaries information.

Field test require drive routes that represent different RF signal strength coverage. Typically, there are a normal coverage (good signal) and a weak signal drive routes. As well, drive routes represent different band classes, which include band class 0 (cellular) and band class 1 (PCS). In addition, drive routes cover different protocol revisions, such as IS-95A, IS-2000 Rev. 0, and Advanced Mobile Phone System (AMPS). In general, all the criteria are combined together for the drive routes selection. Some example of drive routes are normal coverage drive route, weak signal drive route, digital PCS drive route, and digital cellular drive route [17].

While selecting drive route for field test, we also need to take into account the condition of the areas covered by the drive route. Since the end users use the product under various field conditions, drive routes are designed to cover various RF signals conditions as well as driving conditions. Driving condition factors that are used when preparing a drive route include:

- Vehicle speed (from static to 100 km/h, traffic conditions and speed limits permitting)
- Residential roads in suburban areas
- Rural areas

- High density urban areas
- Industrial areas
- Airports
- Shopping malls
- City lanes
- Highways/boulevards
- Freeways
- Elevated highways and bridges
- Hilly terrain
- Canyons
- Flat terrain
- Desert conditions
- Near waterways (lakes, large bodies of water, ocean)
- Tunnels
- Parkades (underground parkades)
- Various weather conditions (rain, snow, sun)
- Areas with line of sight to base station
- Areas with no line of sight (multipath only)
- Areas with a direct path and multipath
- Areas near to and far away from base stations
- Pilot polluted areas
- Handoff areas (hard handoff, inter-band hard handoff, inter-frequency hard handoff, inter-system hard handoff, soft handoff)
- Areas with high traffic conditions

# 5. DATA COLLECTION AND TEST RESULTS ANALYSIS

This chapter is the core of this project. We illustrate some R&D field test cases, that are closely related to the CDG stage 3 testing for CDMA2000 [10]. There are many requirements in the CDMA standards. However, in field test, our focus is on the layer 3 of the CDMA protocol stack, referred to as IS2000.5-0 [1]. In this project, we created four test cases related to CDMA call processing. These test cases are R&D field test cases recommended to be executed before CDG stage 3 testing. We performed detailed testing and carefully analyzed the test results. We conducted the test by using the Samsung N400 as the mobile station in the Telus Mobility 1X network (IS-2000 Rev.0). We used the Spirent Universal Diagnostics Monitor (UDM) as a test tool to capture and analyze the test results. Figure 8 illustrates the test setup used for this project. Appendix A Universal Diagnostics Monitor provides more details regarding the test tool.

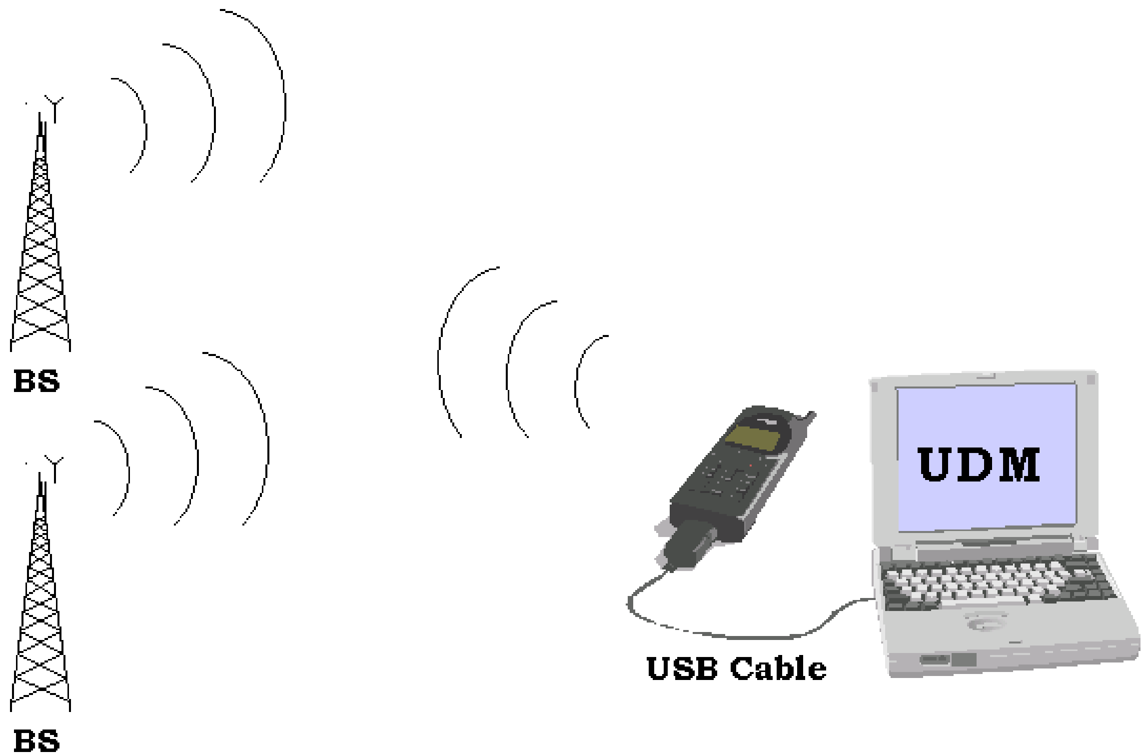



Figure 8: Test setup using Spirent UDM and Samsung N400 communicating with a Telus Mobility base station.

## 5.1 Test Case 1: Mobile originated voice call

### 5.1.1 Objective

The objective of this test case is to ensure that the entrance requirement for "Section 4.2.1 Mobile Originated Call Success Rate" as defined in CDG stage 3 testing for CDMA2000 [10] is met.

### 5.1.2 Test steps

*Precondition*

- Power the mobile station.

- Start the diagnostic monitoring tool, connect it to the MS, and begin to log air messages.
- Use the diagnostic monitoring tool to ensure that the MS performs a power-up registration.
- Ensure that the network provides acknowledgement for the power-up registration sequence from the MS.
- Observe the MS until it provides a service indication to the user.

*Procedures*

- As soon as the MS provides a service indication to the user, the mobile is in the *mobile station idle state*.
- Originate a voice call from the MS to a landline phone.
- Check the audio path in both directions.
- Release the call.
- Power down the MS.

### 5.1.3 Expected results and diagrams

The expected result is shown in Figure 9. The figure shows the actual message sequence for the mobile originated (MO) voice call transaction.

1) *Origination:* MS sends Origination message on the access channel.

2) *Base station acknowledgement order:* Base station (BS) acknowledges that the origination message was received.

3) *Null traffic frames*: BS sends blank frames on forward channel.

4) *Extended channel assignment message*: BS sends a channel assignment message.

5) *Traffic channel preamble*: MS sees at least two good blank frames in a row, and agrees the traffic channel is good to be used. It

sends a preamble of two blank frames of its own on the reverse traffic channel.

6) *Base station acknowledgment order*. BS acknowledges receiving the mobile's preamble.

7) *Service connect message*: BS proposes the call connection to be started.

8) *Service connect completion message*: MS agrees on the connection.

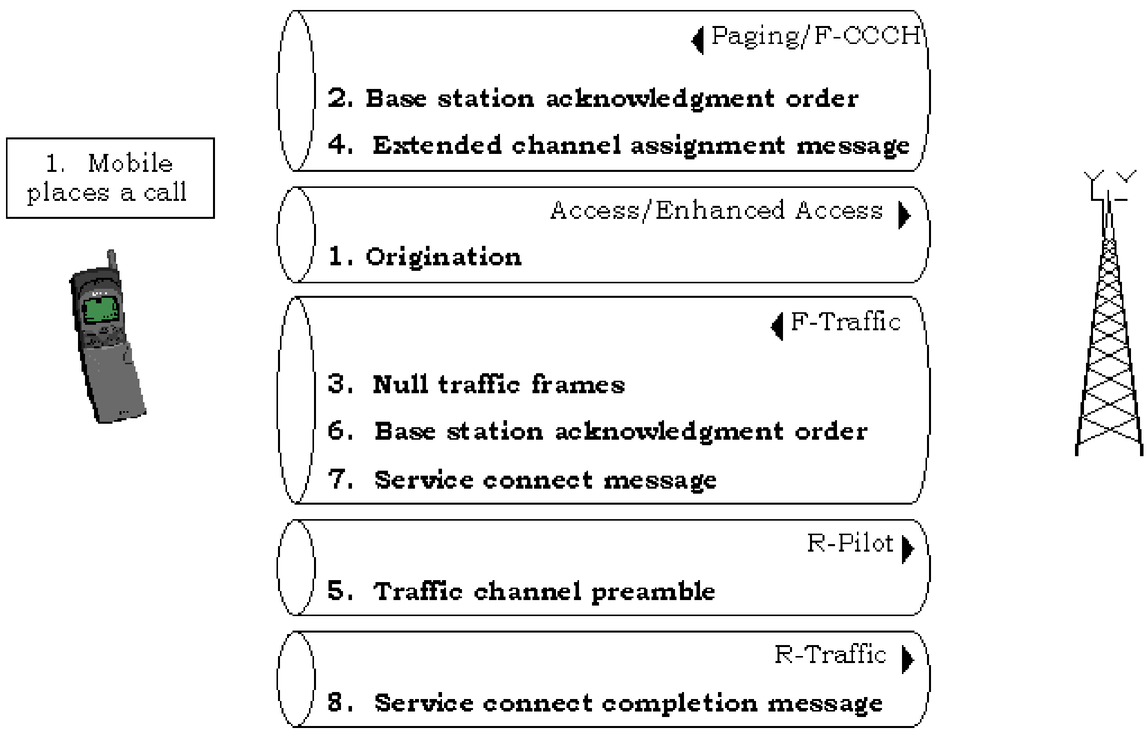
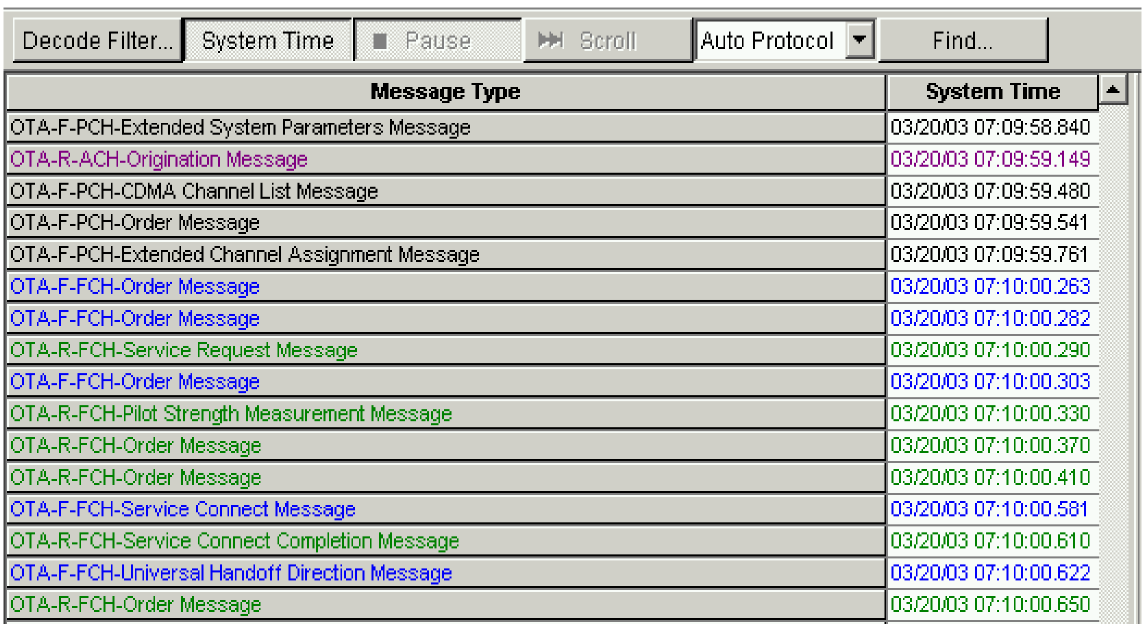



Figure 9: This message sequence diagram illustrates the MS originated voice call setup process [4].

### 5.1.4 Results and loggings

Based on the test steps defined in Section 5.1.2, we executed the test using a Samsung N400 CDMA 1X phone. We started the test with the mobile in the idle state (phone was registered to the network, and no voice or data traffic was active). We captured the actual call processing occurred during the test. It is illustrated in Figure 10.




| Message Type | System Time |
|---|---|
| OTA-F-PCH-Extended System Parameters Message | 03/20/03 07:09:58.840 |
| OTA-R-ACH-Origination Message | 03/20/03 07:09:59.149 |
| OTA-F-PCH-CDMA Channel List Message | 03/20/03 07:09:59.480 |
| OTA-F-PCH-Order Message | 03/20/03 07:09:59.541 |
| OTA-F-PCH-Extended Channel Assignment Message | 03/20/03 07:09:59.761 |
| OTA-F-FCH-Order Message | 03/20/03 07:10:00.263 |
| OTA-F-FCH-Order Message | 03/20/03 07:10:00.282 |
| OTA-R-FCH-Service Request Message | 03/20/03 07:10:00.290 |
| OTA-F-FCH-Order Message | 03/20/03 07:10:00.303 |
| OTA-R-FCH-Pilot Strength Measurement Message | 03/20/03 07:10:00.330 |
| OTA-R-FCH-Order Message | 03/20/03 07:10:00.370 |
| OTA-R-FCH-Order Message | 03/20/03 07:10:00.410 |
| OTA-F-FCH-Service Connect Message | 03/20/03 07:10:00.581 |
| OTA-R-FCH-Service Connect Completion Message | 03/20/03 07:10:00.610 |
| OTA-F-FCH-Universal Handoff Direction Message | 03/20/03 07:10:00.622 |
| OTA-R-FCH-Order Message | 03/20/03 07:10:00.650 |

Figure 10: MO voice call message sequence is captured using the Universal Diagnostics Monitor. Both forward and reverse message transaction are shown.

From the above loggings, we created a message sequence chart and shown in Figure 11. The message sequence is numbered from 1 to 8. Each numbered step corresponds to the expected result defined in

Section 5.1.3. This is to ease for the comparison with the expected result.

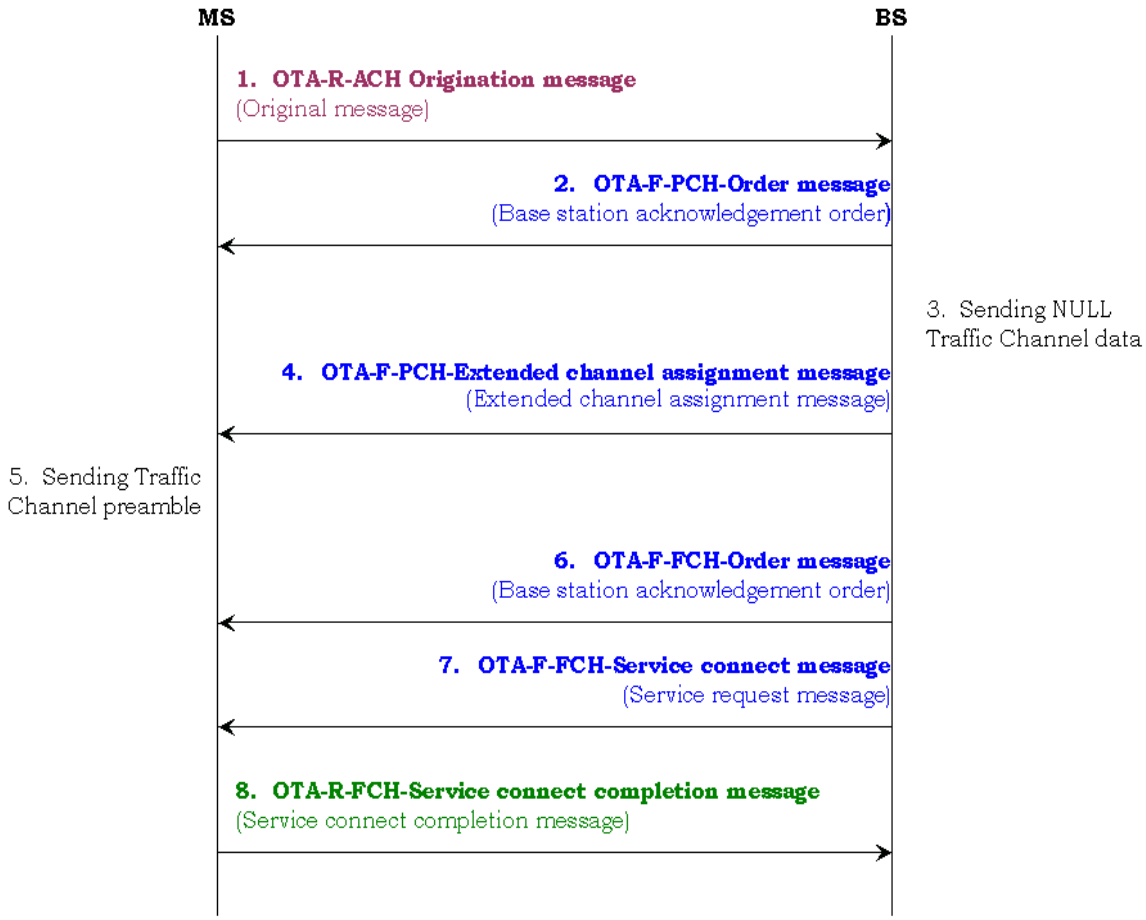



Figure 11: MO voice call message sequence diagram is constructed based on the captured UDM logs.

We have captured the detailed content for each message sequence exchanged between MS and BS. The detailed content for each message transaction is shown in Figures 12 to 17. As a quick summary, we list some of the message contents in Table 4.

| | |
|---|---|
| **OTA-R-ACH-Origination message** (Refer to Figure 12.) | |
| Message type | Origination message |
| ESN | ESN of mobile phone (1059702709) |
| IMSI_S | Mobile phone number (604-230-3145) |
| MOB_P_REV | 6 indicates IS-2000 mode, based on IS-2000-5.0 as defined in Table 3. |
| Service option | 32,768 indicates Qualcomm proprietary voice 13k, based on IS-2000-5.0 [1]. Refer to Table 5 for explanation on service option. |
| CHARi | Recipient phone number (604-618-6645) |
| **OTA-F-PCH-Order message** (Refer to Figure 13.) | |
| Message type | Base station acknowledge |
| IMSI_S | Mobile phone number |
| **OTA-F-PCH-Extended channel assignment message** (Refer to Figure 14.) | |
| Message type | Extended channel assignment message |
| Assign_mode | Traffic channel assignment |
| Num_pilots | Current number of BS “talking” to MS |
| **OTA-F-FCH-Order message** (Refer to Figure 15.) | |
| Message type | Base station acknowledge |
| **OTA-F-FCH-Service connect message** (Refer to Figure 16.) | |
| Message type | Service connect message |
| Service option | 3 indicates EVRC, based on IS-2000-5.0 (Table 5). |
| **OTA-R-FCH-Service connect completion message** (Refer to Figure 17.) | |
| Message type | Service connect completion message |

Table 4: Message content analysis for MO voice call, based on message contents of each message sequence captured using UDM.

Table 5 lists the service options used in the CDMA standard. Samsung phones use the Qualcomm chipset, and the service option should reflect this. Our test phone, Samsung N400, has a service option number of 32,768, which corresponds to the Qualcomm proprietary standard.

| Service option | Type of service | Rate set | Associated standard |
|---|---|---|---|
| 1 | Voice (8K) | I | IS-96A |
| 2 | Loopback | I | IS-126 |
| 3 | EVRC | I | IS-127 |
| 4 | Asynchronous data | I | IS-99 |
| 5 | Group 3 fax | I | IS-99 |
| 6 | SMS | I | IS-637 |
| 7 | Packet data – TCP/IP | I | IS-657 |
| 8 | Packet – CDPD | I | IS-657 |
| 9 | Loopback | II | IS-126A |
| 10 | 8K STU-III voice | I | PN-3571 |
| 11 | 8K STU-III data | I | IS-707 |
| 12 | Asynchronous data | II | IS-707 |
| 13 | Group 3 fax | II | IS-707 |
| 14 | SMS | II | TSB79 |
| 15 | Packet data – TCP/IP | II | IS-707 |
| 16 | Packet data – CDPD | II | IS-707 |
| 4100 | Asynchronous data | I | IS-707 |
| 4101 | Group 3 fax | I | IS-707 |
| 4103 | Packet data – TCP/IP | I | IS-707 |
| 4104 | Packet data – CDPD | I | IS-707 |
| 32768 | Voice (13K) | II | Qualcomm proprietary |
| 32769 | Voice (8K old) | I | Qualcomm proprietary |
| 32770 | Markov (8K old) | I | Qualcomm proprietary |
| 32796 | Markov (13k old) | II | Qualcomm proprietary |
| 32798 | Markov (8K new) | I | Qualcomm proprietary |
| 32799 | Markov (13K new) | II | Qualcomm proprietary |

Table 5: CDMA service options [1]. The reference mobile phone uses option 32768, which corresponds to Qualcomm proprietary standard.

| FIELD | HEX | DEC | DETAIL |
|---|---|---|---|
| MESSAGE_TYPE | | | OTA-R-ACH-Origination Message |
| TIMESTAMP | | | 03/20/03 07:09:59.149 |
| RAW_MESSAGE | | | 0x33447790747E538F6A868CA2409844002E370014281BA9E0000535230C33228040011000300009 |
| MSG_LEN | 0x33 | 51 | |
| PD (2) | 0x1 | 1 | |
| MSG_TYPE (6) | 0x4 | 4 | Origination Message |
| LAC_LENGTH (5) | 0xE | 14 | |
| ACK_SEQ (3) | 0x7 | 7 | |
| MSG_SEQ (3) | 0x4 | 4 | |
| ACK_REQ (1) | 0x1 | 1 | |
| VALID_ACK (1) | 0x0 | 0 | |
| ACK_TYPE (3) | 0x0 | 0 | |
| MSID_TYPE (3) | 0x3 | 3 | |
| MSID_LEN (4) | 0xA | 10 | |
| ESN (32) | 0x3F29C7B5 | 1059702709 | |
| IMSI_CLASS (1) | 0x0 | 0 | |
| IMSI_CLASS_0_TYPE (2) | 0x2 | 2 | |
| RESERVED (1) | 0x0 | 0 | |
| MCC (10) | 0xD1 | 209 | 310 |
| IMSI_S (34) | 0x251204C22 | 9951005730 | 6042303145 |
| AUTH_MODE (2) | 0x0 | 0 | |
| LAC_PADDING (7) | 0x0 | 0 | |
| ACTIVE_PILOT_STRENGTH (6) | 0xB | 11 | |
| FIRST_IS_ACTIVE (1) | 0x1 | 1 | |
| FIRST_IS_PTA (1) | 0x0 | 0 | |
| NUM_ADD_PILOTS (3) | 0x1 | 1 | |
| PILOT_PN_PHASE (15) | 0x5C00 | 23552 | |
| PILOT_STRENGTH (6) | 0x14 | 20 | |
| ACCESS_HO_EN (1) | 0x0 | 0 | |
| ACCESS_ATTEMPTED (1) | 0x0 | 0 | |
| MOB_TERM (1) | 0x1 | 1 | |
| SLOT_CYCLE_INDEX (3) | 0x2 | 2 | |
| MOB_P_REV (8) | 0x6 | 6 | |
| SCM (8) | 0xEA | 234 | |
| REQUEST_MODE (3) | 0x3 | 3 | Either wide analog or CDMA only |
| SPECIAL_SERVICE (1) | 0x1 | 1 | Request special service option |
| SERVICE_OPTION (16) | 0x8000 | 32768 | |
| PM (1) | 0x0 | 0 | |
| DIGIT_MODE (1) | 0x0 | 0 | Use binary representation of DTMF digits |
| MORE_FIELDS (1) | 0x0 | 0 | |
| NUM_FIELDS (8) | 0xA | 10 | |
| CHARi (4) | 0x6 | 6 | 6 |
| CHARi (4) | 0xA | 10 | 0 |
| CHARi (4) | 0x4 | 4 | 4 |
| CHARi (4) | 0x6 | 6 | 6 |
| CHARi (4) | 0x1 | 1 | 1 |
| CHARi (4) | 0x8 | 8 | 8 |
| CHARi (4) | 0x6 | 6 | 6 |
| CHARi (4) | 0x6 | 6 | 6 |
| CHARi (4) | 0x4 | 4 | 4 |
| CHARi (4) | 0x5 | 5 | 5 |

Figure 12: OTA-R-ACH origination message is sent on the over-the-air reverse access channel from the MS to BS.

| FIELD | HEX | DEC | DETAIL |
|---|---|---|---|
| MESSAGE_TYPE | | | OTA-F-PCH-Order Message |
| TIMESTAMP | | | 03/20/03 07:09:59.541 |
| RAW_MESSAGE | | | 0x1007614EC3471CA24098448008A56672 |
| MSG_LEN | 0x10 | 16 | |
| MSG_TYPE (8) | 0x7 | 7 | Order Message |
| ACK_SEQ (3) | 0x4 | 4 | |
| MSG_SEQ (3) | 0x0 | 0 | |
| ACK_REQ (1) | 0x0 | 0 | |
| VALID_ACK (1) | 0x1 | 1 | |
| ADDR_TYPE (3) | 0x2 | 2 | IMSI |
| ADDR_LEN (4) | 0x7 | 7 | |
| IMSI_CLASS (1) | 0x0 | 0 | |
| IMSI_CLASS_0_TYPE (2) | 0x3 | 3 | |
| RESERVED (2) | 0x0 | 0 | |
| MCC (10) | 0xD1 | 209 | 310 |
| IMSI_11_12 (7) | 0x63 | 99 | 00 |
| IMSI_S (34) | 0x251204C22 | 9951005730 | 6042303145 |
| ORDER (6) | 0x10 | 16 | Base Station Acknowledgement Order |
| ADD_RECORD_LEN (3) | 0x0 | 0 | |
| RESERVED (2) | 0x0 | 0 | |
| CRC | 0xBA56672 | 195389042 | |

Figure 13: OTA-F-PCH-order message for BS to acknowledge that the origination message was received.

| FIELD | HEX | DEC | DETAIL |
|---|---|---|---|
| MESSAGE_TYPE | | | OTA-F-PCH-Extended Channel Assignment Message |
| TIMESTAMP | | | 03/20/03 07:09:59.761 |
| RAW_MESSAGE | | | 0x1E15854EC3471CA24098440E0DC00204AFDC042319C000810F0015CFA0AD |
| MSG_LEN | 0x1E | 30 | |
| MSG_TYPE (8) | 0x15 | 21 | Extended Channel Assignment Message |
| ACK_SEQ (3) | 0x4 | 4 | |
| MSG_SEQ (3) | 0x1 | 1 | |
| ACK_REQ (1) | 0x0 | 0 | |
| VALID_ACK (1) | 0x1 | 1 | |
| ADDR_TYPE (3) | 0x2 | 2 | IMSI |
| ADDR_LEN (4) | 0x7 | 7 | |
| IMSI_CLASS (1) | 0x0 | 0 | |
| IMSI_CLASS_0_TYPE (2) | 0x3 | 3 | |
| RESERVED (2) | 0x0 | 0 | |
| MCC (10) | 0xD1 | 209 | 310 |
| IMSI_11_12 (7) | 0x63 | 99 | 00 |
| IMSI_S (34) | 0x251204C22 | 9951005730 | 6042303145 |
| RESERVED_1 (1) | 0x0 | 0 | |
| ADD_RECORD_LEN (8) | 0xE | 14 | |
| ASSIGN_MODE (3) | 0x0 | 0 | Traffic Channel Assignment |
| RESERVED_2 (5) | 0x0 | 0 | |
| FREQ_INCL (1) | 0x1 | 1 | |
| DEFAULT_CONFIG (3) | 0x4 | 4 | Use Mux Opt 1 for RCs at 9600 bps; use Mux Opt 2 at 14400 bps |
| BYPASS_ALERT_ANSWER (1) | 0x0 | 0 | |
| RESERVED (1) | 0x0 | 0 | |
| NUM_PILOTS (3) | 0x0 | 0 | 1 pilots |
| GRANTED_MODE (2) | 0x0 | 0 | |
| FRAME_OFFSET (4) | 0x1 | 1 | 1.25 ms |
| ENCRYPT_MODE (2) | 0x0 | 0 | Encryption disabled |
| BAND_CLASS (5) | 0x1 | 1 | |
| CDMA_FREQ (11) | 0x15E | 350 | |
| PILOT_PN (9) | 0x30 | 48 | 3072 PN chips |
| PWR_COMB_IND (1) | 0x0 | 0 | |
| CODE_CHAN (8) | 0x21 | 33 | |
| FOR_FCH_RC (5) | 0x3 | 3 | |
| REV_FCH_RC (5) | 0x3 | 3 | RC 3 |
| FPC_FCH_INIT_SETPT (8) | 0x38 | 56 | 7.000 dB |
| FPC_SUBCHAN_GAIN (5) | 0x0 | 0 | 0.00 dB |
| RL_GAIN_ADJ (4) | 0x0 | 0 | 0 dB |
| FPC_FCH_FER (5) | 0x4 | 4 | |
| FPC_FCH_MIN_SETPT (8) | 0x8 | 8 | 1.000 dB |
| FPC_FCH_MAX_SETPT (8) | 0x78 | 120 | 15.000 dB |
| REV_FCH_GATING_MODE (1) | 0x0 | 0 | |
| RESERVED (4) | 0x0 | 0 | |
| RESERVED (2) | 0x0 | 0 | |
| CRC | 0x15CFA0AD | 365928621 | |

Figure 14: OTA-F-PCH-extended channel assignment message for BS to send a channel assignment message to the MS.

| FIELD | HEX | DEC | DETAIL |
|---|---|---|---|
| MESSAGE_TYPE | | | OTA-F-FCH-Order Message |
| TIMESTAMP | | | 03/20/03 07:10:00.263 |
| RAW_MESSAGE | | | 0x0801E200400032B2 |
| MSG_LEN | 0x8 | 8 | |
| MSG_TYPE (8) | 0x1 | 1 | Order Message |
| ACK_SEQ (3) | 0x7 | 7 | |
| MSG_SEQ (3) | 0x0 | 0 | |
| ACK_REQ (1) | 0x1 | 1 | |
| ENCRYPTION (2) | 0x0 | 0 | |
| USE_TIME (1) | 0x0 | 0 | |
| ACTION_TIME (6) | 0x0 | 0 | |
| ORDER (6) | 0x10 | 16 | Base Station Acknowledgement Order |
| ADD_RECORD_LEN (3) | 0x0 | 0 | |
| RESERVED (7) | 0x0 | 0 | |
| CRC | 0x32B2 | 12978 | |

Figure 15: OTA-F-FCH-order message for BS to acknowledge receiving the mobile's preamble.

| FIELD | HEX | DEC | DETAIL |
|---|---|---|---|
| MESSAGE_TYPE | | | OTA-F-FCH-Service Connect Message |
| TIMESTAMP | | | 03/20/03 07:10:00.581 |
| RAW_MESSAGE | | | 0x1B142E0000070F00010001F0F00106010003110486301301005290 |
| MSG_LEN | 0x1B | 27 | |
| MSG_TYPE (8) | 0x14 | 20 | Service Connect Message |
| ACK_SEQ (3) | 0x1 | 1 | |
| MSG_SEQ (3) | 0x3 | 3 | |
| ACK_REQ (1) | 0x1 | 1 | |
| ENCRYPTION (2) | 0x0 | 0 | |
| USE_TIME (1) | 0x0 | 0 | |
| ACTION_TIME (6) | 0x0 | 0 | |
| SERV_CON_SEQ (3) | 0x0 | 0 | |
| RESERVED (5) | 0x0 | 0 | |
| RECORD_TYPE (8) | 0x7 | 7 | Service Configuration |
| RECORD_LEN (8) | 0xF | 15 | |
| FOR_MUX_OPTION (16) | 0x1 | 1 | |
| REV_MUX_OPTION (16) | 0x1 | 1 | |
| FOR_RATES (8) | 0xF0 | 240 | |
| REV_RATES (8) | 0xF0 | 240 | |
| NUM_CON_REC (8) | 0x1 | 1 | |
| RECORD_LEN (8) | 0x6 | 6 | |
| CON_REF (8) | 0x1 | 1 | |
| SERVICE_OPTION (16) | 0x3 | 3 | |
| FOR_TRAFFIC (4) | 0x1 | 1 | The service option connection uses primary traffic on the FTC |
| REV_TRAFFIC (4) | 0x1 | 1 | The service option connection uses primary traffic on the RTC |
| UI_ENCRYPT_MODE (3) | 0x0 | 0 | |
| SR_ID (3) | 0x1 | 1 | |
| RLP_INFO_INCL (1) | 0x0 | 0 | |
| RESERVED (1) | 0x0 | 0 | |
| FCH_CC_INCL (1) | 0x1 | 1 | |
| FCH_FRAME_SIZE (1) | 0x0 | 0 | |
| FOR_FCH_RC (5) | 0x3 | 3 | |
| REV_FCH_RC (5) | 0x3 | 3 | |
| DCCH_CC_INCL (1) | 0x0 | 0 | |
| FOR_SCH_CC_INCL (1) | 0x0 | 0 | |
| REV_SCH_CC_INCL (1) | 0x0 | 0 | |
| RESERVED (1) | 0x0 | 0 | |
| RECORD_TYPE (8) | 0x13 | 19 | Non-Negotiable Service Configuration |
| RECORD_LEN (8) | 0x1 | 1 | |
| FPC_INCL (1) | 0x0 | 0 | |
| GATING_RATE_INCL (1) | 0x0 | 0 | |
| RESERVED (2) | 0x0 | 0 | |
| LPM_IND (2) | 0x0 | 0 | |
| RESERVED (2) | 0x0 | 0 | |
| CRC | 0x5290 | 21136 | |

Figure 16: OTA-F-FCH-service connect message for BS to propose the call connection to start.

| FIELD | HEX | DEC | DETAIL |
|---|---|---|---|
| MESSAGE_TYPE | | | OTA-R-FCH-Service Connect Completion Message |
| TIMESTAMP | | | 03/20/03 07:10:00.610 |
| RAW_MESSAGE | | | 0x060E6A00A346 |
| MSG_LEN | 0x6 | 6 | |
| MSG_TYPE (8) | 0xE | 14 | Service Connect Completion Message |
| ACK_SEQ (3) | 0x3 | 3 | |
| MSG_SEQ (3) | 0x2 | 2 | |
| ACK_REQ (1) | 0x1 | 1 | |
| ENCRYPTION (2) | 0x0 | 0 | |
| RESERVED (1) | 0x0 | 0 | |
| SERV_CON_SEQ (3) | 0x0 | 0 | |
| RESERVED (3) | 0x0 | 0 | |
| CRC | 0xA346 | 41798 | |

Figure 17: OTA-R-FCH-service connect completion message for mobile to agree on the connection.

Besides the detailed analysis on the message transaction, it is also important to illustrate the state transition occurring during the MO voice call. The voice call state diagram is shown in Figure 18 [1], and it illustrates the different states of the mobile station. When we start the test by powering up the mobile phone, this sets the mobile phone to the *power-up state*. Once the mobile powered up, it goes through the initialization setup, referred as the *mobile station initialization state*. When the mobile successfully acquires the system timing and registers to the system, it is set to the *mobile station idle state*.

Next step is to place a mobile originated voice call. This essentially requires the mobile to request for system access, meaning to get access to the resource (traffic channel) that is required to setup the call. At this point, the mobile is in the *system access state*. Once the base station assigns the traffic channel to the mobile, the mobile is set to the *mobile* *station control on the traffic channel state*. Finally, we release the voice call and the mobile goes back to the *mobile station initialization state*.

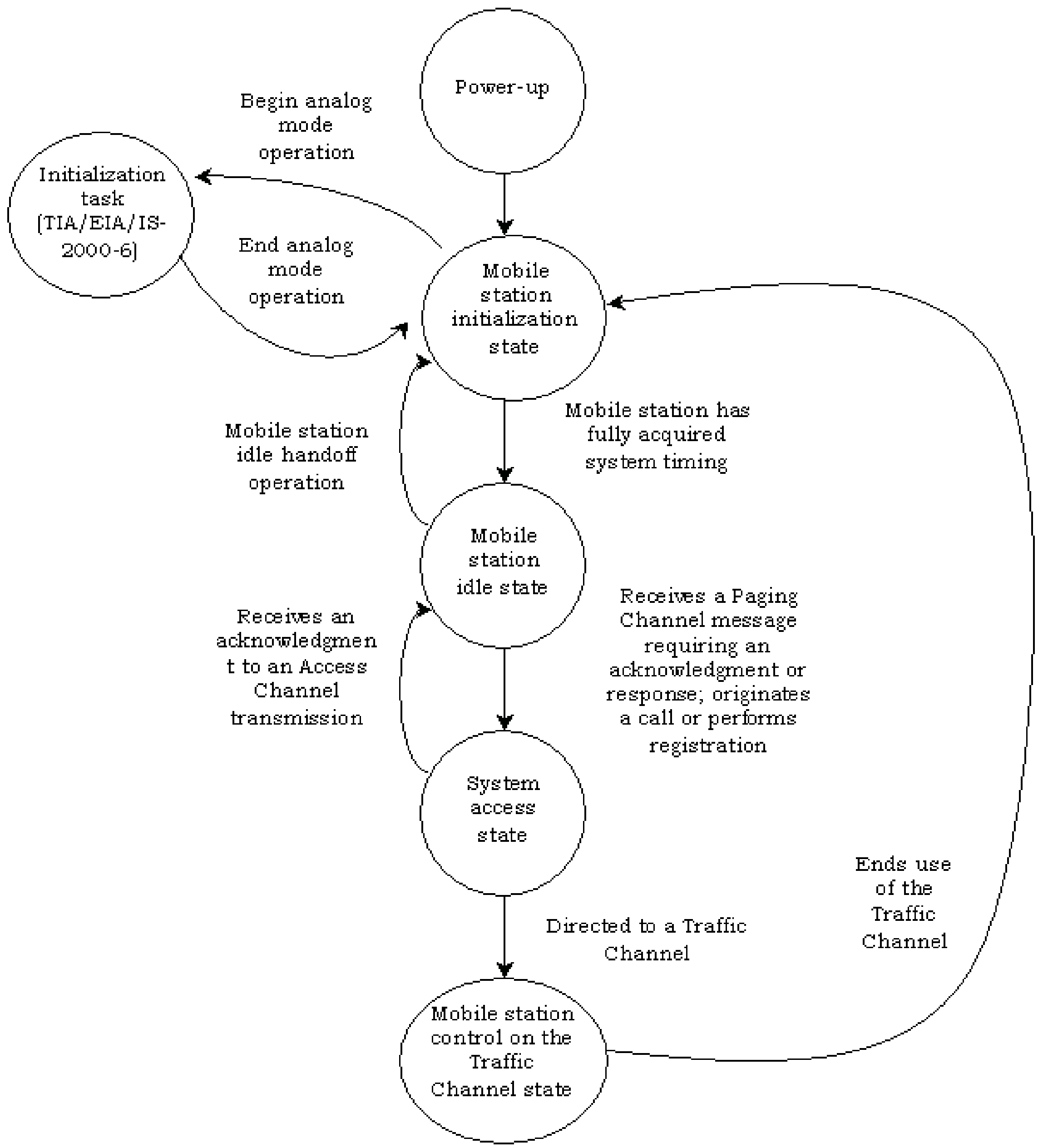



Figure 18: This state diagram illustrates the states that the mobile goes through during the MO voice call test case [1].

## 5.2 Test Case 2: Soft handoff – add to active set

### 5.2.1 Soft handoff background

Soft handoff is a complex process. It is explained in details in this section. This section provides the background knowledge for the three soft handoff test cases to be followed in the Sections 5.2.2, 5.2.3, and 5.2.4.

Mobile station supports handoff as it moves from one area to another. Along the way, it transfers its communication from one base station to another. There are different handoff scenarios in different states of the mobile station. When the mobile is in the *mobile station control on the traffic channel state*, as shown in Figure 18, it supports soft handoff and hard handoff.

Soft handoff occurs when the mobile begins to communicate with the second base station without breaking its communication path with the current serving base station. In general, this is known as the "make-before-break" approach. During the soft handoff, the mobile can communicate with more than two base stations simultaneously. IS-2000.5-0 [1] defines the maximum number of simultaneous links to be six, which implies that the mobile can talk to six base stations at the same time. Each base station has its unique pilot. The pilot provides the mobile stations with a timing reference and the information for the mobile stations to acquire the communication with the network. The pilots of the base stations that the mobile is actively communicating over the traffic channel constitute the mobile's *active set*.

The mobile generally initiates soft handoffs. During a call, when the mobile is in the *mobile station control on the traffic channel state*, it will continuously scan for better pilots. Better pilot refers to the pilot that has a stronger signal strength than the *add threshold* (T_ADD). If better pilots are found, then the mobile reports them to the base station. Thus, the mobile assist the base station in soft handoff. This is characterized as the Mobile Assisted Handoff (MAHO) approach.

In order to achieve soft handoff, the participating base stations must support the same frequency. The mobile transmits on the same frame offset on all communication links. In other words, soft handoff can only be used between CDMA channels having identical frequency assignments.

As mentioned earlier, the mobile maintains the links with multiple base stations during soft handoff. The mobile stores the values for *add threshold* and *drop threshold* (T_DROP) for adding or dropping a base station during soft handoff. These thresholds are supplied to the mobile at call initiation.

The mobile maintains a list, called the *active set*, of the base stations involved in soft handoff. It maintains a list of candidates, called *candidate set*, whose measured signal strength are above the *add threshold*. The mobile assists in soft handoff by reporting both lists to the system whenever a new candidate appears in the *candidate set* or the signal strength of an existing base station in the active set falls below the *drop threshold*. The system can add base stations from the *candidate set* to soft handoff or drop base stations during soft handoff.

Pilot sets are groups of pilots. Pilots are stored in different groups to assist the mobile in soft handoff. Each mobile maintains its own pilot sets when it is on the traffic channel. This set can be changed dynamically during a call by transitioning pilots among different sets:

- *Active Set*: Pilots (based stations) with which mobile is in soft handoff. This *active set* can have up to six pilots.
- *Candidate Set*: Pilots not currently in the *active set*, but are *candidates* for handoffs. These pilots have been received by the mobile with signal strength above the *add threshold*.
- *Neighbor Set*: Pilots that are not currently in *active* or the *candidate set*s but are likely *candidates* for handoffs.
- *Remaining Set*: All possible pilots in the current system excluding pilots in *neighbor set*, the *candidate set* and the *active set*.

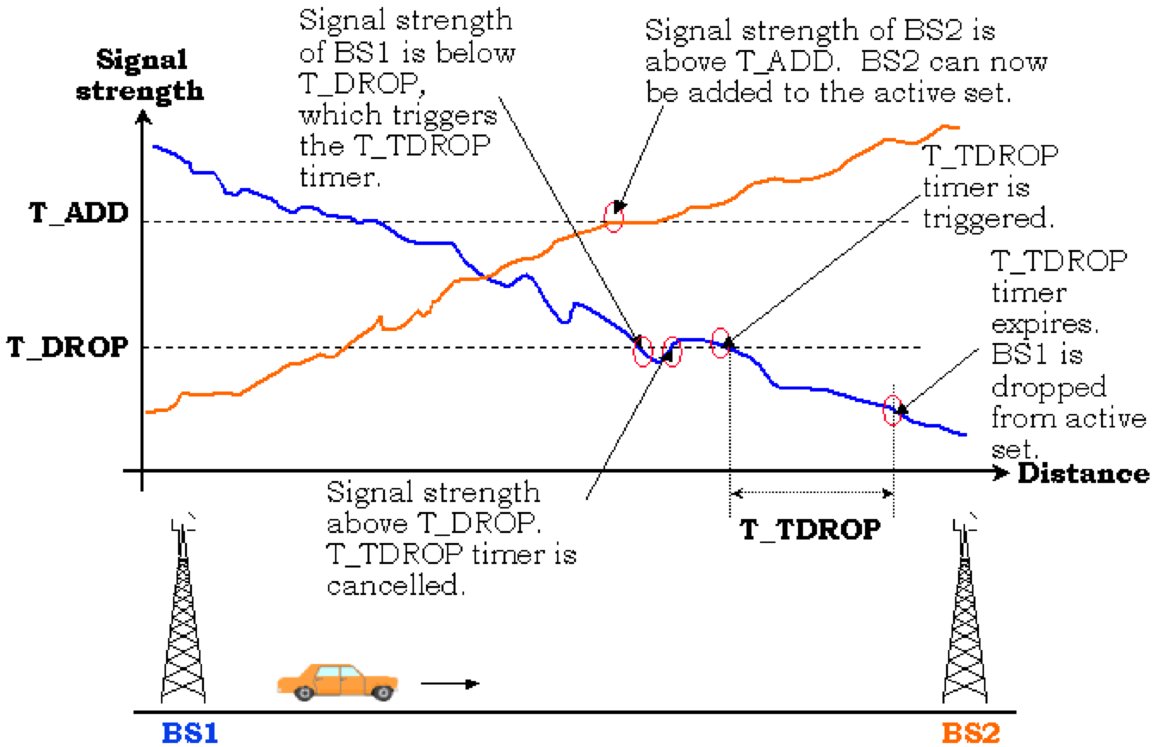



Figure 19: A soft handoff scenario for a mobile station moving from BS1 to BS2.

Figure 19 depicts the trigger for adding and dropping a pilot. In this scenario, mobile starts moving from base station 1 (BS1) towards base station 2 (BS2). As it moves closer to BS2, the signal strength of BS2 becomes stronger. Once the signal strength of this pilot reaches the T_ADD threshold, this pilot can be added to the active set.

At the same time, the signal strength of BS1 drops as the mobile moves away from BS1. Once the signal strength drops below the T_DROP threshold, this event triggers the T_TDROP timer to be set. If the signal strength goes above the T_DROP threshold before the T_TDROP timer expires, the pilot will not be dropped. Only if the signal strength is below the T_DROP threshold for at least the duration of the T_TDROP timer, the pilot will be dropped from the active set.

### 5.2.2 Objective

The objective of this test case is to ensure that the entrance requirement for "Section 4.3.1 Long Call Maintenance with Handoffs and Fading" as defined in CDG stage 3 testing for CDMA2000 [10] is met.

### 5.2.3 Test steps

*Precondition*

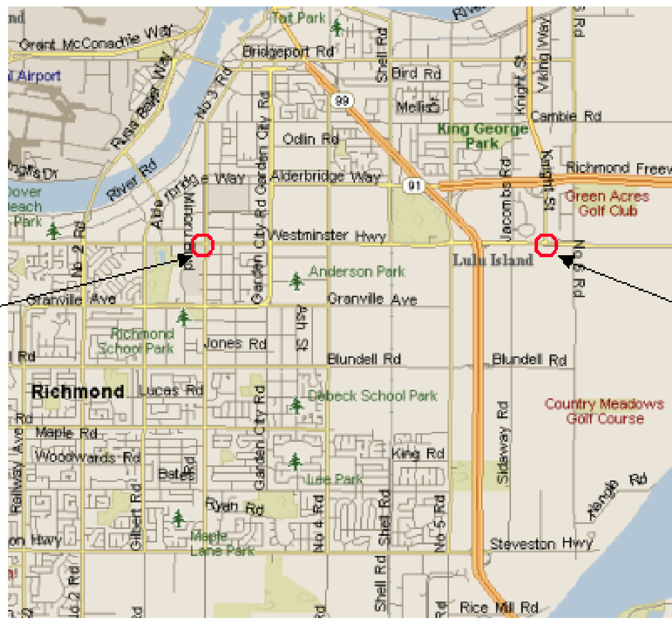
- Plan the drive route with soft handoff in the selected network. In our case, the route is from Knight Street to No. 3 Road along Westminster Highway, in Richmond.
- Power on the MS.
- Start the diagnostic monitoring tool, connect it to the MS, and begin to log air messages.
- Use the diagnostic monitoring tool to ensure that the MS performs a power-up registration.
- Ensure that the network provides acknowledgement for the power-up registration sequence from the MS.
- Observe the MS until it provides a service indication to the user.
- Initiate a call from the mobile phone to a landline phone.

*Procedures*

- Start the drive test at the intersection of Knight Bridge and Westminster Highway. Drive route is shown in Figure 20.

- Initiate a call from the mobile phone to a landline phone.
- Ensure voice call is connected.
- Maintain the voice call during the drive test.
- Continue to drive along Westminster Highway towards No. 3 Road.
- Disconnect the voice call from the mobile phone when we arrive to destination.

Drive test ends at the intersection of No. 3 Road and Westminster Hwy.




Drive test begins at the intersection of Knight Street and Westminster Hwy.

Figure 20: Drive route used for soft handoff test cases with start point and end point.

### 5.2.4 Expected results and diagrams

The call flow in Figure 21 shows the addition of base stations during soft handoff. It details the sequence of messages exchanged between the mobile and the base station to add a pilot during soft handoff.

1. As the mobile continuously scans for better pilots, it detects the pilot for base station BS2. When the signal strength of the pilot

from BS2 rises above the *add threshold*, it then becomes a candidate for soft handoff. The mobile sends a *Pilot Strength Measurement Message* (PSMM) to base station BS1. The PSMM includes both the signal strength of the current serving pilots (*active set*) and potential candidates (*candidate set*).

2. Upon receiving the PSMM through BS1, the network decides to add BS2 to soft handoff. After allocating internal resources in BS2 for the call, the network sends a *Handoff Direction Message* to the mobile through base station BS1. The *Handoff Direction Message* includes information about the set of traffic channels, which includes BS1 and BS2. The BSC starts "multicasting" the forward direction frames.

3. The mobile tunes to BS2 and sends a *Handoff Completion Message* to the network through BS1 and BS2. At this point, BS2 is added to soft handoff. The BSC starts "selection" of frames in the reverse direction. The mobile starts "combining" frames in the forward direction.

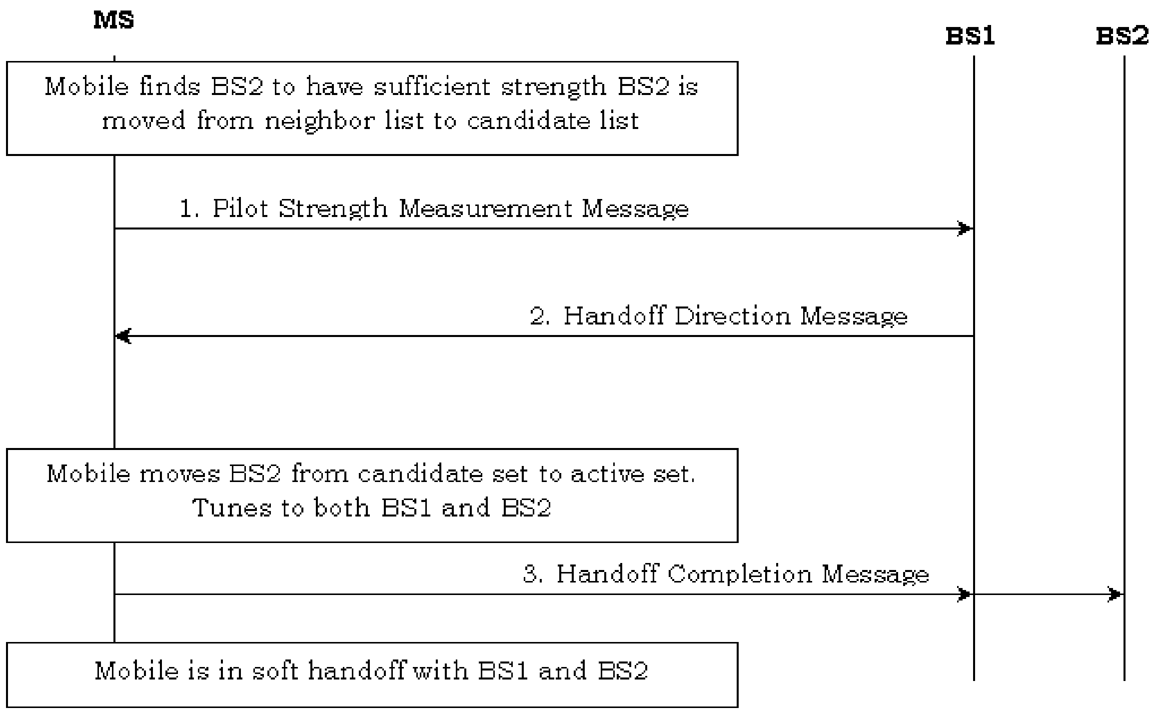



Figure 21: Message sequence diagram showing pilot being added to the active set during soft handoff [4].

### 5.2.5 Results and loggings

Based on the test steps defined in Section 5.2.3, we executed the test case. We captured the complete call processing during the test and it is illustrated in Figure 22. The mobile phone continued to scan for better pilots. Hence, continuous soft handoff transactions were observed in the logs.

| Message Type | System Time |
|---|---|
| OTA-F-FCH-Universal Handoff Direction Message | 03/14/03 07:19:14.214 |
| OTA-R-FCH-Order Message | 03/14/03 07:19:14.222 |
| OTA-R-FCH-Handoff Completion Message | 03/14/03 07:19:14.263 |
| OTA-F-FCH-Universal Handoff Direction Message | 03/14/03 07:19:14.274 |
| OTA-F-FCH-Universal Handoff Direction Message | 03/14/03 07:19:14.333 |
| OTA-R-FCH-Order Message | 03/14/03 07:19:14.362 |
| OTA-R-FCH-Pilot Strength Measurement Message | 03/14/03 07:19:18.322 |
| OTA-R-FCH-Handoff Completion Message | 03/14/03 07:19:18.623 |
| OTA-F-FCH-Universal Handoff Direction Message | 03/14/03 07:19:18.634 |
| OTA-R-FCH-Order Message | 03/14/03 07:19:18.663 |
| OTA-R-FCH-Order Message | 03/14/03 07:19:18.703 |
| OTA-R-FCH-Power Measurement Report Message | 03/14/03 07:19:22.142 |
| OTA-R-FCH-Power Measurement Report Message | 03/14/03 07:19:25.142 |
| OTA-R-FCH-Power Measurement Report Message | 03/14/03 07:19:26.203 |
| OTA-R-FCH-Pilot Strength Measurement Message | 03/14/03 07:19:48.222 |
| OTA-R-FCH-Pilot Strength Measurement Message | 03/14/03 07:19:48.563 |
| OTA-R-FCH-Handoff Completion Message | 03/14/03 07:19:48.643 |
| OTA-F-FCH-Neighbor List Update Message | 03/14/03 07:19:48.854 |
| OTA-F-FCH-Universal Handoff Direction Message | 03/14/03 07:19:48.894 |
| OTA-R-FCH-Order Message | 03/14/03 07:19:48.903 |
| OTA-R-FCH-Handoff Completion Message | 03/14/03 07:19:48.943 |
| OTA-F-FCH-Universal Handoff Direction Message | 03/14/03 07:19:48.954 |
| OTA-F-FCH-Universal Handoff Direction Message | 03/14/03 07:19:49.013 |
| OTA-R-FCH-Order Message | 03/14/03 07:19:49.063 |
| OTA-F-FCH-Universal Handoff Direction Message | 03/14/03 07:19:57.293 |
| OTA-R-FCH-Order Message | 03/14/03 07:19:57.343 |
| OTA-F-FCH-Universal Handoff Direction Message | 03/14/03 07:19:57.354 |
| OTA-R-FCH-Power Measurement Report Message | 03/14/03 07:20:12.422 |
| OTA-R-FCH-Pilot Strength Measurement Message | 03/14/03 07:20:17.683 |
| OTA-F-FCH-Universal Handoff Direction Message | 03/14/03 07:20:17.894 |
| OTA-R-FCH-Order Message | 03/14/03 07:20:17.903 |
| OTA-F-FCH-Universal Handoff Direction Message | 03/14/03 07:20:17.954 |
| OTA-R-FCH-Handoff Completion Message | 03/14/03 07:20:17.962 |
| OTA-F-FCH-Universal Handoff Direction Message | 03/14/03 07:20:19.693 |
| OTA-R-FCH-Order Message | 03/14/03 07:20:19.722 |
| OTA-R-FCH-Order Message | 03/14/03 07:20:19.762 |
| OTA-F-FCH-Neighbor List Update Message | 03/14/03 07:20:19.773 |
| OTA-F-FCH-Universal Handoff Direction Message | 03/14/03 07:20:23.794 |
| OTA-R-FCH-Order Message | 03/14/03 07:20:24.163 |
| OTA-R-FCH-Power Measurement Report Message | 03/14/03 07:20:24.522 |
| OTA-R-FCH-Pilot Strength Measurement Message | 03/14/03 07:20:26.742 |
| OTA-F-FCH-Universal Handoff Direction Message | 03/14/03 07:20:27.034 |
| OTA-R-FCH-Pilot Strength Measurement Message | 03/14/03 07:20:27.063 |
| OTA-F-FCH-Universal Handoff Direction Message | 03/14/03 07:20:27.093 |
| OTA-R-FCH-Order Message | 03/14/03 07:20:27.142 |
| OTA-F-FCH-Neighbor List Update Message | 03/14/03 07:20:27.853 |
| OTA-F-FCH-Order Message | 03/14/03 07:20:27.873 |
| OTA-R-FCH-Order Message | 03/14/03 07:20:27.923 |
| OTA-R-FCH-Power Measurement Report Message | 03/14/03 07:20:31.382 |
| OTA-R-FCH-Pilot Strength Measurement Message | 03/14/03 07:20:37.123 |
| OTA-R-FCH-Order Message | 03/14/03 07:20:37.483 |
| OTA-F-FCH-Neighbor List Update Message | 03/14/03 07:20:37.533 |

Figure 22: Message sequences during soft handoff are captured using UDM.

| | |
|---|---|
| **OTA-F-FCH-Universal direction handoff message** (Refer to Figure 23.) | |
| Message type | Universal handoff direction message |
| Soft slope | Zero indicates fixed threshold algorithm is used according to IS2000.5-0. |
| T_Add | Signal strength threshold for pilot add |
| T_Drop | Signal strength threshold for pilot drop |
| Soft slope | Zero indicates fixed threshold algorithm is used according to IS2000.5-0 |
| Num_pilot | Number of pilots in *active set* |
| Pilot_PN | Pilot PN - currently 380, 12 and 172 are in the *active set*. |
| **OTA-F-FCH-Neighbor list update message** (Refer to Figure 24.) | |
| Message type | Neighbor list update message |
| NGHBR_PN | Neighbor pilot PN |
| **OTA-R-FCH-Power measurement report message** (Refer to Figure 25.) | |
| Message type | Power measurement report message |
| Pilot_strength | Pilot strength measurement for the pilots in the *active set* (Currently, 3 pilots are in the *active set*, so 3 measurements are provided.) |
| **OTA-R-FCH-Pilot strength measurement message** (Refer to Figure 26.) | |
| Message type | Pilot strength measurement message |
| Ref_PN | Reference PN |
| Pilot_strength | Pilot strength of PN |
| Pilot_PN_phase | Other pilots in *active set* or *candidate set* |
| **OTA-R-FCH-Handoff completion message** (Refer to Figure 27.) | |
| Message type | Handoff completion message |
| Pilot_PN | Pilots in *active set* |

Table 6: Message content analysis of soft handoff, based on message contents of each message sequence captured using UDM.

We captured detailed message content for each message sequence exchanged between MS and BS. All the details are available in Figures 23 to 27. As a summary, we present some highlights of the message contents in Table 6.

The Universal Handoff Direction Message (UHDM) is a new message defined in CDMA2000 to support handoffs. The UHDM provides the support for additional features implemented in CDMA2000, and UHDM replaces the General Handoff Direction Message (GHDM) of IS-95B. However, the GHDM is still retained in CDMA2000 for backward compatibility reasons. The UHDM is used for CDMA2000 mobiles with protocol revision of 6 or higher. The GHDM is used for IS-95B mobiles with protocol revision of 5. IS-95A mobiles can use the Extended Handoff Direction Message (EHDM).

| FIELD | HEX | DEC | DETAIL |
|---|---|---|---|
| MESSAGE_TYPE | | | OTA-F-FCH-Universal Handoff Direction Message |
| TIMESTAMP | | | 03/14/03 07:18:30.193 |
| RAW_MESSAGE | | | 0x1A220A356A9C808C000050C50A6BE00400600C05620840004F3F |
| MSG_LEN | 0x1A | 26 | |
| MSG_TYPE (8) | 0x22 | 34 | Universal Handoff Direction Message |
| ACK_SEQ (3) | 0x0 | 0 | |
| MSG_SEQ (3) | 0x2 | 2 | |
| ACK_REQ (1) | 0x1 | 1 | |
| ENCRYPTION (2) | 0x0 | 0 | |
| USE_TIME (1) | 0x0 | 0 | |
| HDM_SEQ (2) | 0x3 | 3 | |
| PARMS_INCL (1) | 0x0 | 0 | |
| SEARCH_INCLUDED (1) | 0x1 | 1 | |
| SRCH_WIN_A (4) | 0x5 | 5 | Window Size = 20 |
| SRCH_WIN_N (4) | 0xA | 10 | Window Size = 100 |
| SRCH_WIN_R (4) | 0xA | 10 | Window Size = 100 |
| T_ADD (6) | 0x1C | 28 | |
| T_DROP (6) | 0x20 | 32 | |
| T_COMP (4) | 0x2 | 2 | 1.00 dB |
| T_TDROP (4) | 0x3 | 3 | 4 seconds |
| SOFT_SLOPE (6) | 0x0 | 0 | |
| ADD_INTERCEPT (6) | 0x0 | 0 | |
| DROP_INTERCEPT (6) | 0x0 | 0 | |
| EXTRA_PARMS (1) | 0x0 | 0 | |
| USE_PWR_CNTL_STEP (1) | 0x1 | 1 | |
| PWR_CNTL_STEP (3) | 0x2 | 2 | 0.25 dB |
| CLEAR_RETRY_DELAY (1) | 0x0 | 0 | |
| SCH_INCL (1) | 0x0 | 0 | |
| FPC_SUBCHAN_GAIN (5) | 0xC | 12 | 3.00 dB |
| USE_PC_TIME (1) | 0x0 | 0 | |
| CH_IND (3) | 0x5 | 5 | Fundamental Channel and Continuous Reverse Pilot Channel |
| ACTIVE_SET_REC_LEN (8) | 0xA | 10 | |
| NUM_PILOTS (3) | 0x3 | 3 | |
| SRCH_OFFSET_INCL (1) | 0x0 | 0 | |
| PILOT_PN (9) | 0x17C | 380 | 24320 PN chips |
| ADD_PILOT_REC_INCL (1) | 0x0 | 0 | |
| PWR_COMB_IND (1) | 0x0 | 0 | |
| CODE_CHAN_FCH (11) | 0x10 | 16 | |
| QOF_MASK_ID_FCH (2) | 0x0 | 0 | |
| PILOT_PN (9) | 0xC | 12 | 768 PN chips |
| ADD_PILOT_REC_INCL (1) | 0x0 | 0 | |
| PWR_COMB_IND (1) | 0x0 | 0 | |
| CODE_CHAN_FCH (11) | 0x30 | 48 | |
| QOF_MASK_ID_FCH (2) | 0x0 | 0 | |
| PILOT_PN (9) | 0xAC | 172 | 11008 PN chips |
| ADD_PILOT_REC_INCL (1) | 0x0 | 0 | |
| PWR_COMB_IND (1) | 0x1 | 1 | |
| CODE_CHAN_FCH (11) | 0x21 | 33 | |
| QOF_MASK_ID_FCH (2) | 0x0 | 0 | |
| RESERVED (4) | 0x0 | 0 | |
| REV_FCH_GATING_MODE (1) | 0x0 | 0 | |
| RESERVED (7) | 0x0 | 0 | |

Figure 23: OTA-F-FCH-universal direction handoff message is a new message defined in IS-2000.

| FIELD | HEX | DEC | DETAIL |
|---|---|---|---|
| MESSAGE_TYPE | | | OTA-F-FCH-Neighbor List Update Message |
| TIMESTAMP | | | 03/14/03 07:18:30.333 |
| RAW_MESSAGE | | | 0x1D082E237078D0020D0394CD677070B0145D2E128B41E2015C0A004765 |
| MSG_LEN | 0x1D | 29 | |
| MSG_TYPE (8) | 0x8 | 8 | Neighbor List Update Message |
| ACK_SEQ (3) | 0x1 | 1 | |
| MSG_SEQ (3) | 0x3 | 3 | |
| ACK_REQ (1) | 0x1 | 1 | |
| ENCRYPTION (2) | 0x0 | 0 | |
| PILOT_INC (4) | 0x4 | 4 | 256 PN chips |
| NGHBR_PN (9) | 0xDC | 220 | 14080 PN chips |
| NGHBR_PN (9) | 0x3C | 60 | 3840 PN chips |
| NGHBR_PN (9) | 0xD0 | 208 | 13312 PN chips |
| NGHBR_PN (9) | 0x4 | 4 | 256 PN chips |
| NGHBR_PN (9) | 0x34 | 52 | 3328 PN chips |
| NGHBR_PN (9) | 0x1C | 28 | 1792 PN chips |
| NGHBR_PN (9) | 0x14C | 332 | 21248 PN chips |
| NGHBR_PN (9) | 0x1AC | 428 | 27392 PN chips |
| NGHBR_PN (9) | 0x1DC | 476 | 30464 PN chips |
| NGHBR_PN (9) | 0x38 | 56 | 3584 PN chips |
| NGHBR_PN (9) | 0xB0 | 176 | 11264 PN chips |
| NGHBR_PN (9) | 0x28 | 40 | 2560 PN chips |
| NGHBR_PN (9) | 0x174 | 372 | 23808 PN chips |
| NGHBR_PN (9) | 0x170 | 368 | 23552 PN chips |
| NGHBR_PN (9) | 0x128 | 296 | 18944 PN chips |
| NGHBR_PN (9) | 0x168 | 360 | 23040 PN chips |
| NGHBR_PN (9) | 0x78 | 120 | 7680 PN chips |
| NGHBR_PN (9) | 0x100 | 256 | 16384 PN chips |
| NGHBR_PN (9) | 0x15C | 348 | 22272 PN chips |
| NGHBR_PN (9) | 0x14 | 20 | 1280 PN chips |
| RESERVED (7) | 0x0 | 0 | |
| CRC | 0x4765 | 18277 | |

Figure 24: OTA-F-FCH-neighbor list update message for BS to send this list to update the neighbor list in the MS.

| FIELD | HEX | DEC | DETAIL |
|---|---|---|---|
| MESSAGE_TYPE | | | OTA-R-FCH-Power Measurement Report Message |
| TIMESTAMP | | | 03/14/03 07:18:31.701 |
| RAW_MESSAGE | | | 0x0B066C0960CD774F0019FA |
| MSG_LEN | 0xB | 11 | |
| MSG_TYPE (8) | 0x6 | 6 | Power Measurement Report Message |
| ACK_SEQ (3) | 0x3 | 3 | |
| MSG_SEQ (3) | 0x3 | 3 | |
| ACK_REQ (1) | 0x0 | 0 | |
| ENCRYPTION (2) | 0x0 | 0 | |
| ERRORS_DETECTED (5) | 0x2 | 2 | |
| PWR_MEAS_FRAMES (10) | 0x160 | 352 | |
| LAST_HDM_SEQ (2) | 0x3 | 3 | No EHDM, GHDM, or UHDM received |
| NUM_PILOTS (4) | 0x3 | 3 | |
| PILOT_STRENGTH (6) | 0x17 | 23 | |
| PILOT_STRENGTH (6) | 0x1D | 29 | |
| PILOT_STRENGTH (6) | 0xF | 15 | |
| DCCH_PWR_MEAS_INCL (1) | 0x0 | 0 | |
| SCH_PWR_MEAS_INCL (1) | 0x0 | 0 | |
| RESERVED (6) | 0x0 | 0 | |
| CRC | 0x19FA | 6650 | |

Figure 25: OTA-R-FCH-power measurement report message for MS to report the power measurement of the pilots in the *active set*.

| FIELD | HEX | DEC | DETAIL |
|---|---|---|---|
| MESSAGE_TYPE | | | OTA-R-FCH-Pilot Strength Measurement Message |
| TIMESTAMP | | | 03/14/03 07:18:35.903 |
| RAW_MESSAGE | | | 0x1505FA5F12B411860C15DAB054BAC3AF8D0CA26EF2 |
| MSG_LEN | 0x15 | 21 | |
| MSG_TYPE (8) | 0x5 | 5 | Pilot Strength Measurement Message |
| ACK_SEQ (3) | 0x7 | 7 | |
| MSG_SEQ (3) | 0x6 | 6 | |
| ACK_REQ (1) | 0x1 | 1 | |
| ENCRYPTION (2) | 0x0 | 0 | |
| REF_PN (9) | 0x17C | 380 | 24320 PN chips |
| PILOT_STRENGTH (6) | 0x12 | 18 | |
| KEEP (1) | 0x1 | 1 | |
| PILOT_PN_PHASE (15) | 0x3411 | 13329 | |
| PILOT_STRENGTH (6) | 0x21 | 33 | |
| KEEP (1) | 0x1 | 1 | |
| PILOT_PN_PHASE (15) | 0x305 | 773 | |
| PILOT_STRENGTH (6) | 0x1D | 29 | |
| KEEP (1) | 0x1 | 1 | |
| PILOT_PN_PHASE (15) | 0x2B05 | 11013 | |
| PILOT_STRENGTH (6) | 0x12 | 18 | |
| KEEP (1) | 0x1 | 1 | |
| PILOT_PN_PHASE (15) | 0x6B0E | 27406 | |
| PILOT_STRENGTH (6) | 0x2F | 47 | |
| KEEP (1) | 0x1 | 1 | |
| PILOT_PN_PHASE (15) | 0xD0C | 3340 | |
| PILOT_STRENGTH (6) | 0x28 | 40 | |
| KEEP (1) | 0x1 | 1 | |
| RESERVED (1) | 0x0 | 0 | |
| CRC | 0x6EF2 | 28402 | |

Figure 26: OTA-R-FCH-pilot strength measurement message for MS to return the pilot strength to BS, including pilots in both *active* and *candidate set*.

| FIELD | HEX | DEC | DETAIL |
|---|---|---|---|
| MESSAGE_TYPE | | | OTA-R-FCH-Handoff Completion Message |
| TIMESTAMP | | | 03/14/03 07:18:49.923 |
| RAW_MESSAGE | | | 0x090A4677C6E2B02916 |
| MSG_LEN | 0x9 | 9 | |
| MSG_TYPE (8) | 0xA | 10 | Handoff Completion Message |
| ACK_SEQ (3) | 0x2 | 2 | |
| MSG_SEQ (3) | 0x1 | 1 | |
| ACK_REQ (1) | 0x1 | 1 | |
| ENCRYPTION (2) | 0x0 | 0 | |
| LAST_HDM_SEQ (2) | 0x3 | 3 | |
| PILOT_PN (9) | 0x17C | 380 | |
| PILOT_PN (9) | 0xDC | 220 | |
| PILOT_PN (9) | 0xAC | 172 | |
| RESERVED (2) | 0x0 | 0 | |
| CRC | 0x2916 | 10518 | |

Figure 27: OTA-R-FCH-handoff completion message for MS to return this message to BS after soft handoff is completed.

During the test drive from starting point to destination point, multiple soft handoffs had occurred. From the captured loggings, we performed a detailed analysis on the soft handoffs happened during the test drive route. It is presented in Appendix C Detailed soft handoff analysis. Steps 1 to 7 deal with the analysis of adding pilots to the *active set*.

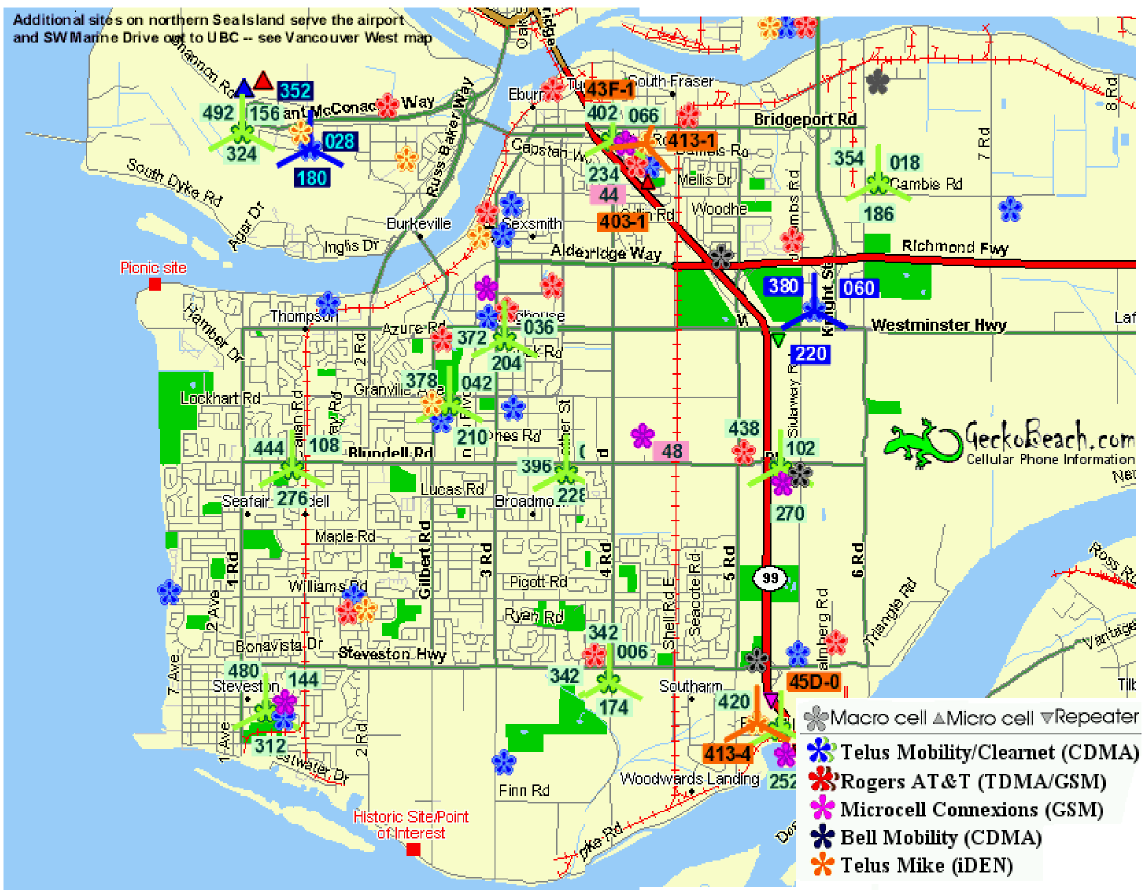



Figure 28: Richmond cellular or PCS equipment map presents the locations of the base station sites for the carriers' networks [18].

Figure 28 is a map showing the cellular and PCS equipments in Richmond. This map might not contain the latest update pilot numbers in the network. Nevertheless, it provides the concept of the base stations' locations. We started the execution of the mobile soft handoff at the intersection of Knight Street and Westminster Highway. The voice call was maintained as the mobile moves towards No. 3 Road and Westminster Highway. Table 7 in Appendix C Detailed soft handoff analysis shows that the mobile started with pilot 380 in the *active set* (step 1). Soon, pilots 60 and 220 were added to the *candidate set* (step 5), and eventually, were added to the *active set* (step 6). Table 7 also shows that pilot 204 was detected (step 92). The relevant pilots are set in red in Table 7.

## 5.3 Test Case 3: Soft handoff – drop from active set

### 5.3.1 Objective

The objective of this test case is to ensure that the entrance requirements for "Section 4.3.1 Long Call Maintenance with Handoffs and Fading" as defined in CDG Stage 3 Testing for CDMA2000 [10] are met.

### 5.3.2 Test steps

*Precondition*

- Follow the same precondition as described in Section 5.2.3.

*Procedures*

- Follow the same procedures as described in Section 5.2.3.

### 5.3.3 Expected results and diagrams

The call flow shown in Figure 29 illustrates the deletion of a base station from the soft handoff. In this scenario, the mobile is initially in a soft handoff with BS1 and BS2.

1. The mobile detects that the signal strength from BS1 is getting weaker. When the strength of BS1 falls below the *drop threshold* value, MS starts a timer. If the signal strength remains below the *drop threshold* value when the timer expires, the mobile sends a *Pilot Strength Measurement Message* (PSMM) to the base station. The PSMM includes the pilot measurement of the current active pilots BS1 and BS2.
2. The network decides to drop BS1 from soft handoff and sends a *Handoff Direction Message*, containing only BS2 in the active set, to the mobile through BS2.
3. The mobile drops the link to BS1 and continues communicating with BS2. It sends a *Handoff Completion Message* to the network through BS2 indicating that BS1 is no longer in the active set. At this point, BS1 is deleted from soft handoff. The BS stops "multicasting" of the frames in the forward direction and "selection" of frames in reverse direction.

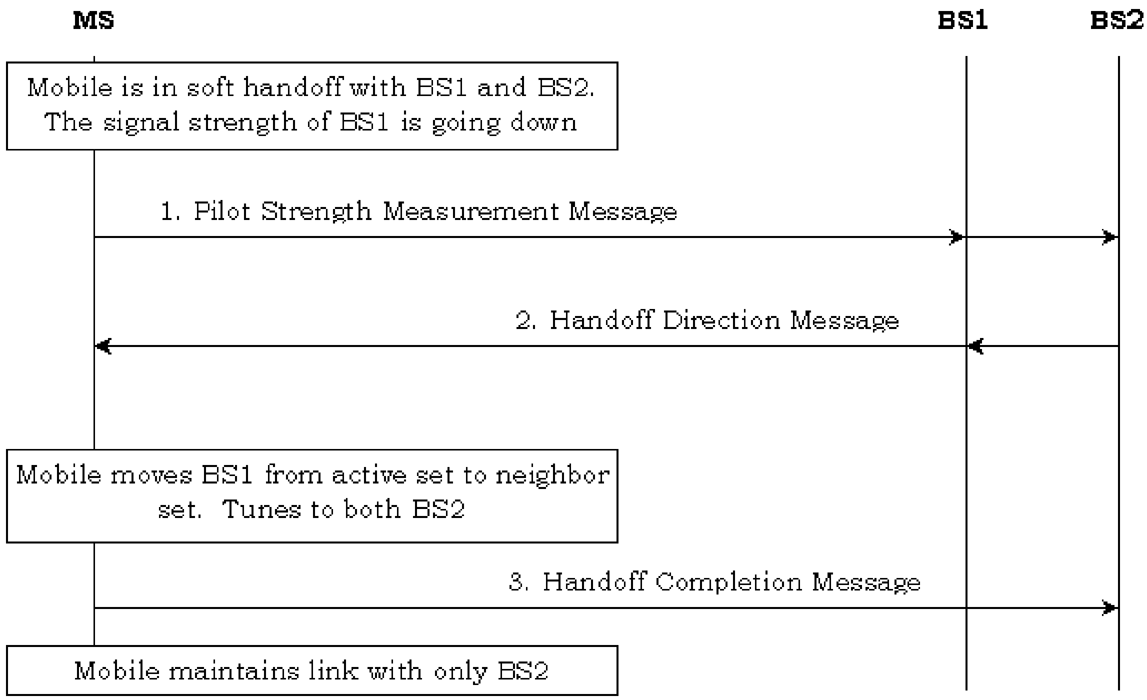



Figure 29: Message sequence diagram illustrates a pilot being dropped from the *active set* during soft handoff [4].

### 5.3.4 Results and loggings

The detailed analysis of test results is presented in Table 7 in Appendix C Detailed soft handoff analysis. Steps 10 to 14 provide the analysis of a pilot being dropped from the *active set*.

## 5.4 Test Case 4: Soft handoff – maximum active set

### 5.4.1 Objective

The objective of this test case is to ensure that the entrance requirement for "Section 4.3.1 Long Call Maintenance with Handoffs and Fading" as defined in CDG stage 3 testing for CDMA2000 [10] is met.

### 5.4.2 Test steps

*Precondition*

- Follow the same precondition as described in Section 5.2.3.
- Test drive route should go through locations with good signal strength with many base stations available.

*Procedures*

- Follow the same precondition as described in Section 5.2.3.

### 5.4.3 Expected results and diagrams

As defined in IS-2000-5.0 [1], there can only be a maximum of six pilots in the *active set* at any given time. The six pilots represent the six base stations with the strongest signal strength communicating with the mobile. Even though there might be more than six pilots available, only six will be in the *active set*.

### 5.4.4 Results and loggings

We have presented the detailed analysis of these test results in Table 7 in Appendix C Detailed soft handoff analysis. Steps 68 to 73 provide the analysis of maximum pilots in the *active set*.

# 6. CONCLUSIONS

The main purpose of this project is to demonstrate the activities related for the evaluation of the field test performance of a CDMA2000 mobile handset.

We have successfully illustrated the complexity of field test for a CDMA2000 mobile phone. This requires significant work, ranging from detailed planning, network information collection, field test activities preparation, up-to-date knowledge of the standards, test engineers selection, extensive training, as well as dedication and hard work in the field test execution.

In this project, we have described four R&D field test cases for CDMA2000, which are performed before the CDG stage 3 test and the carrier acceptance test. In addition, we have executed the test cases in a live network with a CDMA2000 mobile phone. With the diagnostic monitor test tool, we have captured the test results for all the test scenarios. Detailed air interface layer 3 messages are captured, and detailed analysis of the field test cases is also performed.

In this project, we choose to develop the field test cases related to voice call activities, and to verify the voice services in CDMA2000. Besides the enhancement of the voice services, one key feature in CDMA2000 is the support of high-speed packet data. As data services are becoming more popular in the market, users will demand more bandwidth from the carriers' networks. It would be of interest to some readers if we could illustrate the field test cases related to the data services, once the service is available in the market. This is an area for further study and investigation.

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# APPENDIX A UNIVERSAL DIAGNOSTICS MONITOR

Testing equipment is essential in the testing the mobile phone. In order to understand the behavior of the mobile phone and the communication path with the base station, we need reliable test tools to help us gather the necessary information. In this Appendix, we present the most commonly used test tool. It is a diagnostics monitor tool used by both field test and laboratory test. A diagnostics monitor tool provides monitoring and control capabilities that can be used by various engineering disciplines, including design team, test team, manufacturing, and certification laboratories. It is used to analyze both CDMA mobile and network performance.

There are many different diagnostics monitor tool in the market to support field test of CDMA mobile phones. In particular, a few of them supports the latest CDMA2000 protocol. However, some of them are proprietary and only support a limited number of handset manufacturers. For instance, CDMA Air Interface Tester (CAIT) is the diagnostics monitor tool created by Qualcomm, and it only supports handsets with Qualcomm's CDMA chipset. Among all the diagnostics monitor tools available in the market, the Spirent Universal Diagnostics Monitor (UDM) tool [19] is one of the most commonly used tool. It supports monitoring the CDMA devices from various different manufactures.

UDM is a full-featured diagnostics monitor for CDMA devices [19]. Multiple instances of the UDM can be started simultaneously. This is especially handy when performing drive tests, which typically involve logging field test data from several CDMA devices at the same time. Figure 30 shows UDM uses real-time graphs and tables to display the performance of the connected CDMA device.

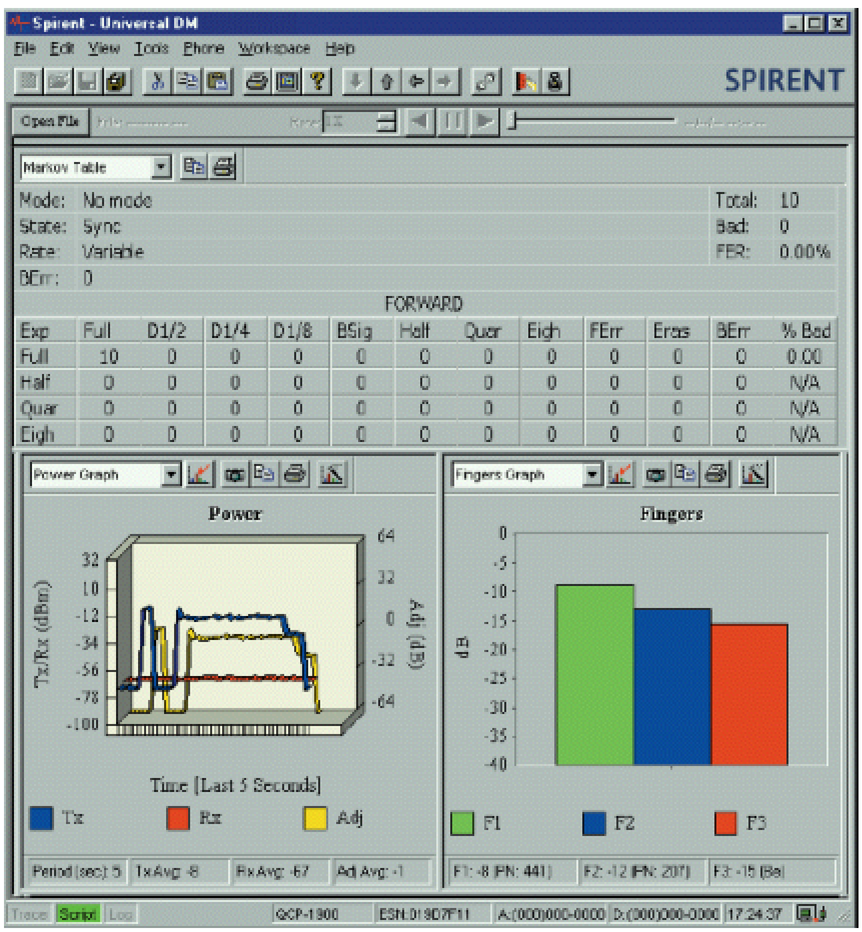


Figure 30: UDM with real-time graphs and tables display the performance of the connected CDMA device [19].

Besides the advantage of monitoring multiple devices, it allows users to display CDMA parameters on a real-time basis for simplified analysis. This includes key CDMA parameters like finger energies, frame error rate, vocoder rate, receive power, transmit power, and energy of desired pilot alone over the total energy received (Ec/Io). Figure 31 illustrates the phone status function, displaying real-time information of the CDMA parameters with user configurable graphs and tables. It also provides users scripting capability to control a CDMA device. Hence, user may write scripts to automate testing of a CDMA device.

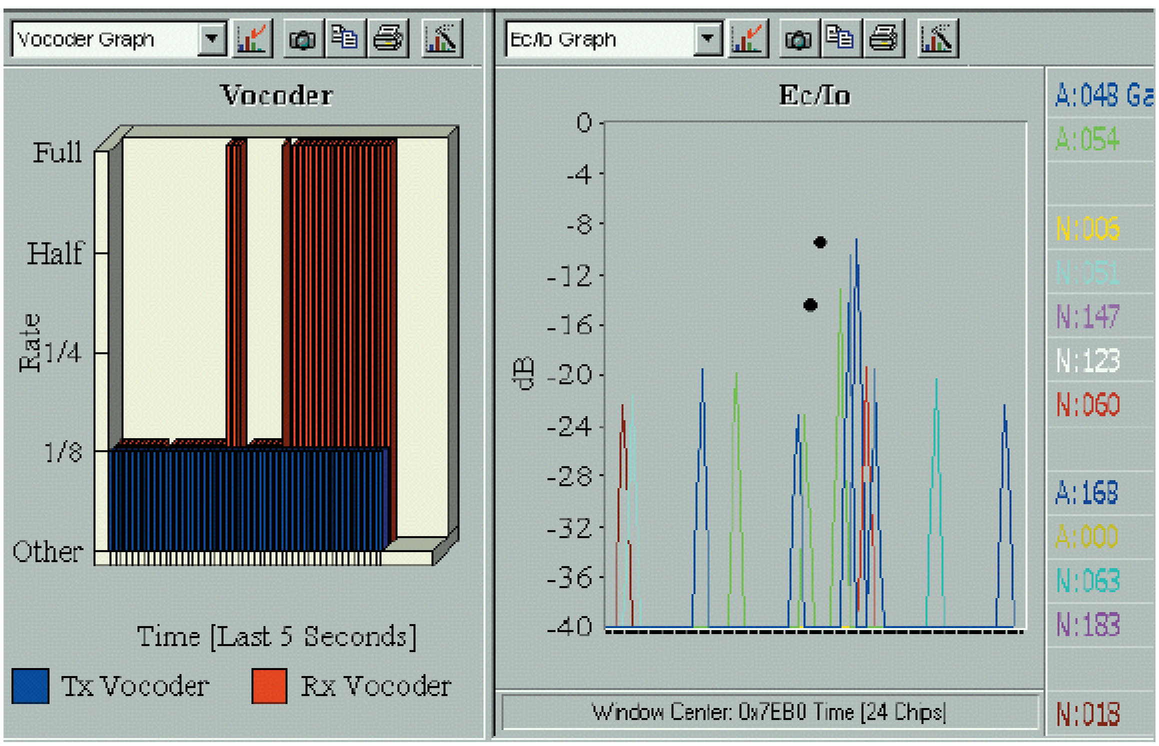


Figure 31: Phone status function in UDM displaying real-time information of CDMA parameters [19].

The phone status function can log software debug messages to the display or to a file for analysis and problem determination. These messages are essential for the developer to quickly identify and troubleshoot behavior or performance issues with the phone. An example of software trace function is shown in Figure 32. UDM also supports the logging of the IS-95 and IS-2000 over the air messages and GPS coordinates for real-time analysis and post-processing. GPS information can be used to check location-based information for the mobile test analysis required by the field test team.

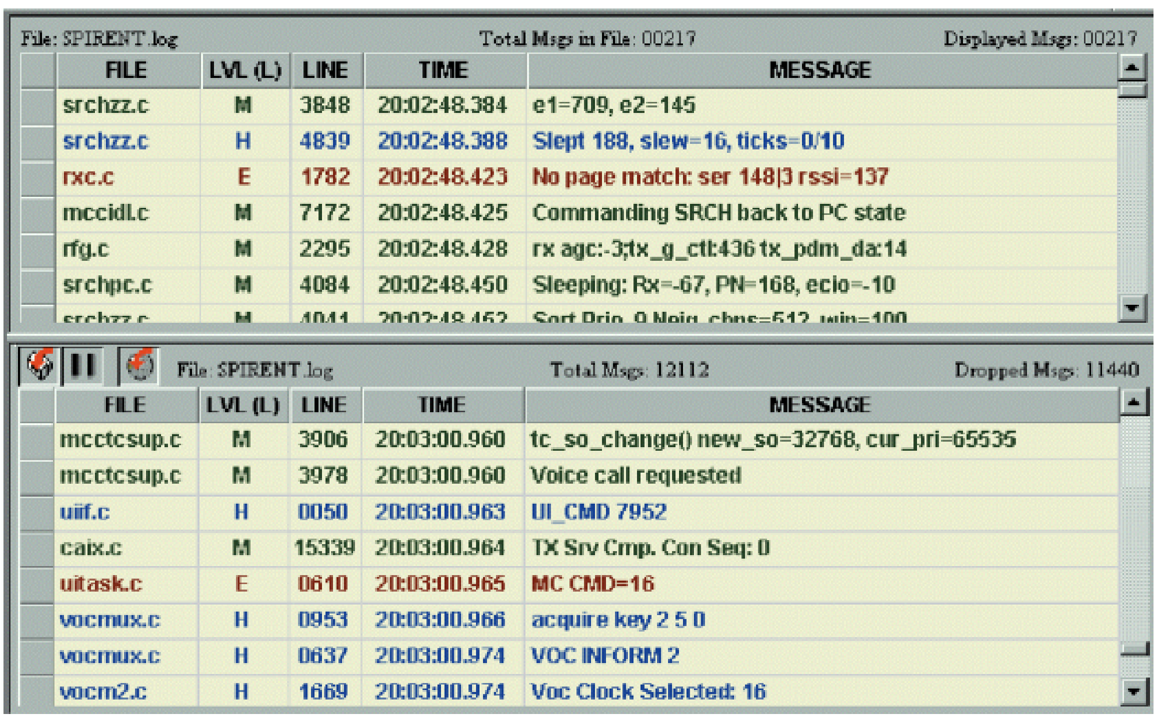


Figure 32: Trace function in UDM displays in-depth debug messages [19].

# APPENDIX B SAMPLE OF FIELD TEST CASES

In this Appendix, we provide the titles for some sample CDMA2000 1X field test cases for both laboratory and actual field tests.

## B.1 Sample in-lab test cases

| **IN-LAB TEST CASES** | |
|---|---|
| **1** | **Registration** |
| 1.1 | Power up registration |
| 1.2 | Power down registration |
| 1.3 | Timer based registration |
| 1.4 | Zone based registration |
| 1.5 | Registration while performing idle handoff |
| **2** | **Voice calls** |
| 2.1 | Mobile originated call (base station release) – good coverage |
| 2.2 | Mobile originated call (mobile release) - good coverage |
| 2.3 | Mobile terminated call (base station release) - good coverage |
| 2.4 | Mobile terminated call (mobile release) - good coverage |
| 2.5 | Mobile originated call (base station release) – poor coverage |
| 2.6 | Mobile terminated call (mobile release) - poor coverage |
| 2.7 | Mobile termination while mobile is doing a registration (timer or zone) |
| 2.8 | Other voice test |
| **3** | **Handoffs** |
| 3.1 | Soft handoff |
| 3.2 | Inter-frequency handoff |
| 3.3 | Inter-band handoff |
| 3.4 | Inter-system hard handoff |
| **4** | **DTMF** |
| 4.1 | DTMF manual (short/fixed) |
| 4.2 | DTMF manual (long/continuous) |
| 4.3 | DTMF stored entry |
| 4.4 | DTMF manual (short/fixed) in digital roaming |
| 4.5 | DTMF manual (long/continuous) in digital roaming |
| 4.6 | DTMF stored entry in digital roaming |
| **5** | **SMS** |
| 5.1 | Short SMS mobile terminated (no call back number)- idle state |

| IN-LAB TEST CASES | |
|---|---|
| 5.2 | Short SMS mobile terminated (with call back number)- idle state |
| 5.3 | Long SMS mobile terminated - idle state |
| 5.4 | Short SMS mobile originated - idle state |
| 5.5 | Long SMS mobile originated - idle state |
| 5.6 | Short SMS mobile terminated - while in a call |
| 5.7 | Long SMS mobile terminated - while in a call |
| 5.8 | Short SMS mobile originated - while in a call |
| 5.9 | Long SMS mobile originated - while in a call |
| 5.10 | SMS message undeliverable |
| 5.11 | SMS reply option |
| 5.12 | SMS message while in a call and with more than 1 active set |
| **6** | **Asynchronous data and fax** |
| 6.1 | Asynchronous data |
| 6.2 | Asynchronous fax |
| **7** | **Mini browser** |
| 7.1 | Mini browser (1X) |
| 7.2 | Mini browser (IS95) |
| 7.3 | Mini browser (handoffs 2G-3G) |
| **8** | **High speed packet data - simple IP** |
| 8.1 | HSPD simple IP - basic connection to Internet |
| 8.2 | HSPD simple IP - file transfer data rate |
| 8.3 | HSPD simple IP - active/dormant state transition |
| 8.4 | HSPD PPP or IP expiration |
| 8.5 | HSPD simple IP - active mode - mobile termination |
| 8.6 | HSPD simple IP - dormant mode - mobile origination |
| 8.7 | HSPD simple IP - dormant mode - mobile termination |
| 8.8 | HSPD simple IP - soft handoff (active mode) |
| 8.9 | HSPD simple IP - soft handoff (dormant mode) |
| 8.10 | HSPD simple IP - hard handoff (active mode) |
| 8.11 | HSPD simple IP - hard handoff (dormant mode) |
| **9** | **High speed packet data - mobile IP** |
| 9.1 | Mobile IP - idle |
| **10** | **MMS** |
| 10.1 | MMS mobile terminated - idle state |
| 10.2 | MMS mobile originated - idle state |
| 10.3 | MMS mobile terminated - while in a call |
| 10.4 | MMS mobile originated - while in a call |
| **11** | **Authentication** |
| 11.1 | Authentication test |

| IN-LAB TEST CASES | |
|---|---|
| **12** | **Call features** |
| 12.1 | Call waiting |
| 12.2 | Call forwarding |
| 12.3 | Caller ID |
| 12.4 | 3-way calling |
| **13** | **Voice mail** |
| 13.1 | Idle state - notification |
| 13.2 | Traffic state - notification |
| **14** | **E911** |
| 14.1 | E911 test |

## B.2 Sample test cases in actual field

| FIELD TEST CASES | |
|---|---|
| **1** | **Registration** |
| 1.1 | Power up registration |
| | Channel |
| | Band class |
| | PN |
| 1.2 | Power down registration |
| 1.3 | Timer based registration |
| | Registration period |
| 1.4 | Zone based registration |
| 1.5 | Registration while performing idle handoff |
| | Registration |
| | 2nd PN |
| | 1st cell power |
| | 2nd cell power |
| **2** | **Voice calls** |
| 2.1 | Mobile originated call (BS release) – good |
| | Service option |
| | Cell power |
| | PN |
| | Total call |
| | Number of failure |
| | Audio |
| 2.2 | Mobile originated call (Mobile release) – good |
| | Total call |
| | Number of failure |

| FIELD TEST CASES | |
|---|---|
| | Repeat test |
| | Total call |
| | Number of failure |
| | Audio |
| 2.3 | Mobile terminated call (BS release) – good |
| | Total call |
| | Number of failure |
| | Audio |
| 2.4 | Mobile terminated call (mobile release) – good |
| | Total call |
| | Number of failure |
| | Audio |
| 2.5 | Mobile originated call (BS release) – poor |
| | Cell Power |
| 2.6 | Mobile terminated call (mobile release) - poor |
| | Cell power |
| 2.7 | MT while registering (timer or zone) |
| | Other voice test |
| | Cell power |
| 2.8 | MO |
| | Total call |
| | Number of failure |
| | Audio |
| 2.9 | MT |
| | Total call |
| | Number of failure |
| | Audio |
| | IS95A (P_REV 3) |
| **3** | **Handoffs** |
| 3.1 | Soft handoff: PN0 <=> PN8 |
| | Total tries |
| | Number of failure |
| 3.2 | Inter-frequency handoff |
| 3.3 | Inter-band handoff |
| 3.4 | Inter-system hard handoff |
| | Total tries |
| | Number of failure |
| **4** | **DTMF** |
| 4.1 | DTMF manual (short/fixed) |

| **FIELD TEST CASES** | |
|---|---|
| 4.2 | DTMF manual (long/continuous) |
| 4.3 | DTMF stored entry |
| 4.4 | DTMF manual (short/fixed) in digital roaming |
| 4.5 | DTMF manual (long/continuous) in digital roaming |
| 4.6 | DTMF stored entry in digital roaming |
| **5** | **Network acquisition** |
| 5.1 | Initial home network acquisition |
| 5.2 | Home network reacquisition |
| 5.3 | Roaming acquisition |
| 5.4 | Roaming reacquisition |
| 5.5 | Home network reacquisition from roaming |
| 5.6 | Home network reacquisition from roaming on power-up |
| **6** | **Registration** |
| 6.1 | Power-up and power-down registration |
| 6.2 | Timer-based registration |
| 6.3 | Zone-based registration |
| 6.4 | Distance-based registration |
| 6.5 | Parameter-based registration |
| **7** | **Service indicators** |
| 7.1 | In use indicator |
| 7.2 | No service indicator |
| 7.3 | In-call indicators |
| **8** | **Handoffs** |
| 8.1 | Idle handoffs |
| 8.2 | Hard handoffs |
| **9** | **Releases** |
| 9.1 | MS release |
| | Total calls |
| | Failures |
| 9.2 | Network release |
| | Total calls |
| | Failures |
| **10** | **Subscriber features** |
| 10.1 | Call forwarding |
| 10.2 | Call waiting |
| 10.3 | Mute |
| 10.4 | 3-Way calling termination |
| 10.5 | 3-Way calling origination |
| 10.6 | Caller ID |

| **FIELD TEST CASES** | |
|---|---|
| 10.7 | Message waiting indicator |
| **11** | **DTMF** |
| 11.1 | Manual DTMF |
| 11.2 | Stored DTMF |
| **12** | **Messaging** |
| 12.1 | MT SMS in idle state |
| 12.2 | MO SMS in idle state |
| 12.3 | MT SMS in traffic state |
| 12.4 | MO SMS in traffic state |
| 12.5 | MT MMS in idle state |
| 12.6 | MO MMS in idle state |
| 12.7 | MT MMS in traffic state |
| 12.8 | MO MMS in traffic state |
| 12.9 | Email |
| **13** | **Voice mail** |
| 13.1 | Idle state notification |
| 13.2 | Traffic state notification |
| 13.3 | No answer with release order |
| **14** | **High speed packet data** |
| 14.1 | Basic Internet connection |
| 14.2 | PPP active/dormant state in handoffs and fading |
| 14.3 | PPP active/dormant HSPD with voice activity |
| 14.4 | HSPD MIP PSDN dormant idle handoff |
| 14.5 | HSPD MIP PSDN hard handoff |
| 14.6 | HSPD and SMS |
| 14.6 | PPP dormant state - call drop or loss of service |
| 14.8 | PPP active state - call drop or loss of service |
| 14.9 | PPP dormant state - ping |
| **15** | **Browser** |
| 15.1 | Browsing on IS-95 networks |
| 15.2 | Browsing on IS-2000 networks |
| 15.3 | Browsing during handoffs between IS-95 and IS-2000 networks |

# APPENDIX C DETAILED SOFT HANDOFF ANALYSIS

In this Appendix, we provide the logs that we captured for the soft handoff test cases in Sections 5.2, 5.3, and 5.4. These logs are captured using the UDM test tool. The detailed analysis for each message in the logs is shown in the Table 7.

| Step | Message | Time | Pilot_PN | Pilot strength | Notes |
|---|---|---|---|---|---|
| 1 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:19:14:214 | **380** | | This is the forward channel handoff direction message. Pilot 380 is available in the *active set*. |
| 2 | OTA-R-FCH-Handoff Completion Msg | 03/14/03 07:19:14:263 | 380 | | |
| 3 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:19:14:274 | 380 | | |
| 4 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:19:14:333 | 380 | | |
| 5 | OTA-R-FCH-Pilot Strength Measurement Msg | 03/14/03 07:19:18:322 | 380<br>3841/64 = **60**<br>14080/64 = **220** | 9<br>33<br>19 | Mobile continues to scan for better pilots. It detects pilots 60 and 220 from the *neighbor list* that are higher than the power threshold. Pilots 60 and 220 now become the *candidate set*. Mobile suggests to the base station those *candidate set* can be added to the |

| Step | Message | Time | Pilot_PN | Pilot strength | Notes |
|---|---|---|---|---|---|
| | | | | | *active set.* |
| 6 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:19:18:634 | 380<br>220<br>60 | | Three pilots are now in the active set. |
| 7 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:19:22:142 | 380<br>220<br>60 | 10<br>40<br>20 | Mobile returns power measurement for the three pilots in the *active set.* Pilot 380 has the strongest signal. |
| 8 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:19:25:142 | 380<br>220<br>60 | 13<br>37<br>17 | |
| 9 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:19:26:203 | 380<br>220<br>60 | 15<br>27<br>13 | |
| 10 | OTA-R-FCH-Pilot Strength Measurement Msg | 03/14/03 07:19:48:222 | 60<br>24321/64 = 380<br>14081/64 = 220 | 5<br>63<br>53 | Mobile continues to scan for pilots. Pilot 60 is getting stronger. |
| 11 | OTA-R-FCH-Pilot Strength Measurement Msg | 03/14/03 07:19:48:563 | 60<br>24322/64 = 380<br>14081/64 = 220 | 5<br>45<br>48 | Pilot 60 has the strongest signal. Both pilots 380 and 220 have fairly weak signal. |
| 12 | OTA-R-FCH-Handoff Completion Msg | 03/14/03 07:19:48:643 | 220<br>60 | | Pilot 380 is dropped from the *active set.* |
| 13 | OTA-F-FCH-Neighbor List Update Msg | 03/14/03 07:19:48:854 | | | Forward channel sends the neighbor list where it contains all the neighbor pilots information. |
| 14 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:19:48:894 | 60 | | Only pilot 60 is in the *active set* because pilot 220 has low signal strength, and is dropped from the *active set.* |
| 15 | OTA-R-FCH-Handoff Completion Msg | 03/14/03 07:19:48:943 | 60 | | |
| 16 | OTA-F-FCH-Universal | 03/14/03 07:19:48:954 | 60 | | |

| Step | Message | Time | Pilot_PN | Pilot strength | Notes |
|---|---|---|---|---|---|
| | Handoff Direction Msg | | | | |
| 17 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:19:49:013 | 60 | | |
| 18 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:19:57:293 | 220<br>60 | | Pilot 220 is back to the active set, as signal strength gets better. |
| 19 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:19:57:354 | 220<br>60 | | |
| 20 | OTA-R-FCH-Pilot Strength Measurement Msg | 03/14/03 07:20:17:683 | 220<br>3840/64 = 60<br>13338/64 = 208 | 32<br>11<br>25 | In addition to pilots 220 and 60, mobile returns pilot 208. Pilot 208 is now in the *candidate set*. |
| 21 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:20:17:894 | 220<br>60<br>208 | | Three pilots available in the *active set*. |
| 22 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:20:17:954 | 220<br>60<br>208 | | |
| 23 | OTA-R-FCH-Handoff Completion Msg | 03/14/03 07:20:17:962 | 220<br>60<br>208 | | |
| 24 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:20:19:693 | 220<br>60<br>208<br>28 | | |
| 25 | OTA-F-FCH-Neighbor List Update Msg | 03/14/03 07:20:19:773 | | | |
| 26 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:20:23:794 | 60<br>28 | | |
| 27 | OTA-R-FCH Power | 03/14/03 07:20:24:522 | | 22<br>12 | |

| Step | Message | Time | Pilot_PN | Pilot strength | Notes |
|---|---|---|---|---|---|
| | Measurement Report Msg | | | | |
| 28 | OTA-R-FCH-Pilot Strength Measurement Msg | 03/14/03 07:20:26:742 | 60<br>1799/64 = 28<br>13337/64 = 208<br>2825/64 = 44 | 26<br>18<br>55<br>28 | |
| 29 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:20:27:034 | 44<br>60<br>28 | | |
| 30 | OTA-R-FCH-Pilot Strength Measurement Msg | 03/14/03 07:20:27:063 | 60<br>1799/64 = 28<br>13338/64 = 208<br>2825/64 = 44 | 27<br>19<br>51<br>25 | |
| 31 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:20:27:093 | 44<br>60<br>28 | | |
| 32 | OTA-F-FCH-Neighbor List Update Msg | 03/14/03 07:20:27:853 | | | |
| 33 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:20:31:382 | | 26<br>19<br>27 | |
| 34 | OTA-R-FCH-Pilot Strength Measurement Msg | 03/14/03 07:20:37:123 | 60<br>2825/64 = 44<br>1799/64 = 28<br>14080/64 = 220 | 18<br>26<br>31<br>29 | |
| 35 | OTA-F-FCH-Neighbor List Update Msg | 03/14/03 07:20:37:533 | | | |
| 36 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:20:41:594 | 44<br>220<br>60 | | |
| 37 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:20:42:762 | | 22<br>43<br>23 | |

| Step | Message | Time | Pilot_PN | Pilot strength | Notes |
|---|---|---|---|---|---|
| 38 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:20:44:102 | | 16<br>43<br>27 | |
| 39 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:20:47:082 | | 11<br>28<br>31 | |
| 40 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:20:48:682 | | 19<br>30<br>16 | |
| 41 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:20:49:713 | 44<br>60 | | |
| 42 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:20:50:093 | 44<br>364<br>60 | | |
| 43 | OTA-R-FCH-Handoff Completion Msg | 03/14/03 07:20:50:123 | 44<br>364<br>60 | | |
| 44 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:20:50:153 | 44<br>364<br>60 | | |
| 45 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:20:50:923 | | 12<br>32<br>43 | |
| 46 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:20:51:982 | | 14<br>25<br>43 | |
| 47 | OTA-R-FCH-Pilot Strength Measurement Msg | 03/14/03 07:20:52:441 | 60<br>2821/64 = 44<br>23302/64 = 364<br>1796/64 = 28 | 38<br>16<br>32<br>25 | |
| 48 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:20:52:624 | | 14<br>36<br>41 | |
| 49 | OTA-F-FCH-Universal | 03/14/03 07:20:52:674 | 44<br>364 | | |

| Step | Message | Time | Pilot_PN | Pilot strength | Notes |
|---|---|---|---|---|---|
| | Handoff Direction Msg | | 60<br>28 | | |
| 50 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:20:52:754 | 44<br>364<br>60<br>28 | | |
| 51 | OTA-R-FCH-Handoff Completion Msg | 03/14/03 07:20:52:763 | 44<br>364<br>60<br>28 | | |
| 52 | OTA-R-FCH-Pilot Strength Measurement Msg | 03/14/03 07:20:57:362 | 28<br>2817/64 = 44<br>23297/64 = 364<br>3837/64 = 60 | 28<br>13<br>28<br>45 | |
| 53 | OTA-F-FCH-Neighbor List Update Msg | 03/14/03 07:20:57:794 | | | |
| 54 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:21:10:441 | | 9<br>25<br>23 | |
| 55 | OTA-R-FCH-Pilot Strength Measurement Msg | 03/14/03 07:21:35:122 | 44<br>23296/64 = 364<br>1792/64 = 28 | 11<br>28<br>41 | |
| 56 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:21:35:293 | 44<br>364 | | |
| 57 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:21:35:333 | 44<br>364 | | |
| 58 | OTA-R-FCH-Handoff Completion Msg | 03/14/03 07:21:35:362 | 44<br>364 | | |
| 59 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:21:35:393 | 44<br>364 | | |
| 60 | OTA-F-FCH-Neighbor List | 03/14/03 07:21:48:773 | | | |

| Step | Message | Time | Pilot_PN | Pilot strength | Notes |
|---|---|---|---|---|---|
| | Update Msg | | | | |
| 61 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:22:09:682 | | 15<br>16<br>30 | |
| 62 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:22:13:253 | 44<br>364<br>28<br>72 | | |
| 63 | OTA-R-FCH-Handoff Completion Msg | 03/14/03 07:22:13:341 | 44<br>364<br>28<br>72 | | |
| 64 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:22:14:802 | | 23<br>15<br>26<br>35 | |
| 65 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:22:15:174 | 44<br>364<br>28<br>72<br>496 | | |
| 66 | OTA-R-FCH-Handoff Completion Msg | 03/14/03 07:22:15:241 | 44<br>364<br>28<br>72<br>496 | | |
| 67 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:22:15:253 | 44<br>364<br>28<br>72<br>496 | | |
| 68 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:22:18:634 | 44<br>364<br>28<br>72<br>496<br>456 | | Six pilots are in the *active set* (six is the maximum allowed). The list is 44, 364, 28, 72, 496, and 456. |
| 69 | OTA-R-FCH-Handoff Completion Msg | 03/14/03 07:22:18:683 | 44<br>364<br>28<br>72<br>496<br>456 | | |
| 70 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:22:18:722 | | 29<br>26<br>29<br>44<br>24<br>25 | |
| 71 | OTA-R-FCH- | 03/14/03 | 456 | 37 | Mobile returns seven |

| Step | Message | Time | Pilot_PN | Pilot strength | Notes |
|---|---|---|---|---|---|
| | Pilot Strength Measurement Msg | 07:22:20:182 | 2816/64 = 44<br>23296/64 = 364<br>1796/64 = 28<br>4634/64 = 72<br>31766/64 = 496<br>3343/64 = 52 | 32<br>35<br>25<br>59<br>30<br>25 | pilots measurement. Pilot 52 is added as a *candidate set*. Pilot 72 (*active set)* is very low in signal. |
| 72 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:22:20:481 | | 33<br>38<br>23<br>48<br>35<br>35 | |
| 73 | OTA-R-FCH-Handoff Completion Msg | 03/14/03 07:22:20:813 | 44<br>364<br>28<br>496<br>456<br>52 | | *Active set* is changed. Dropping pilot 72 and adding pilot 52. Only six pilots are maintained in the *active set*. |
| 74 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:22:20:893 | 44<br>364<br>28<br>496<br>456<br>52 | | |
| 75 | OTA-F-FCH-Neighbor List Update Msg | 03/14/03 07:22:21:153 | | | |
| 76 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:22:22:522 | | 37<br>50<br>16<br>35<br>31<br>23 | |
| 77 | OTA-R-FCH-Pilot Strength Measurement Msg | 03/14/03 07:22:24:942 | 456<br>2816/64 = 44<br>23294/64 = 364<br>1797/64 = 28<br>31766/64 = 496<br>3344/64 = 52 | 30<br>49<br>58<br>10<br>35<br>35 | |
| 78 | OTA-F-FCH- | 03/14/03 | 28 | | |

| Step | Message | Time | Pilot_PN | Pilot strength | Notes |
|---|---|---|---|---|---|
| | Universal Handoff Direction Msg | 07:22:25:214 | 496<br>456<br>52 | | |
| 79 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:22:27:481 | | 15<br>30<br>25<br>27 | |
| 80 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:22:30:833 | 44<br>28<br>456<br>52 | | |
| 81 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:22:30:873 | 44<br>28<br>456<br>52 | | |
| 82 | OTA-R-FCH-Handoff Completion Msg | 03/14/03 07:22:30:881 | 44<br>28<br>456<br>52 | | |
| 83 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:22:34:322 | | 18<br>47<br>18<br>63 | |
| 84 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:22:34:594 | 44<br>364<br>456 | | |
| 85 | OTA-F-FCH-Neighbor List Update Msg | 03/14/03 07:22:34:714 | | | |
| 86 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:22:34:754 | 44<br>364<br>28<br>456 | | |
| 87 | OTA-F-FCH-Universal Handoff Direction Msg | 03/14/03 07:22:35:034 | 44<br>364<br>52<br>456 | | |
| 88 | OTA-F-FCH-Neighbor List Update Msg | 03/14/03 07:22:35:354 | | | |
| 89 | OTA-F-FCH-Neighbor List Update Msg | 03/14/03 07:22:35:813 | | | |
| 90 | OTA-F-FCH-Universal | 03/14/03 07:22:39:074 | 44<br>456 | | |

| Step | Message | Time | Pilot_PN | Pilot strength | Notes |
|---|---|---|---|---|---|
| | Handoff Direction Msg | | | | |
| 91 | OTA-R-FCH Power Measurement Report Msg | 03/14/03 07:22:41:182 | | 20<br>15 | |
| 92 | OTA-R-FCH-Pilot Strength Measurement Msg | 03/14/03 07:22:43:023 | 44<br>29187/64 = 456<br>23296/64 = 364<br>13057/64 = **204**<br>1798/64 = 28 | 10<br>33<br>31<br>38<br>63 | |
| 93 | OTA-R-FCH-Handoff Completion Msg | 03/14/03 07:22:43:362 | 44<br>364<br>204<br>456 | | |

Table 7: Detailed soft handoff analysis from the captured UDM logs with the current pilots, pilot strength, and explanation.