Dyaptive SYSTEMS

Dyaptive Mobile Terminal Simulator
White Paper

1 Introduction

The deployment of 3G infrastructures has begun, but the challenges of testing and optimizing these networks has yet to be adequately addressed. The challenges faced by network operators are wide-ranging in this new and rapidly evolving technology.

Today, infrastructure manufacturers and carriers rely on a handful of handsets to test their wireless products. While reproducing the effect of a few phones is achievable, it is impossible with this method and technology to simulate the effects of real world conditions in which networks may be loaded with thousands of calls from users in random locations traveling at various speeds.

As high-speed data applications roll out with 3G, network operators will be faced with the challenge of quantifying the impact of these applications on their overall network performance and reliability. The challenge is magnified even further as intergenerational mobile devices operate on the network.

2 The Dyaptive Mobile Terminal Simulator (DMTS™)

Dyaptive's DMTS takes the concept of a CDMA load box to a new level of capability by leveraging Software-Defined-Radio (SDR) technology. The DMTS provides unparalleled density and flexibility in loading a CDMA network with traffic at any layer of the protocol from RF to application layer.

The DMTS introduces the virtual mobile terminal (VMT) - a software equivalent of a test handset. Since no actual handsets are used in the DMTS, complex wiring is eliminated. There is only a single RF path per sector no matter how many VMTs are running in a DMTS. The channel impairments normally emulated by RF attenuators or aftermarket channel simulators are introduced in software independently to each VMT. Tens or even hundreds of VMTs can run in a DMTS, and since they are software entities, the density and scalability achieved by the DMTS is limited only by processing power and system connections.

In the DMTS, channel simulation is provided independently on the forward- and reverse-links for each VMT. In addition the impairments are controllable and so can be used to model a number of different RF fading profiles.

The DMTS, by using SDR, can support multiple CDMA technologies. In the DMTS, all IF and baseband processing is performed by reprogrammable hardware and software. As a result, the DMTS can be used to optimize and test networks running IS-95A, IS-95B, 1xRTT Release 0, 1xRTT Release A, 1xEV-DO, and future 3G technologies including UMTS / W-CDMA and 1xEV-DV.

Each VMT can be configured to run independent applications or even different protocols. This capability allows simulation of complex, heterogeneous environments with mixes of user equipment. Each VMT also provides detailed insight into the events and transactions at every layer of the protocol, providing the opportunity for detailed understanding of network performance and fine-tuning of network parameters.

The mobile density, combined with independent mobile channel simulation, and the potential for a completely flexible heterogeneous load test, makes the DMTS stand out as the ultimate CDMA network optimization and test tool.

3 Bulk Call Simulation

3.1 Traditional Load Box

The problem of balancing Quality, Capacity, and Range (QCR) of a CDMA system is well described in the literature. The better strategies for control of the QCR of a CDMA system recognize the important interplay between the system and mobiles as well as the hardware and software. A demonstrated strategy to actively solving the QCR puzzle in CDMA utilizes "load boxes". The load boxes provide a controlled, known sequence of test calls on the network, thus allowing for the recording and benchmarking of system performance. The subject of network optimization using a test system is covered in further detail in the next section of this document. This section examines practical load boxes.

Known load boxes suffer from a number of problems. First, the load boxes are comprised of mobile handsets, which can be challenging to connect and control. Each handset requires a separate RF connection, with independent attenuation, and a control connection. Consumer handsets may be used, but often load boxes are populated with special test handsets that allow very specific control functions and provide additional operational information. The test handsets are often several times more expensive than consumer handsets. Clearly, the physical and electrical arrangement of these load boxes becomes impractical beyond a few dozens of handsets. Also, as the network matures and features are added, the load box handsets must be replaced with newer models.

The second major problem with known load boxes is that they must be physically scattered throughout the network under test. This activity presents difficulties in securing locations for the load boxes in terms of permission, access to power, and risk of theft and damage. The costs associated with temporarily locating, removing, and then relocating the load boxes is another negative aspect. All of these costs are incurred several times over according to the number of test boxes used.

Finally, either the load boxes must be attended or under remote control. This also adds to the cost and complexity of performing tests on a CDMA network with load boxes.

3.2 Channel Simulator

Certain characteristics of an actual mobile handset, like fading and multipath conditions, can only be simulated at the radio-frequency level. The traditional approach used is to introduce an RF channel fading simulator into the load box. The fading simulator, a monolithic piece of test equipment in its own right, is expensive. The number of fading simulators applied to a test scenario with traditional load boxes is limited by the cost and practicality of connection and configuration. Typically, it might only be practical to use one fading simulator for an entire load test.

3.3 Mobile Firmware and Network Evolution

The traditional load box, populated with handsets, is limited with respect to the mobile's firmware. Whatever handsets are used, the firmware operates on a fixed system protocol revision, P_REV, and exhibits a particular set of bugs. It can be difficult to upgrade the firmware of a mobile handset deployed in a load box, assuming such an upgrade is available.

Most traditional load boxes are populated with a homogeneous set of mobile handsets. However, the subscribers accessing a CDMA network are certainly not all using the same model of handset. Therefore, it may be advantageous to provide a heterogeneous set of mobile handsets in a traditional load box. While this is possible, it is limited in use since very large numbers of handsets must be plugged in and out of the load box to provide for all possible combinations. If a group of heterogeneous handsets is populated into a load box in a fixed manner, it obviates the need to swap handsets, but severely limits the benefit of a heterogeneous load box. Therefore, a heterogeneous test environment is rarely seen in practice.

As a CDMA network introduces new services, or embraces newer-generation digital standards such as 2.5G and 3G, the need for heterogeneous load testing becomes more profound. The specific aspects of such testing are discussed later in this document. However, it is clear that network evolution forces a new dimension of testing not handled well by the traditional load box.

3.4 The DMTS Load Box

By loading the network with virtual mobile terminals (VMTs) rather than actual handsets, the DMTS eliminates the need for complex wiring.

In the DMTS, channel simulation is provided independently on the forward- and reverse-links for each VMT. In addition, the impairments are soft-programmable and so can be used to model a number of different RF fading profiles.

By using SDR technology the DMTS can host hundreds or even thousands of virtual terminals.

The DMTS also reduces the other problems associated with traditional load boxes. Since the DMTS is an integrated high-density load box and channel simulator, it is not necessary to secure many semi-permanent, unattended physical locations for load testing the CDMA network. Because of its high density, many test cases that would otherwise be performed in the field can be executed in a controlled lab environment. Since DMTS is self-contained, tests may be performed directly by a single operator.

The traditional load box can never match these capabilities.

4 Network Planning

CDMA network planning involves the use of software tools to predict RF propagation. Based on simulated traffic, interference levels can be estimated allowing, for example, tradeoffs to be made between cell coverage and blocking probability. Traffic models are largely empirical, and simplifying assumptions are made about mobile power control, degradation of orthogonality, to name a few.

In the context of network planning, DMTS connected to a testbed of network equipment can be utilized to accurately simulate mixed voice and data traffic in high-mobility, dynamic environments requiring frequent and all types of handoffs. In this role, DMTS would complement the RF planning tool, using signal strength data from the planning tool database (or from field measurements). This would enable the planner to look closely at critical handoff zones, for example.

5 Network Optimization

The process of network optimization begins long before the deployment of any equipment and continues through the entire life of the equipment. Prior to the installation of any base station, it is first necessary to perform site evaluation measurements to determine an appropriate location for the base station. The real crux of network optimization begins after initial site evaluation measurements, base station installation, configuration, and acceptance testing.

Optimization and troubleshooting must be continually performed during the life of the base station as new cell sites are added to the network for increased capacity or additional geographic coverage and as new applications are deployed. Other factors impacting the overall performance of the network are new buildings, growth of trees, changing foliage conditions, and equipment deterioration all of which contribute to the changes in the RF properties in the system.

In addition, interference levels change as new cells are added (including interference from competing networks), and as the subscriber base increases, or the geographic distribution of traffic changes. Because of this dynamic environment, the CDMA network must be continually monitored and adjusted to optimize performance and resource usage. In particular, cell breathing caused by varying cellular traffic usage throughout the day is difficult for a network operator to characterize in a controlled manner. It is the incremental changes to the network after the initial base station site assessment, and deployment that compromise the overall network performance.

Optimization is the key to maximizing existing capital investment. To optimize a network is to maximize the capacity of existing spectrum and equipment, and maximize revenue and profit without deploying additional capital. The DMTS is the instrument for precise tuning of any CDMA network, ensuring the spectrum and equipment are utilized to their fullest potential.

5.1 The DMTS Optimization Approach

Performance issues currently faced by network operators fall in five major categories, (1) cell site capacity, (2) backhaul capacity, (3) call processing issues, (4) RF propagation issues, and (5) network evolution. The DMTS allows for the network operator to address all of these major areas in network optimization.

By using the DMTS in a captive network or deploying the DMTS onto the network during off peak hours, the network operator can generate controlled traffic loading. It is under this known loading that the operator may fully characterize the operation of a base station, or of several base stations in close proximity. Problem conditions may be reproduced exactly, greatly simplifying the troubleshooting process.

Adjustment of network parameters such as the neighbor list, or the parameters that control the mobile's set maintenance (such as T_ADD, T_DROP, SOFT_SLOPE, etc.) can greatly impact a network's performance. The DMTS allows for changes to these parameters to be fully characterized under very specific load conditions. Network tuning may be carried out using test equipment in the lab or during off-peak hours without impacting the subscriber, instead of during peak-hours using the uncontrolled and risky loading of real subscribers.

For example, soft handoff has always been touted as one of the great features of CDMA, however it is also found to be a point of weakness in the IS-95A release of the CDMA standard. In IS-95A it was found that mobiles were spending too much time in soft handoff tying up valuable resources that could otherwise be allocated to additional users. IS-95B attempts to resolve this issue by introducing dynamic threshold values, but the question for network operators is what threshold values are best in different areas of their network, at different times of day - and how do they quantify the chosen settings?

The DMTS allows for complete control of reverse link signal strengths returned to specific sectors of a base station. Because the DMTS controls the signal to interference levels received by each sector of the base station, the conditions of the soft handoff are precisely known and repeatable. With this precision and repeatability, and with the enhanced logging capability of the DMTS, the network operator may repeat the handoff test with different network parameters until the best performance is found. With the DMTS, call failure mechanisms such as failed signaling, forward channel failure, network rejection, message retransmissions, etc. may be logged providing the network operator with great insight into performance issues with their network.

The value in being able to precisely control network loading and in depth logging for optimization purposes will become even more evident as 2.5G and 3G data applications are type approved for use on a given network. Characterizing the impact of these new resource hungry applications on the network performance, and the effect on the overall subscriber base will be difficult without a tool such as the DMTS that provides controlled loading of a server, virtually unlimited logging information, and allows the operator access to all of the mobile parameters.

6 Failure Analysis

The DMTS provides detailed control and diagnostics that cannot be obtained from commercial handsets used in "load boxes". Handsets are typically controlled through a Mobile Diagnostic Monitor (MDM) that provides limited access to the mobile's internal parameters and operations. The Virtual Mobile Terminals (VMTs) are designed from the ground up to allow full traceability of the phone's behavior from the physical layer up to the call processing layers. Various factors can cause a mobile to drop a call, for example: fading conditions preventing the mobile from receiving a signal from the base station, network overloading causing the mobile to timeout while waiting for a response from the base station, and so on. To accurately determine the cause of such problems, the tester must have access to detailed information relating to high level transactions such as registration or call origination, retransmissions of messages, low-level frame types, power control, to name a few. The DMTS provides this information for each VMT in the system. In addition, the DMTS allows control of the behavior of the VMTs by controlling the individual parameters within each layer of the protocol in order to create sophisticated test scenarios. This includes initiating transactions, injection of failures into any layer forcing retransmissions, timeouts or overriding the network's power control on the reverse link.

Through the advanced user interface, the user is able to process the large amounts of information necessary to determine the exact causes for failures, and control all the parameters necessary to reproduce and fix the problems.

7 Test Scenarios

Current handset test equipment provides predefined test scenarios designed to exercise specific features of mobile phones. Open standards have been defined to allow conformance testing and to ensure interoperability between equipment vendors. The complexity is greatly increased when testing one or more base stations with several tens or hundreds of mobiles.

This is addressed by integrating an advanced scripting mechanism into the DMTS, allowing definition and execution of elaborate test scenarios representing real-world conditions. This is particularly useful for the development and rollout of 2.5G and 3G packet-switched technology, where behavior is much more difficult to model and predict than the current circuit-switched technology.

Test scenarios include load testing, simulating peak-hour usage of the network, boundary condition testing, verification of proper error handling and recovery by the network, protocol revision and feature testing, network behavior when new protocol features are enabled. The latter allows providers to analyze the business case of upgrading their network and customer equipment.

8 Data Applications

To date, wireless networks have supported only a limited set of applications, voice, or low rate data. The move with 2.5G (1xRTT) and 3G (1xEV-DO, 1xEV-DV and UMTS) is towards medium and high rate data. These technologies bring with them new physical layer encodings, new protocols, as well as a much greater mix of potential applications. The planning and optimization for these new networks will be exponentially more complex than 2G technologies because of all of the new permutations of these variables.

As wireless service providers seek to increase the return from their investment in spectrum and infrastructure through deployment of new data networks and data applications, they will have to understand how network load and performance vary. Only the DMTS can test and analyze network operation with mixed wireless applications over mixed protocols under loaded conditions.

As data applications become more widely used, it becomes critical for equipment manufacturers and network providers to load test these individual applications as well as the combination of data applications running simultaneously. The DMTS enables the pre-screening of new data applications before deploying them on live networks. DMTS VMTs can run independently selectable data applications allowing sophisticated modeling and measurement of the data profile of an application mix. This will allow more rapid deployment of data applications resulting in earlier revenue from data subscribers and faster ROI from 3G spectrum and equipment investment.

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