

Dyaptive SYSTEMS

DMTS-8000 Assisted Planning, Dimensioning and
Optimization of CDMA2000 Networks



April 13, 2005

1	Introduction	1
2	Understanding Network Planning & Dimensioning Issues in Load Sensitive CDMA2000 Networks	1
3	Capacity, Coverage and QoS Optimization using DMTS-8000	3
4	DMTS-8000 Driven Performance Measurement and Optimization Framework	10



1 Introduction

Performance Tuning and Network Optimization of a CDMA2000 network is an ongoing process with the main objective of mitigating the impact of numerous risks taken during the network planning and dimensioning phase. Various aspects that were overlooked during the planning phase are revisited and reconsidered as more and more information on the live-performance of the network becomes available. Effective performance tuning and network optimization maintains continual optimality of coverage, capacity and QoS without adding to the infrastructural and operational costs of the network.

A network that was meticulously planned on the drawing board and prototype-tested in a lab setup may not necessarily live up to the expectations. This is primarily because of numerous unknowns and inaccuracies present at the time of its conception. Notably, during the network planning phase, numerous projections are made and various models are assumed in lieu of real data. For example, the subscriber penetration is estimated; traffic intensity is forecasted; and various mobility, traffic, service and channel models are assumed. In addition, the initial inaccuracy of these estimates, forecasts and models is likely to be magnified due to various demographical, sociological and economical changes occurring between the conception and the actual deployment of the network. Moreover, such changes will continue during the life span of a network, due to factors like population growth, real estate developments in the area, changes in the transportation systems and patterns, and changes in the environment significantly impacting the assumptions regarding channel conditions and subscriber traffic and mobility. Various marketing and pricing strategies coupled with the emergence of new devices and 'killer apps' will also have a non-deterministic impact on the predictability of network performance. The aforementioned considerations and concerns imply that the QoS experienced by a CDMA2000 subscriber may in fact be significantly inferior to the QoS predicted during the planning phase, thus, necessitating the need for regular tuning and optimization of the network. For economical viability, it is desirable that the networks accommodate or adapt to such evolutions without adding to the infrastructure costs as much as possible.



2 Understanding Network Planning & Dimensioning Issues in Load Sensitive CDMA2000 Networks

In the context of CDMA2000 cellular networks, network planning and dimensioning means identifying site locations and configurations, and estimating the site density. Once a CDMA2000 Wireless Service Provider is issued a license to offer wireless services in a country or a region, the long walk to a successful network operation commences with the design of an optimal layout of the sites in the service area. If designed correctly, a network plan may prove to be a giant leap towards high Return on Investment (ROI). Contrarily, a suboptimal network plan may not only result in cost overruns but also leave numerous customers unsatisfied, resulting in high customer churn. Consequently, the network planner is not only tasked with ensuring that there is sufficient capacity for the existing subscribers, but also that the network as planned will be able to accommodate the future growth and withstand reasonable fluctuations in subscriber distribution and traffic.

Designing an optimal cdma2000 system is, however, anything but trivial. It is a multidimensional problem involving numerous interdependent user, environment and system variables. The relatively simplistic planning principles and practices of frequency reuse based 2G networks no longer apply to such 3G networks. The root cause of this

intricacy is the notion of soft capacity. Like any other CDMA system, the capacity of a CDMA2000 carrier is constrained by interference, load and power. When a conventional reuse sector is full, it is full. However, a CDMA carrier will continue to accommodate more calls at the expense of some deterioration in quality until outage or soft blocking occurs. Moreover, an increase in the traffic load is not only detrimental to the bit error rate (BER) of all the connections sharing the carrier, but also impacts the cell coverage. With the increase in traffic load, the path loss deteriorates for both the uplink as well as the downlink. The impact, however, is more profound on the downlink channel because the power of the base station is shared by all the mobiles being served. As more mobiles are added to the cell, the range of the downlink channel is decreased, resulting in cell shrinkage. The coverage of a CDMA2000 sector or cell is therefore limited by the load on the downlink channel and the power constraints of the mobiles on the uplink channel.

The capacity of a CDMA carrier can be construed as being assigned collectively to a group of cells as opposed to being assigned individually to each cell. Under the right conditions, a cell can softly borrow capacity from its neighbors and use more than its fair share. However the CDMA capacity not only depends on the interference from within the cell but also from neighboring cells and from other sectors in the same cell. This leads to interesting intricacies never experienced in traditional frequency reuse based cellular systems where inter-cell interference is effectively mitigated by cell placement and careful frequency planning. For transmission quality requirements, a minimum signal-to-interference ratio (SIR) must be achieved. The base-station location, its pilot-signal power (which determines the size of the cell), and the transmission power of the mobiles all affect the received SIR. In conventional frequency reuse based cellular networks, traffic is usually overflowed into the neighboring cells or sectors if the primary sector or cell is full. In a CDMA channel, the interference caused by overflowing the call will be more damaging to this non-serving sector than overloading it with the extra call. Thus, once a sector's CDMA channel is full, its traffic may have to be blocked rather than overflowed. Another interesting discrepancy to note is that in traditional cellular networks smaller cells are used in areas of high demand while larger cells are used in areas of low demand. In CDMA networks, differing usage results in differing inter-cell interference. When large cells are adjacent to small cells, users at the boundaries of large cells can cause a lot of interference to users in small cells. This in-turn causes a reduction in the capacity of the small cells.

Being interference limited, any decrease in the amount of interference translates into a capacity gain in CDMA systems. Increasing the pilot-signal power of a base station increases the coverage region of that cell and thus increases the number of users and the intra-cell interference in that cell. However, it will decrease the number of users in the adjacent cells, thus decreasing the inter-cell interference on this base station. Changing the location and size of a base station thus not only changes the coverage region of that cell but also the coverage regions of the adjacent cells. Exploiting this pliability of soft capacity by appropriately selecting base-station location, pilot-signal power and transmission power of each mobile, and controlling traffic load, which in turn controls the intra-cell and inter-cell interference, is the key motivation behind the network planning and dimensioning process.

The other factor that impacts the CDMA soft capacity is the soft handoff. Soft handoffs improve network capacity as the mobile power in the reverse link is reduced due to diversity gain. In the forward link, on the other hand, additional channels (and also trunks) are used to support the same call. The number of mobiles in the soft handoff therefore needs to be carefully estimated and controlled. Every cell layout has



boundaries between cells, so avoiding 2-way handoffs is impossible. Also every cell layout has to have some place where these cell boundaries come together in triple-points, so avoiding 3-way handoffs is also impossible. Handoffs where 4 or more nearly equal cells are involved may need to be avoided. In such zones, too much interference may be present. The term used for this is 'pilot pollution'. In fact, average soft handoff levels in excess of around 2.5 seldom result in capacity gains.

Even when compared to its predecessor IS-95A, characteristics such as multi-user detection and diversity resulting from a broader spectrum and support for additional features such as bit-rates of the order of 3.4 Mbps, packet-switching, power control in forward as well as reverse channels etc. put CDMA2000 in a separate league of networks. CDMA2000 allows service providers to offer a broad spectrum of services ranging from voice & low bit-rate data services to video-phone, video-conferencing and high bit-rate data services. The variety of different services offered by CDMA2000 inadvertently also adds to the complexity of cell planning. This is because different services demand different levels of coverage, have differing processing gains and Eb/No requirements, are tolerant to different quality of service levels, etc. Again, there are more dimensions to this perplexity. For example, if there are trunking inefficiencies in the backhaul network then an increase in the number of high bit-rate users may in fact increase the soft capacity as the number of users will be reduced causing reduction in interference to the neighboring cells and consequently increasing the percentage of shared soft capacity.

All the factors highlighted above are directly linked to cell placement and planning of managed interference. Planning and dimensioning CDMA2000 networks is thus a painstaking task aimed at striking a fine balance between capacity, coverage and Quality-of-Service (QoS) by iteratively engineering the interdependence among users, services, environment and the system variables. Further, adjustment of this balance must be anticipated as network usage grows, and offered services change. The bright side to this is that these intricacies also offer new opportunities to manage resources more efficiently than the conventional 2G networks, and realize the potential offered by CDMA2000.



3 Capacity, Coverage and QoS Optimization using DMTS-8000

The DMTS-8000 provides invaluable insight into the functioning of CDMA2000 systems. By emulating the users and environment in a controlled fashion, it allows monitoring of internal aspects of a live CDMA2000 system that would be impractical to measure otherwise. Given a CDMA2000 system composed of a single or multiple sectors or cells in a lab environment or in the field, the DMTS-8000 emulates terrain, propagation, and subscriber demand for each service being offered. Simulated subscriber populations start their calls in proportion to the Erlang counts specific to their location area. Each service type and population has its own distribution of call duration. Once calls appear in the CDMA2000 system, their access and paging messages are counted, and once the calls are active, the forward and reverse CDMA channels, including power control are observed. As the call continues, the simulated users can move and may change radio conditions by doing so. This leads to power changes in the CDMA channel that may lead to handoffs, which may be soft, softer, or hard as needed. The messages associated with power management and handoffs are also monitored. Under marginal radio conditions messages can be lost, calls can be lost, or perhaps they may end normally. The DMTS-8000 allows for new channel models to be constructed based on the signal strength measurements obtained from the field in addition to offering traditional channel models. The impact of indoor/outdoor calls as well as calls from different elevations (different

floors of the buildings in commercial areas) is also considered. The DMTS-8000 not only emulates users and environment but keeps detailed statistics of what happens to each call in the CDMA2000 system. Periods of high blocking, services with reduced call quality, or regions with a lot of lost calls can be simulated and diagnosed. Not only can the DMTS-8000 user determine the root cause of a system problem, but can also test solution strategies before the system is actually commissioned.

Although the DMTS-8000 is not there to guarantee QoS, it can help design a network that can offer such guarantees with greater confidence. Consider a multi-cell CDMA2000 system engineered for a GoS (Grade of Service) of 2 percent blocking during the busy hour. Even though the system, on the average, may meet the universal 2 percent blocking, the service provider may want to be 99 percent confident that the blocking rate will be less than 3 percent. In order to test the system's conformance to such GoS constraints, each base station has to experience thousands of calls to give us that 99 percent confidence. Setting up such a test is a task unimaginable in a live network.

The use case described below outlines the CDMA2000 Network Planning and Dimensioning process and exemplifies the pivotal role that the DMTS-8000 plays at each critical step of the process.

1. A Wireless Service Provider has been issued a license to offer CDMA2000 services in a specific country or a region within the country.

The network planner has now the audacious task of coming up with a cell plan that maximizes ROI while satisfying the GoS/QoS expectations of the subscribers. The plan must be forward looking to minimize any future costs-per-gross-add.

2. The network planner partitions the coverage area into small bins. Each bin reflects the anticipated subscriber density & traffic intensity (perhaps in erlangs) for each service being offered. The bins are collapsed into contiguous regions of dense-urban, urban, suburban and rural areas. Major commercial/shopping/sporting complexes are identified along with strips of highways and railways. Public events associated with the area are identified along with their venues and times.

3. The key vendors of CDMA2000 equipment are identified. A simple prototype of the CDMA2000 network is assembled in a lab setup.

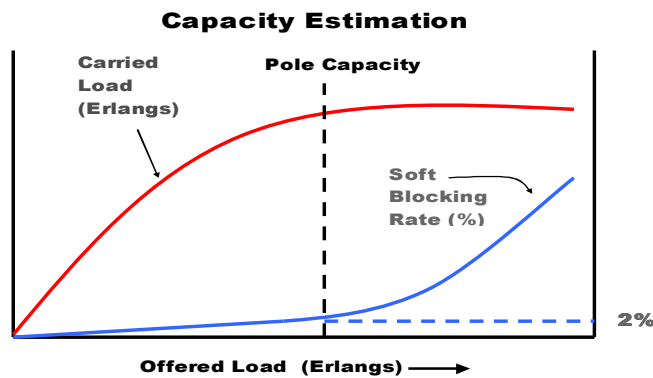
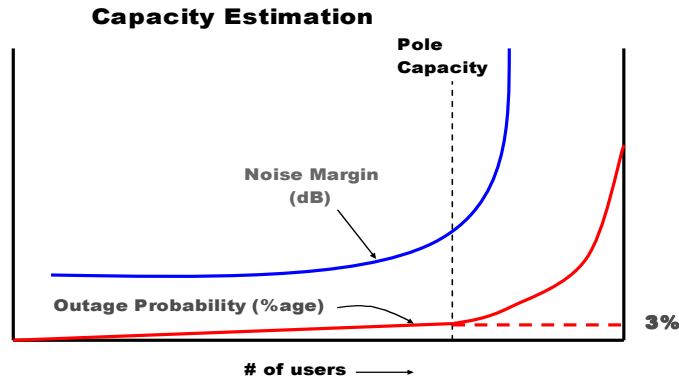
The problem at hand is to determine the best equipment, an optimal placement and configuration of base-stations in the service area, and optimal orientation as well as sizes of sectors & cells.

4. The first estimate that the network planner needs to start the planning and dimensioning process is the link budget i.e. the maximum manageable capacity available in the forward and the reverse link. In the presence of all the imperfections and inaccuracies of the equipment and procedures e.g. rake receivers, power control procedures, load management algorithms, etc., the practical link budget will be lower than the theoretical predictions (Pole Capacity). The network planner configures the DMTS-8000 with channel models, subscriber distribution models, and subscriber mobility models appropriate to the location of interest and CDMA channel types expected to be of preference in that area. The subscriber distribution is normally chosen to be uniform. The DMTS-8000 is connected to a single sector. No interference from the other sectors or cells is produced. The load is increased until the SINR deteriorates below the



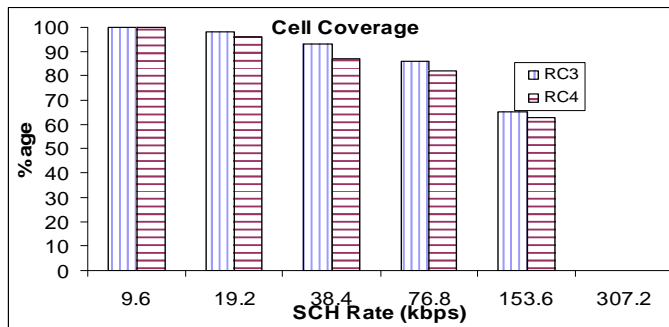
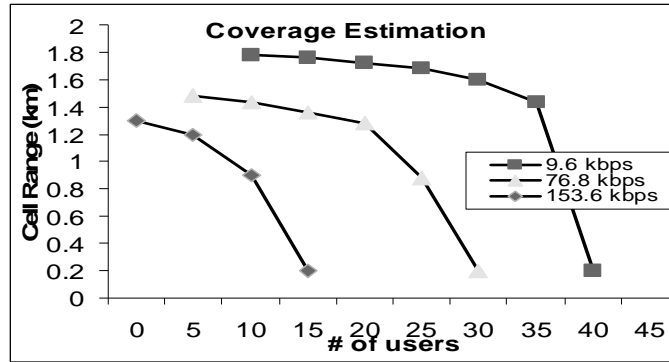
acceptable levels. This may be repeated on each of the candidate equipment models to benchmark the vendor-specific capabilities.

Usually the link budgets are estimated for conventional voice service only. But CDMA2000 is a multi-service network offering rates of up to 3.4 Mbps. The DMTS-8000, therefore, allows calculations of link budget with respect to a wide spectrum of services including voice, high-quality voice and high bit-rate data by using appropriate traffic models and traffic mixes.



5. Next, the network planner determines a rough estimate of number of sites for the coverage area. For this, the network planner configures the DMTS-8000 with a uniform subscriber distribution. Local variations in the subscriber density are ignored for this preliminary plan and the subscriber density is assumed to be normalized over that area. The DMTS-8000 is connected to a single sector or cell. The coverage area of the sector/cell is increased, by increasing the Pilot Signal Power, until the soft blocking starts deteriorating below the acceptable levels. In addition, the associated load on the signaling channels, due to access probes of MOCs (Mobile Originating Calls) and the paging requests of MTCs (Mobile Terminating Calls) as well as the power-up and other registration requests, are also measured.

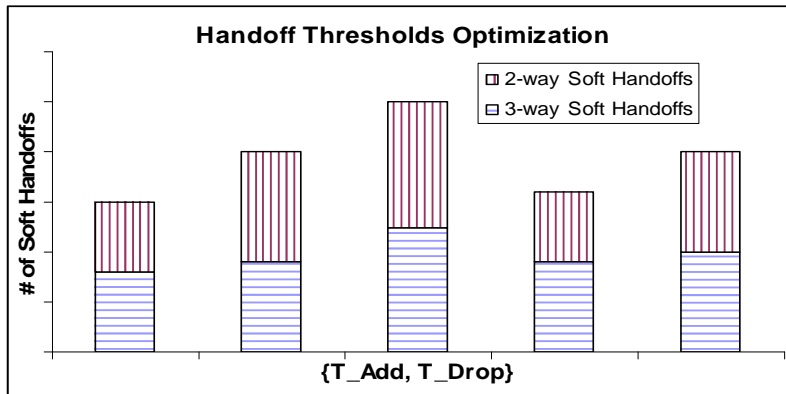
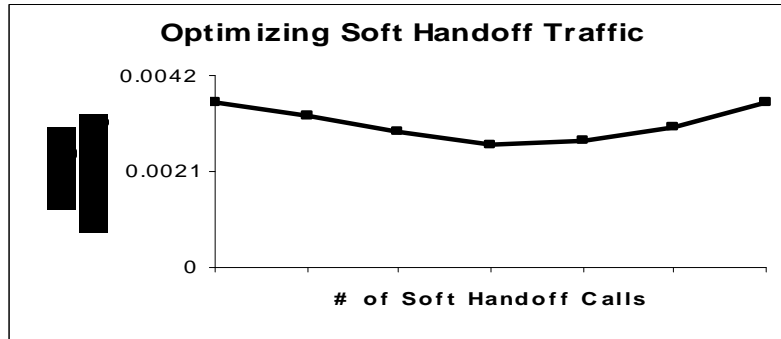
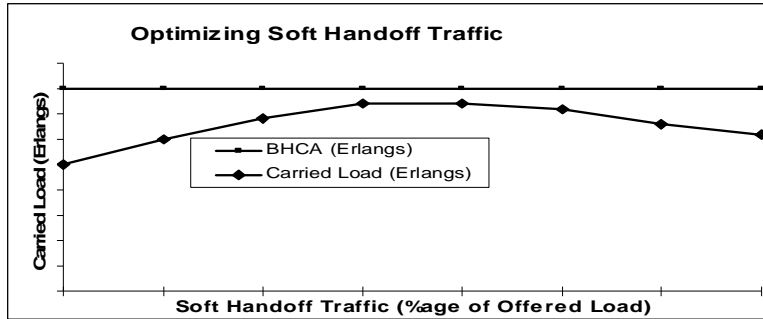
The Network Planner tiles the area under consideration with the footprint of this cell to obtain a preliminary estimate of sites needed to provide the desired coverage.



6. The optimal sizes of the soft handoff areas are determined next. The DMTS-8000 is configured to increase the percentage of calls involved in 2-way, 3-way and perhaps 4-way soft-handoffs. Gains in capacity are anticipated with increase in proportion of calls involved in soft handoffs until the degradation in the Forward Channel overwhelms this gain. The forward and reverse SINR is measured along with soft blocking. The offered load is increased, to fill up this extra capacity released by soft handoffs, until soft blocking deteriorates below the acceptable levels. Once the optimal number of handoff calls is determined using the DMTS-8000, suitable combinations of (T_ADD, T_DROP) pair and T_TDROP timer (also SOFT_SLOPE, ADD_INTERCEPT, and DROP_INTERCEPT if available) values are determined to ensure that the optimal number of soft handoffs are allowed in the network. Reverse SINR will deteriorate if T_ADD&T_DROP are raised whereas Forward SINR will improve.

The (T_ADD, T_DROP) pair and the T_TDROP timer also impact the Mean Number of Updates per minute in the Active Set of a mobile and, therefore, optimization of these parameters with respect to the signaling load, that they generate, is also conducted. The signaling load impacts the call setup delay. Therefore, the (T_ADD, T_DROP) pair and T_TDROP timer values are varied until the desired balance between handoff capacity gain and the call setup delay is obtained. Additionally, in some deployments of CDMA networks, the mobiles are frequently forced to report PSMM (Pilot Strength Measurement Message), either through polling or by using timers. Tradeoff between reduction in Pilot-Pollution and the signaling load as a result of frequent transmission of PSMMs by the mobiles is quantified.





The base station directs the mobiles for handoffs by sending Extended/General/Universal Handoff Direction Messages. If the Handoff Direction Message is not received, the handoff does not proceed and it may result in a dropped call. This may happen if handoff directive message was lost due to excessive noise on the channel (Pilot Pollution) or if the message was delayed due to congestion in the signaling channel. The above tests thus also help determine the optimum load on the signaling channels to minimize the call drop rate.

7. System Zone size (also known as Location Area) is optimized next. The load due to paging messages is directly related to the System Zone Size. The bigger the size of the System Zone, the more paging messages will be needed to locate the user and thus more likelihood of fluctuation and deterioration in call setup delay. However, the smaller the System Zone size, the more location updates or System Zone registrations a moving user will have to perform. Using the DMTS-8000 the network planner emulates different zone sizes by allocating different number of base stations to a System Zone and optimizes the signaling load with respect to the call setup delay in Mobile Terminated Calls.

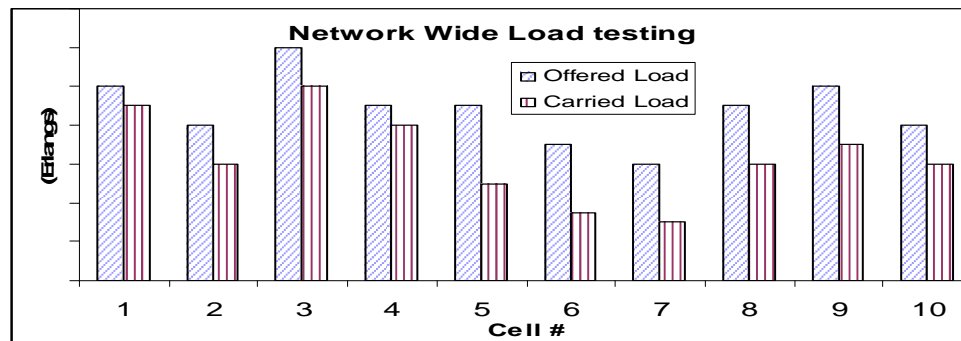
8. The network planner now provisions the capacity of signaling channels. Given the BHCA (Busy Hour Call Attempts) as well as the maximum acceptable Call Setup Delay, the signaling load on the common signaling channels is increased using the DMTS-8000 until the Call Setup Delay and Failure Rates start deteriorating below the acceptable levels. It should be noted that this signaling load is in addition to the signaling load associated with the voice traffic, power management, and handoffs in the cell and is generated by the DMTS-8000 by controlling Distance from Cell Threshold, Timer-based Registration Timer Threshold, Zone List Entry Timer Threshold, Zone List Size, SID/NID List Entry Timer Threshold and List Size, etc. Such DMTS-based tests allow network planner to optimize location, distance, and timer based registrations, and also aid in provisioning capacity for signaling channels.

The capacity leftover for SMSs and SDBs in the signal channels is estimated by configuring the DMTS-8000 to increase SMS and SDB (Short Data Burst) load until the call set up performance deteriorates below the acceptable values.

9. The network planner finally needs to fine-tune his plan by catering to (inter-cell) user mobility and non-uniform subscriber distribution. Typically, there are also temporal aspects to this non-uniformity of subscriber distribution that are caused by daily, weekly, monthly or yearly cultural/sporting/commercial events.

10. Iterate the above process as actual site location data is determined based on economic and physical constraints.

Using a cell cluster, constructed in a lab environment, the network planner uses the DMTS-8000 to generate appropriate non-uniform traffic in adjacent sectors or cells of the cell cluster, and predict the changes needed in the cell coverage (via Pilot Signal power and user signal power adaptation) to redistribute traffic among cells to maximize system capacity. However, as mentioned earlier, when large cells are created adjacent to small cells to accommodate non-uniform traffic load, users at the boundaries of large cells cause a lot of interference to users in small cells. This in-turn causes further reduction in the capacity of the small cells. To alleviate this problem, the nominal power of the mobiles in every cell shall be carefully adjusted, and multi-carrier deployment can be modeled.



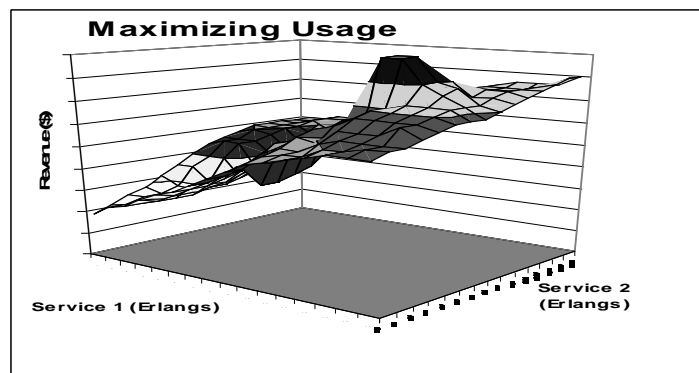
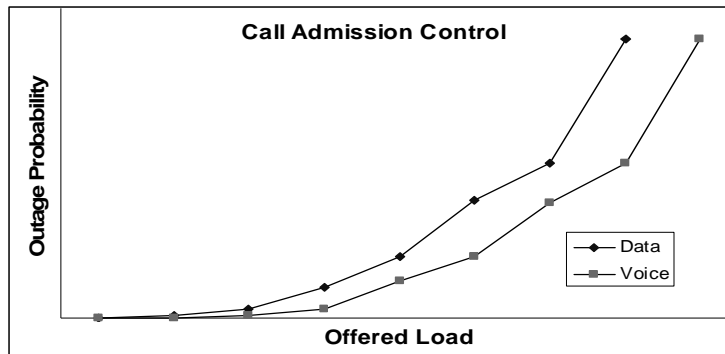
Using the ability of the DMTS-8000 in emulating varying degrees of user mobility (by controlling signal attenuation and fading in proportion to direction and speed of emulated subscribers), the network planner visualizes the impact of traffic flow through soft handoff areas. A service area infested with highways and railways is typically simulated (in the lab) using a linearly arranged cell cluster. The DMTS-8000 is configured to use relatively shorter cell residency times to account for the speed of the mobiles and proportional to the size of the cell. The handoff arrival rates to the cells are set proportional to the volume of traffic expected on the highways during rush hours. The Markov calls are

modified to request a soft handoff (2-way, 3-way or 4-way), an exponentially distributed time span after its invocation, and then stay in the handoff region for another exponentially distributed time span. The exponential durations of each call before, during and after soft handoffs are based on the user mobility and sizes of the cells and handoff regions.

Steps 4 to 10 are repeated until a cell plan is devised that maximizes coverage, capacity and QoS. The network planner may consider adding more sites to the original plan or changing the site placements to increase capacity.

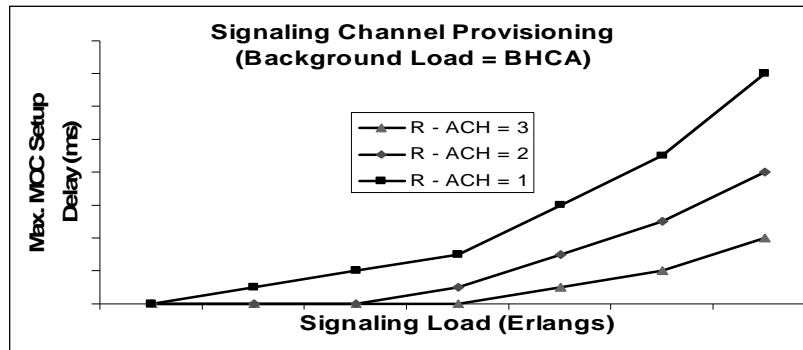
11. To deal with Hot Spots with high subscriber density such as commercial zones full of skyscrapers or campuses, overlay micro-cell & macro-cell configurations are considered. Larger cells are overlaid on top of smaller cells using different carriers. The traffic is overflowed from micro- to macro-cells using hard handoffs. DMTS-8000 allows simulation of such configurations and generates traffic for different carriers at the same time as responding to hard handoffs appropriately to test the load balancing.

12. To support service priorities and provide differentiated services, the network planner considers various code/channel reservation plans. Some codes (capacity) are exclusively reserved for the high priority (revenue generating) services whereas the rest of the capacity is available to all on a first-come-first-served basis. The call admission control schemes or scheduling policies that help achieve the desired differentiated throughput, and consequently the desired Return-on-Investment, while maintaining the acceptable levels of QoS in the test-bed are considered for deployment in the network.



13. The impact of excessive load on the signaling channels on the call setup delay and call blocking probability can also be minimized by adding more signaling channels, in particular forward and reverse common channels (F-PCH, F-BCCH, F-CACH, R-ACH, R-EACH). However this would mean borrowing capacity that would otherwise be used for transporting user data. Other parameters associated with call attempts such as backoff

window size (BKOFFs), parameter P of the MAC-SDUReady.Request primitive, number of Access Attempt Sequences, Access Probes per Sequence, Initial Access Probe Power, and Probe Step Size could be fine tuned to achieve enhancements in the call setup performance.



14. Once the capacity, coverage and QoS issues pertaining to RF channels are sorted out, any impediment caused by the backhaul (IS-2001) or the signaling (IS-41) is resolved. The key issues are trunking efficiency and the capacity of IS-41 SCPs (Signaling Control Points) such as HLR (Home Location Register), VLR (Visitor's Location Register) and AC (Authentication Centre), respectively.

As far as trunking efficiency is concerned, connecting each base station directly to the BSCs and similarly connecting each BSC directly to the MSCs will achieve the lowest probability of calls being blocked. However such star-like connectivity is certainly not cost-effective for wireless service providers. The base stations, BSCs and MSCs therefore share trunks or T1/T3 circuits usually leased from local telephone service providers. Using the DMTS enabled test-bed, the efficiency of various trunk arrangements in the backhaul network is investigated, and the most cost-effective strategy for actual deployment is devised.

Similarly, the performance of HLR, VLRs and ACs under BHCA is evaluated. Any delay in authentication and/or registration adds to the call setup delay. The response of HLRs, VLRs and ACs to heavily loaded network conditions and large subscription (resulting in large number of records in the lookup tables of the database) is monitored; the effect of cold starts and hot starts on the call setup delay is measured; and the dimensioning of these servers from memory cache and CPU perspectives is conducted. If the performance continues to be substandard, various approaches such as replication/distribution of subscriber information in the network could be evaluated and selected, for example, caching authentication information at the base stations to improve round-trip time of authentication messages.

4 DMTS-8000 Driven Performance Measurement and Optimization Framework

Numerous possibilities exist for optimization of an operational CDMA2000 network. These options range from tilting an antenna of a base station or changing its orientation to improve coverage to the full-scale alterations to Channel Plan, Code/Channel Reservation Schemes, CAC (Call Admission Control) policies, and Cell Coverage through Power Control. There are about 18 numeric constants and over 80 time constants defined in the CDMA2000 standard alone. Fine calibration of these constants along with numerous other thresholds and timers associated with various CDMA2000 protocols is at the core of this tuning and optimization process. Furthermore, improving the terrestrial



trunk arrangements that interconnect Base Stations, BSCs (Base Station Controllers) and MSCs (Mobile Switching Centers), and replication/caching of subscriber profiles at various parts of the network to improve service quality and availability are also worth exploring. As facilitation of these explorations in a live network is next to impossible; and extending the network downtime to conduct such experiments may prove to be expensive, it is logical to use a prototype test-bed for such purposes in a lab set up, before resetting the actual network. The efficacy of performance tuning and network optimization would thus depend significantly on the ability to replicate, and recreate realistic traffic, mobility and channel models, and other environment conditions, based on the data from a live network, in the lab environment.

The DMTS-8000 elegantly drives the performance tuning and network optimization operations for CDMA2000 networks. The field data is effectively reused by the DMTS-8000 to recreate realistic conditions for the network. For example, once the network is deployed, the drive tests are conducted to develop the coverage map. Signal strength measurements are obtained from the field. The DMTS-8000 utilizes these signal strength measurements to update the channel models. Furthermore, as statistics such as call rates, handoff rates, data throughput, FERs, channel power, channel noise, channel usage and mobile power etc., from a live network, start pouring into the Network Operation Centers, the DMTS-8000 updates the mobility, channel, interference, traffic and service models as well as BHCA rates accordingly. By applying the data derived from real network statistics, the effects of various schemes and parameters, highlighted above, on the QoS levels are observed. The schemes and parameter values that improve the network performance are selected for application to the deployed networks. In addition, network conditions leading up to user complaints or trouble tickets are re-enacted in the lab to pin-point the weak-spots in the network. Strategies to strengthen the weak-spots are subsequently devised using the DMTS-8000. If the tuning and optimization strategies, highlighted above, fail to accommodate the fluctuations in traffic and channel conditions, and do not yield the desired quality of user experience, then it is back to the drawing board for the network planner. In this situation either market objectives would need to be modified or budgets will need to be increased to enhance the network capability, perhaps by adding more sites into the network.

The key role that the DMTS-8000 plays in performance optimization and network planning is that it provides for a flexible emulation and modeling of users and background environment for testing, verification and fine-tuning of a CDMA2000 System. An exhaustive list of DMTS-8000 enabled parameterization of test conditions for CDMA2000 networks is provided below.

Coverage Area Granularity: The DMTS-8000 can test a single Sector, a single Cell, a Cell cluster, or all the cells connected to an MSC collectively.

Call types: The DMTS-8000 can generate desired number of MOCs (Mobile Originating Calls), MTCs (Mobile Terminating Calls), and MMCs (Mobile-to-Mobile Calls).

CDMA Channel Types: The DMTS-8000 can generate traffic using any of the CDMA2000 channel types e.g. RC1, RC2, RC3, RC4 etc. and any of the associated rates.

Traffic Models: The DMTS-8000 emulates a wide variety of service types. There are several in-built models to choose from for each of these service types.

Voice Call Models: Deterministic i.e. Fixed Inter-arrival times and fixed Duration; or Markov i.e. Poisson Arrival and Exponential Duration



Data Call/Session Models: Call or session oriented data services are modeled as Deterministic, Markov, Pareto (Pareto Inter-Arrival and Pareto duration), or General (General Inter-Arrival and General Duration)

Packet Traffic Models: Packet Inter-Arrival times and Packet Durations, or Burst Size and Burst Inter-Arrival Times during an always-on data session or a real-time data session are also modeled according to Deterministic, Markov, Pareto or General distributions.

SMS: The SMS traffic is modeled according to Poisson Arrivals and Exponential/Binomial message size Distribution.

Subscriber Location Distribution Models: Within a specified coverage area the DMTS-8000 supports uniform as well as non-uniform subscriber distributions. The subscribers could be further Near Cell Dense or Far Cell Dense.

Subscriber Density: The number of subscribers per unit coverage area could be specified by appropriately selecting Urban Dense, Urban, Rural, Suburban, Highways/Railways, Commercial/Shopping/Sporting Complexes and Manhattan example, or could be arbitrarily specified by the DMTS-8000 user.

Mobile Speed: The DMTS-8000 emulates the effect of mobility by attenuating RF signals between the mobile and the base-station and causing corresponding propagation path loss and channel fading. The DMTS-8000 user can select Stationary, Slow, Medium, or Fast mobiles or specify an arbitrary speed.

Sojourn Time in Cell or Handoff Region: The time an active mobile spends in a cell, sector or handoff area is calculated using the mobile speed and the sector, cell or handoff region area and follows Exponential or General distribution.

Mobility Models: The subscriber mobility could be specified to be Random, Markov (with a Transition Matrix dictating the probabilities of transition from a cell to all of its neighbors), Fluid Flow (in which the amount of traffic from one region to another region within the coverage area is a function of area, perimeter, speed, density), Linear (such as in Highways/Railways), and Mobility Equilibrium (i.e. the amount of traffic flowing out of a region is in equilibrium to the amount of traffic flowing into the region).

Soft Handoffs: The DMTS-8000 supports 2-way, 3-way, and 4-way handoffs.

Soft Handoff Call Model: A simulated Markov call that traverses non-handoff and handoff regions during its life span due to subscriber mobility has at least three distinct Generally Distributed phases – 1st phase in soft handoff region, 2nd phase in the inner cell region and the 3rd phase in soft handoff region. The residence time in each phase depends on soft-handoff area, mobile speed and mobility model.

GoS (Grade of Service) Parameters: The DMTS-8000 can be configured to monitor Call Blocking Rate (%age), Call Dropping Rate (%age), Handoff Call Blocking Rate (%age), Call Setup Delay (secs), Call Throughput (Erlangs), Packet Throughput (packets/sec or Erlangs) in a CDMA2000 system during its testing.

QoS (Quality of Service) Parameters: The DMTS-8000 can be configured to monitor SINR (FER, BER or Eb/lo in dBm), Packet Loss (percentage), Packet Delay (sec), Packet Jitter (sec) in a CDMA2000 system during its testing.

Service Types: The DMTS-8000 can create the desired mix of service types e.g. conversational, streaming, and best-effort etc.



Channel Models: The DMTS-8000 emulates a wide range of channel conditions including characteristics of an indoor vs. an outdoor call, calls made from higher floors of skyscrapers vs. low elevations. Although traditional channel models such as Okumura-Hata models etc. are supported, empirical models could also be constructed using propagation measurements collected from the field.

Mobile Terminal Types: The DMTS-8000 allows emulation of non-conventional mobile terminals in addition to conventional mobile terminals such as Cell-Phones, and Laptops and PDAs equipped with CDMA cards. These non-conventional mobile terminals may have power control limitations, extraneous terminal noise and antenna constraints. In addition, they may not support all the CDMA2000 protocol variations, perhaps just a few select ones, such as limited support for service options, radio configurations or coding schemes to name a few.

