

Dyaptive SYSTEMS

# CDMA Network Performance Testing



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## 1 Introduction

Transaction, node, and system performance testing of networks can serve many purposes including: measurement of service capabilities, identification of equipment problems, evaluation of configuration changes, identification of manufacturing process changes, and evaluation of equipment upgrades. Performance tests can range from highly focused tests that measure very specific transactions under very specific conditions, to tests that measure typical behaviours under representative, statistically generated samples of conditions. The former is most useful for detailed, diagnostic investigations of a transaction or a node, while the latter is more meaningful for end-to-end system characterization and tracking of performance variations over time, where such variation may come from a number of sources.

For CDMA wireless network testing, performance testing at both ends of this range is a challenge because of the varied conditions present in deployed systems and the difficulty of reproducing those conditions in a controlled and repeatable way. Conditions such as multi-path, softer and soft handoff, and channel propagation have special, or even unique, implications for CDMA networks. As a result, it is particularly important to perform these measurements for CDMA networks because of the susceptibility of the network performance to variation from these conditions.

The challenge when planning the performance testing is to design tests that offer a balance of the simplicity of a detailed, specific test with the comprehensiveness and value of a statistical, general test.

The purpose of this document is to provide a framework to aid in the preparation of statistical tests that retain sufficient simplicity that they can be designed and executed by a relatively small number of people, both in a laboratory setting and in a field setting.



## 2 Framework for Performance Measurements

### 2.1 Background

A performance test makes a specific measurement to provide insight into a capability of the system. For example, the test might measure the elapsed time between an origination message sent from a mobile and the channel assignment message response from the network. This time measurement is then used to characterize the channel set-up time for the network.

Such a measured value should be considered a sample of an underlying process. As such, repeated measurements of the same process will exhibit a variation that depends on the variability of the system environmental conditions over the duration of the measurements. This source of variability puts further burdens on the measurement taker because appropriate statistical methods should be used; the variability should be measured, and the results should be considered and reported in the context of the variability. The statistical significance of the measurement is of at least as much value as the measurement itself. For example, reporting the channel set-up time as 2 seconds is not nearly as valuable as reporting the channel set-up time as 2 seconds plus or minus ½ seconds 95% of the time. The latter provides a much stronger statement about the capability of the network and hence the end-user experience.

In general, the measurement taker can follow one of two directions for making the measurements statistically significant: in the presence of high variability, a large number

of measurements can be taken, or the variability can be reduced through greater specification and control of the system environment. Field measurements tend towards the former scenario, while laboratory measurements tend towards the latter. Field measurements must contend with higher variability and hence larger numbers of measurements in order to achieve statistical significance than lab measurements. At the same time, these measurements are harder to set up and take longer than lab measurements. Field measurements, of course, have the advantage of directly sampling the same environment as the end-user, but this environment is only approximately known.

Consider the following example:

In characterizing the data throughput capability of a network, an engineer measures the average bit rate of a series of large data transfers, 5MB. The transfers are made during the busy hours of a network and are performed serially so as not to affect each other. The summary of the measurements is:

	Measurement
Number of transfers	15 samples
Average transfer rate	88.8 kbps
Average transfer time	7.7 mins
Standard deviation in transfer rate	10.8 kbps
Desired confidence	95%
Confidence interval for average transfer rate	82.8 to 94.8 kbps
Confidence interval for std. dev. of transfer rate	7.9 to 17.0 kbps
Range for 2 std. dev. from average	48.7 to 128.8 kbps

A later set of measurements is taken after the addition of channels. The channels are intended to increased soft-handoff capacity in order to reduce interference and improve performance. The measurement summary is:

	Measurement
Number of transfers	15 samples
Average transfer rate	99.5 kbps
Average transfer time	6.9 mins
Standard deviation in transfer rate	9.2 kbps
Desired confidence	95%
Confidence interval for average transfer rate	94.4 to 104.6 kbps
Confidence interval for std. dev. of transfer rate	6.8 to 14.6 kbps
Range for 2 std. dev. from average	65.2 to 133.8 kbps



Some interesting points about these measurements are:

- The very wide range that analysis predicts the end-user is likely to experience, 49 to 129 kbps in the first case, and 65 to 134 kbps in the second.
- Even though the sample means, 88.8 kbps and 99.5 kbps, seem to indicate a substantial improvement in performance, in fact the confidence intervals for the two sets of measurements overlap. The data do not substantiate the claim of a substantial improvement in performance.

It is important to note that the above example does not indicate that the performance did not improve, but that the data do not support the claim. It could be that the average performance did improve, but the environment is subject to high variability. It could also be that additional soft-handoff capacity did not improve performance because other factors more strongly limit it.

## 2.2 The System Environment

The system environment is the background system activity that is occurring in conjunction with the feature under test. As such it should be controlled and repeatable. A CDMA network is too complex of a system for exhaustive reproduction of all possible system environments, so a manageable subset must be used. At the same time, an overly specified subset is likely to miss interesting interactions between the feature under test and the environment. The method proposed in this document is to pseudo-randomly generate the system environment from a manageable list of parameters. By being pseudo-random, the environment generator will explore many combinations of the parameters, but also allow regeneration of a given environment.

A number of parameters suggest themselves as good candidates for specifying the system environment because they model important real-world conditions and they can be adequately specified and controlled. A good candidate list of modeling parameters is:

- **Call Attempt Rate** - the rate at which mobile-originated calls arrive at the network.
- **Call Duration** - the length of a call. This parameter is set for only one of the two phones involved in the call.
- **Traffic Type** - the type of traffic exchanged during a call.
- **Access Attempt Rate** - the rate at which system access attempts are made that are not for purposes of call setup (e.g. registration, message response, or data burst)
- **Access Attempt Type** - the type of system access attempt to perform
- **Mobile Location** - the location within a cell from which the call is initiated.
- **Mobile Mobility** - the mobile speed at the time of the call.
- **Softer Handoff Level** - the number of softer handoff candidates present at the time of the call.
- **Soft Handoff Level** - the number of soft handoff candidates present at the time of the call.

### 2.2.1 Call Attempt Rate

Call Attempt Rate is modeled with a pool of available mobiles and a Poisson random variable that is used to generate the intervals at which an available mobile is taken from



the pool and instructed to originate a call. The number of mobiles required in the pool need only be nominally greater than the expected call capability (Erlangs) of the network elements being tested. The test case must specify the average call attempt rate. The number of attempt rates to test can be reasonably simplified by selecting a small number of rates. Three rates, slow, medium, and fast, is a small enough set to be manageable.

In a field environment, mobiles would be real or simulated mobiles that interact with the system through an RF link. In a laboratory environment, mobiles may be a combination of real and simulated mobiles. Simulated mobiles may interact through RF, baseband, some higher layer of the protocol stack, or a combination of these.

	Average Call Attempt Rate
Slow	60 secs
Medium	15 secs
Fast	5 secs

### 2.2.2 Call Duration

Call Duration is the time duration of a call for circuit-switched calls, or the user data length for packet-switched calls. For modeling, the call duration is determined at the time of the call. It can be modeled as a random variable from a distribution, such as exponential or gamma. An adequate simplification is a weighted, random selection from a small set of call durations, such as short, medium, and long.

	Circuit Call Duration	Packet Call Duration	Call Duration Selection Weight
Short	10 secs	300 bytes	50%
Medium	60 secs	30 KB	30%
Long	600 secs	3 MB	20%

### 2.2.3 Traffic Type

The Traffic Type is the class of traffic used by the call. At the time of setting up a call, a model must be used to select a traffic type from a list of traffic types. An adequate selection model is a weighted, random selection.

An example list of traffic types and weights is:

Traffic Type	Traffic Type Selection Weight
RC1 Voice (EVRC)	20%
RC2 Voice (QCELP-13)	0%
RC3/3 Voice (EVRC)	40%
RC 3/3 2x Data	20%
RC 3/3 4x Data	10%
RC 3/3 8x Data	5%
RC 3/3 16x Data	5%

### 2.2.4 Access Attempt Rate

Access Attempt Rate is similar to Call Attempt Rate in that it is modeled with a pool of available mobiles and a Poisson random variable that is used to generate the intervals at which an available mobile is taken from the pool and instructed to initiate a system access (note that this pool will typically be much smaller than the pool for call attempts because access attempts are much shorter). The test case must specify the average access attempt rate. The number of attempt rates to test can be reasonably simplified by selecting a small number of rates. Three rates, slow, medium, and fast, is a small enough set to be manageable.

In a field environment, mobiles would be real or simulated mobiles that interact with the system through an RF link. In a laboratory environment, mobiles may be a combination of real and simulated mobiles. Simulated mobiles may interact through RF, baseband, some higher layer of the protocol stack, or a combination of these.

	Average Access Attempt Rate
Slow	30 secs
Medium	10 secs
Fast	2 secs

### 2.2.5 Access Attempt Type

The Access Attempt Type is the class of access attempt. At the time of setting up a call, a model must be used to select a type from a list of access types. An adequate selection model is a weighted, random selection.

An example list of access types and weights is:

Access Attempt Type	Access Attempt Type Selection Weight
Power-up registration	10%
Timer registration	40%
Zone registration	35%
Parameter registration	10%
SMS data burst	5%

### 2.2.6 Mobile Location

The Mobile Location is the physical location and propagation environment of the mobile in the network. Again, a limited set of discrete locations is an adequate model. Depending on the comprehensiveness of the test, only a limited subset might be used. For example, when testing includes only a single base station, near and far would be used, but only one of urban, suburban, and rural because the base station is only going to be present in a single environment.

In a field test, the mobile location is set by the physical location of the phone or test equipment. In a lab test, the mobile location would be approximated by appropriate use of a channel simulator. In particular, this modeling parameter is meant to specify the static and slow fading channel propagation properties.



An example list of locations is:

Mobile Location	Mobile Location Selection Weight
Near Cell Dense Urban	75%
Near Cell Suburban	0%
Near Cell Rural	0%
Far Cell Dense Urban	25%
Far Cell Suburban	0%
Far Cell Rural	0%

### 2.2.7 Mobile Mobility

The Mobile Mobility is the dynamic propagation environment of the mobile in the network. When a test case is executed in a field environment, Mobile Mobility and Mobile Location are tightly coupled especially with respect to Near / Far and Mobility. In a laboratory or simulation environment, Mobile Mobility is meant to specify the fast fading behavior of the channel as a result of mobility, so may be kept decoupled from Mobile Location (i.e. a mobile that is Near but moving at 100 km/h need not ever transition to Far or leave the coverage area of the serving sector).

Mobile Mobility	Mobile Mobility Selection Weight
3 km/h	50%
30 km/h	30%
100 km/h	20%

### 2.2.8 Softer Handoff Level

Softer Handoff Level is the number of softer handoff candidates available at the time of the call and affects the amount of processing load and channel capacity on the serving base station. In a field test environment, this must be controlled through appropriate physical location at the time of the call. In a laboratory environment, this is controlled through cabling and channel simulation.

Softer Handoff Level	Softer Handoff Selection Weight
No softer handoff candidates	60%
1 softer handoff candidates	40%

### 2.2.9 Soft Handoff level

Soft Handoff Level is the number of soft handoff candidates available at the time of the call and affects the amount of processing load and channel capacity on the serving base station and the available back haul capacity. In a field test environment, this must be controlled through appropriate physical location at the time of the call. In a laboratory environment, this is controlled through cabling and channel simulation.

Soft Handoff Level	Soft Handoff Selection Weight
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Soft Handoff Level	Soft Handoff Selection Weight
No soft handoff candidates	60%
1 soft handoff candidates	25%
2 soft handoff candidates	10%
3 soft handoff candidates	4%
4 soft handoff candidates	1%

### 3 Using the Framework

The purpose of the framework is to create a specific, but realistic environment under which a feature of the system can be tested. In essence, the framework generates a script, or timeline of events.

The environment is generated from a pseudo-random process so it will capture much of the complexity of the real environment it is modeling, yet still be repeatable. The environment is specified by the initialization of the pseudo-random generator and the call selection models. Initializing the pseudo-random process differently generates different environments, as does changing any of the selection criteria. If an aspect of the network is changed (e.g. a software load on one of the network elements) a past test can be repeated by initializing the process the same way.

#### 3.1 In the Laboratory

In the laboratory, the primary goal is a repeatable environment that embodies the primary factors affecting the feature under test. Even a simple CDMA network includes a substantial number of network elements, probably all of which are designed for capacity well beyond what is achievable in a laboratory using only end-user equipment. Consequently, controllable load generation is a critical aspect of creating a sufficient test environment. As shown in the figure below, load generation is important at any point within the network that can strongly affect the feature under test.

When planning the laboratory setup, it is important that the load generation be coordinated in order to make the environment repeatable. A load controller (not shown in the figure) is responsible for coordinating the activity on each of the generators so that it is repeatable and conforms to the environmental model. Coordination may be explicit, real-time control of the generators, or it may be batch-mode, preconfiguration of the generators with adequate time synchronization.



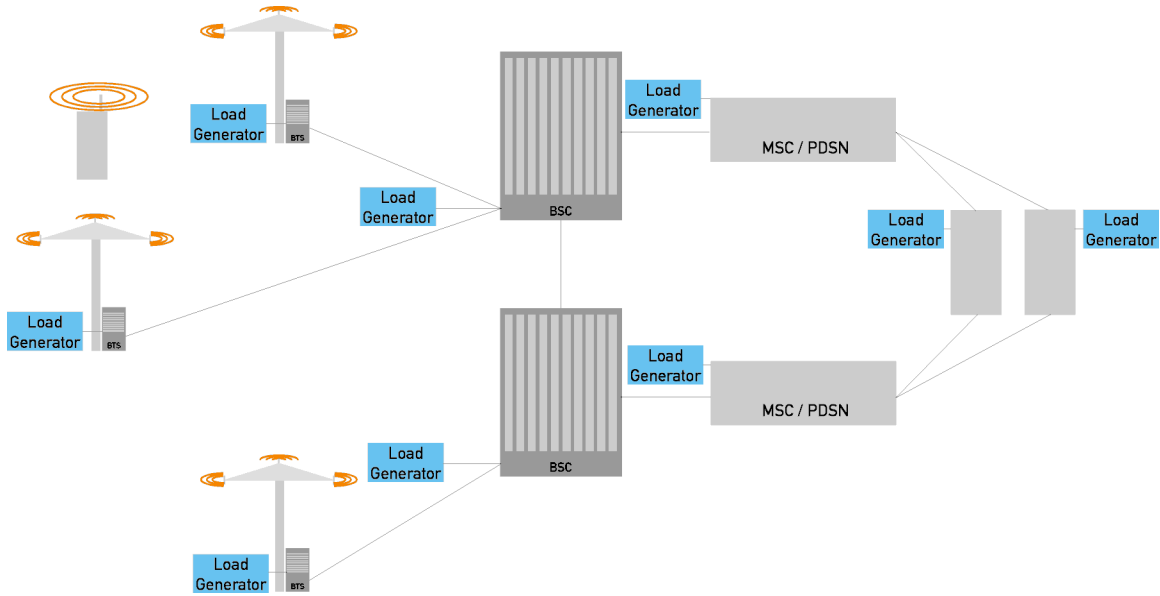


Figure 1 - Laboratory Test Configuration

### 3.2 In the Field

In the field, real traffic is at least part of the environment. Additional, controlled background can be included in the environment by pre-calculating the series of events (call times, call types, locations, etc.). The actions are then performed at the correct times. Variability will clearly be higher than in the lab because of limitations of time coordination, the presence of live traffic, availability of equipment, etc. Nonetheless, it is possible to generate an environment that is more controlled and repeatable than testing purely “in the wild.”

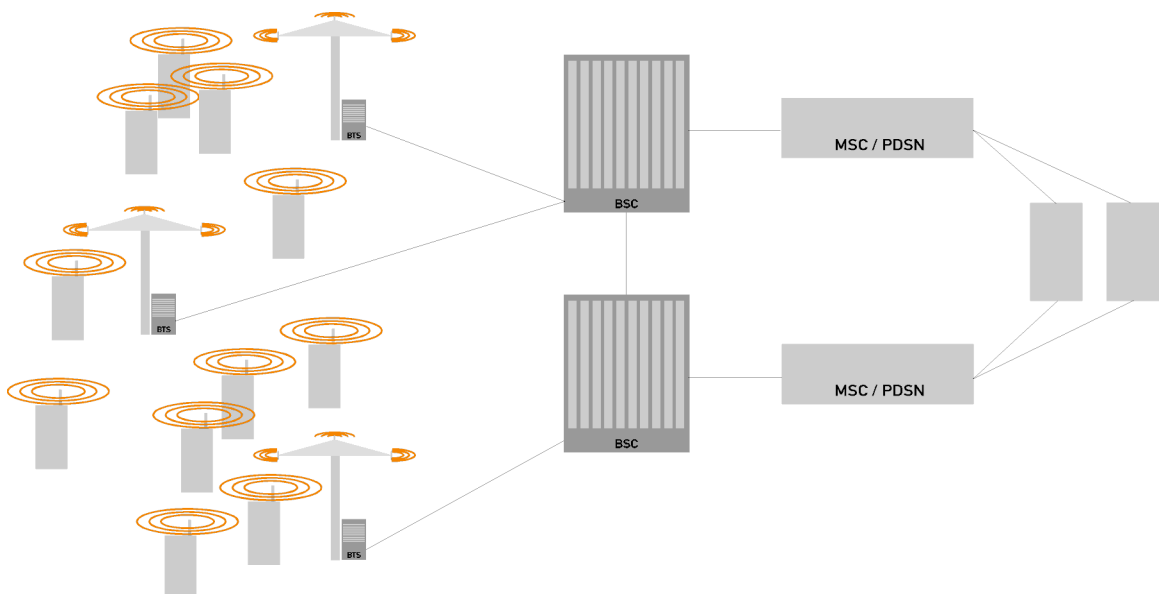


Figure 2 - Field Test Configuration

## 4 Conclusion

Performance testing of CDMA networks is a substantial challenge: live networks are subject to high variability due to user load and complex interactions between network nodes, while lab networks typically only weakly model live networks. As more features and technologies are deployed in the network, performance testing is increasingly important both to verify the operation of the additions and to insure the continued operation of the existing infrastructure.

Performance testing of a feature of the network is a challenge in either the live network or a lab network because of the difficulty of reproducing and controlling a wide variety of network conditions. In a field test, the environment is only weakly reproducible and not controllable. In most lab tests, the environment typically only targets a very limited set of live conditions.

The approach presented here is to select a manageable list of environmental conditions, develop simple models for each condition based on field measurement, then generate test cases from a pseudo-random selection from the permutations of the simple models. This approach has the advantage of being achievable with existing equipment, generates reproducible test cases, and subjects the feature under test to a representative sample of live network conditions.

