8 CDMA module

8.1 Introduction

SEAMCAT allows the simulation of cellular networks employing Code Division Multiple Access modulation scheme. The specific CDMA standard (e.g. CDMA2000-1X, or W-CDMA/UMTS) can be selected by incorporating the appropriate link level curves into the simulation scenario. Only the interference impact of/on "voice" users can be studied using SEAMCAT. The CDMA examples given in this manual are based on 3GPP UMTS specifications.

CDMA and OFDMA share common panels and calculation. You are invited to consult Section 7.5 for the cellular topology, Reference Cell etc.. Section 7.6 for the Pathloss and Effective Pathloss definition etc.

8.2 CDMA system tab

Introduction

Whether you want to simulate CDMA UL (uplink) or CDMA DL (downlink), you can import from the system library (Figure 186 – (a)), the cellular system you want (Figure 186 – (b)). You can also export the characteristics of your CDMA network to the library for later reuse.

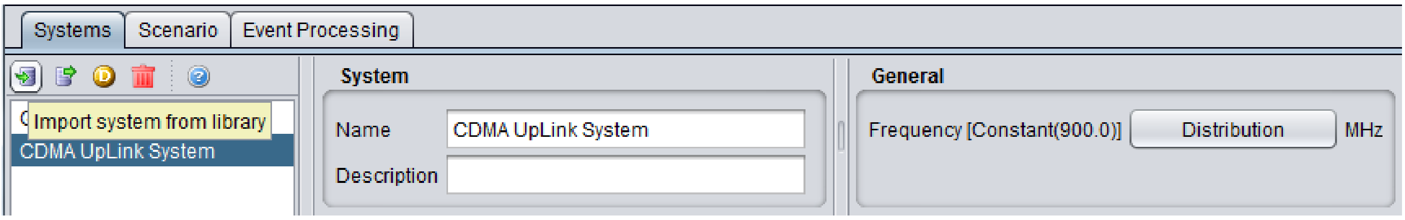

Figure 186: Selection of a CDMA cellular network from the system library

8.2.1 System

You can name and write some description of the CDMA system you want to simulate. It is the same layout as when a generic system is selected.

8.2.2 General

You can enter the frequency. The frequency value is overwritten at the “Scenario” tab level.

Table 26: General system panel

Description	Symbol	Type	Unit	Comments
Frequency	f	Distribution or Scalar	MHz	Distribution of the centre frequency of the system

It is used to define the necessary parameters for the modelling of CDMA systems. The CDMA interface has been split into 2 tabs.

8.3 General settings

Introduction

The General settings tabsheet contains a range of CDMA system parameters as well as some parameters that depend on the modelled direction of CDMA link (uplink vs. downlink). 7 panels characterised the CDMA system. The below graphic represent the CDMA UL when a victim.

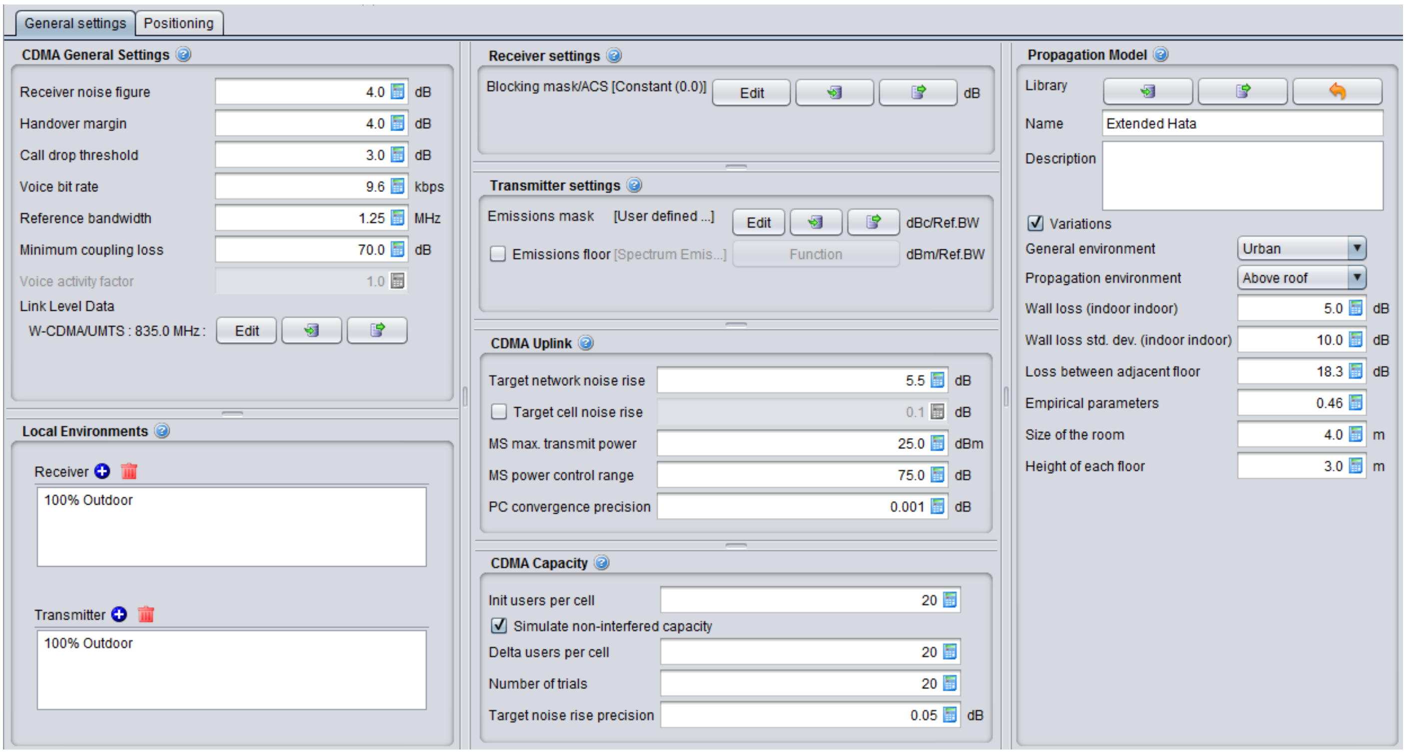

Figure 187: CDMA UL general settings

The only differences with CDMA DL are the following 2 panels (CDMA Downlink and CDMA Capacity).

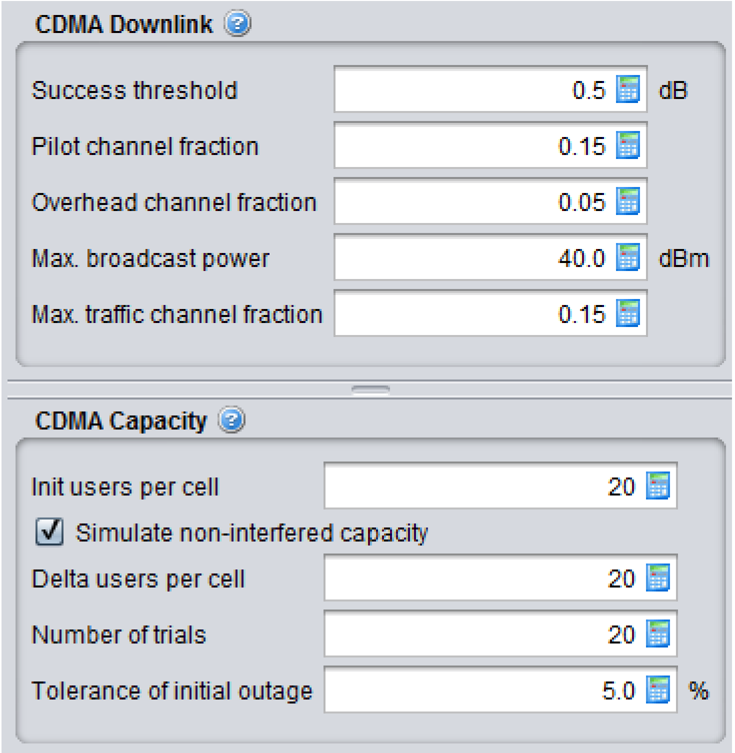

Figure 188: CDMA DL general settings difference with CDMA UL

8.3.1 CDMA general settings

Table 27: CDMA general settings input parameters

Description	Symbol	Type	Unit	Comments
Receiver Noise Figure		Scalar	dB	Equipment-specific noise figure of receiver. It is used to calculate the noise floor. See Section1.2.2
Handover margin		Scalar	dB	Specifies the maximum difference between the links in users active list. The actual active-list selection is based on pathloss calculations.
Call drop threshold		Scalar	dB	Threshold to determine call drops. It is used by the power control to determine if a user should be dropped when not meeting exact target requirement.
Voice bit rate		Scalar	kbps	it is used to calculate the processing gain. See Section 8.7.1. processingGain = 10*log10(systemBandwidth (MHz) / voiceBitRate (kbps) * 1000);
Reference bandwith		Scalar	MHz	Bandwidth of the system. It is the same for either UL or DL.
Voice activity factor	-	-	-	It is set to 1, i.e. 100% (all voice users that are generated are active). It is not editable.

Minimum Coupling Loss		Scalar	dB	The minimum path loss. It is used in the calculation of the effective path loss depicted in section 7.6.1
Link Level Data		Function (X,Y)		Drop-down selection of Link level data look-up functions from Library. It is user's responsibility to choose an appropriate set of data. See Section 8.5 for further details

8.3.2 Local environment

You can choose the suitable indoor and outdoor ratio for the mobile station to be used by the propagation model. Further details are presented in Section 5.4.3.

8.3.3 Receiver settings

This content of this panel depends whether CDMA system is a victim or an interfering system. If the CDMA is a victim, you will have to set the blocking mask. It is a shared interface with OFDMA.

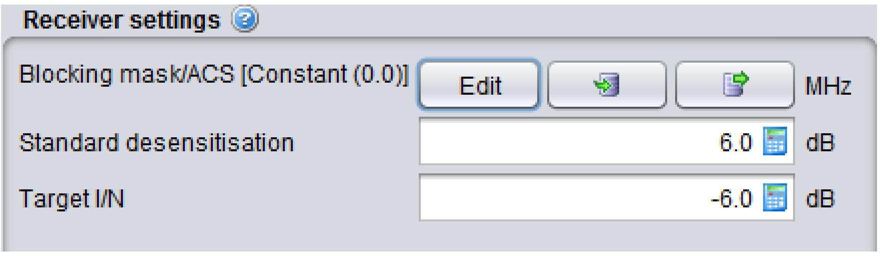

Figure 192: Cellular panel receiver settings

Table 27: Receiver settings of a cellular system

Description	Symbol	Type	Unit	Comments
Blocking mask/ACS : Receiver frequency response (receiver blocking performance)	*blocking*	Function (X,Y) (MHz)	dB	It is similar to the blocking response depicted in Figure 12 except that it is to be set as user defined mode only. In case that the blocking mask is defined with negative values, the parameters Standard desensitization and I/N_target (described below) are used to compute the blocking mask used in the simulations. See section A9.1 (and subsections A9.1.1 to A9.1.3) for the equations
Standard desensitization			dB	It is value of desensitization of the receiver as defined in the standards.

Target I/N			dB	It is the protection criteria used for the simulation.

8.3.4 Transmitter settings

This content of this panel depends whether CDMA system is a victim or an interfering system. If the CDMA is an interferer, you will have to set the spectrum emission mask and the emissions floor. It is a shared interface with OFDMA.

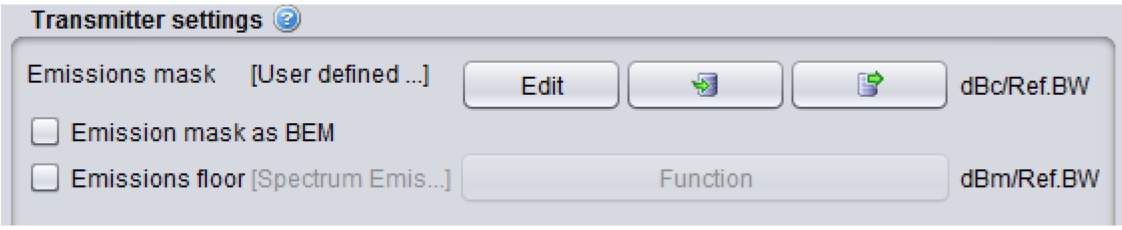

Figure 190: Cellular panel transmitter settings

When defining the Emission Mask (not as BEM) the units of the user defined mask are: Offset (MHz); Mask Values (dBc); Reference Bandwidth (kHz).

When defining the Emission mask as a Block Edge Mask (BEM), SEAMCAT sets to 0 dBi the peak gain of the transmitter antenna and uses the power entries of the Mask as e.i.r.p (already including the gain of the antenna). So, if the Emission mask is defiend as BEM, the units of the user defined mask are: Offset (MHz); Mask Values (dBm e.i.r.p.); Reference Bandwidth (kHz).

8.3.5 CDMA uplink

This is only available if CDMA UL selected.

Table 29: CDMA UL input parameters for the power control

Description	Symbol	Type	Unit	Comments
Target network noise rise		Scalar	dB	Specific level of noise that the network is willing to handle, when this level is reached it starts removing UEs to reduce its noise level
cell noise rise selection		Boolean	-	Select the algorithm that allow the cell selection based on a noise rise increased. If selected, then the measure of the noise rise per each cell is considered and the algorithm, recursively, tries to identify the number of affected cells due to a single source/cluster of interferers and remove users. If not selected, then the measure of the noise rise over the whole network is considered (See Section 8.7.6 for details)

Target cell noise rise		Scalar	dB	Only available when Cell noise rise selection is active. It is set to 0.1 dB by default. The “cell noise rise” algorithm will assess whether to drop users from any cell in which the noise rise exceeds the threshold indicated above. The default value of 0.1 dB has been chosen to ensure that the analysis does not disregard any cases of interfered cells, since users may also be dropped as the consequence of a low noise rise.
MS maximum transmit power		Scalar	dB	Maximum transmit power of the MS (i.e. the UE)
MS power control range		Scalar	dB	Span of the fluctuation of the power

PC convergence precision		Scalar	dB	In the uplink, each mobile station perfectly achieves the target C/I, Eb/N0_target, during the power control loop convergence, assuming that the maximum transmit (TX) power, max_MS_Tx_Pw, is not exceeded. Those mobile stations not able to achieve Eb/N0_target after convergence of the power control loop are considered in outage (i.e. they are dropped). The power control loop is considered to converge when all mobile stations are within the max_MS_Tx_Pw and their Tx power is adjusted by less than the “PC convergence precision” value for the last power balancing iteration.

8.3.6 CDMA downlink

This panel is available only if CDMA DL selected.

Table 30: CDMA DL input parameters for the power control

Description	Symbol	Type	Unit	Comments
Success threshold		Scalar	dB	Threshold to determine perfect link quality.
Base Station Pilot Channel Fraction	*pilot_frac*	Scalar	-	Fraction of max BS power allocated to pilot.
Base Station Overhead Channel Fraction	*Overhead_frac*	Scalar	-	Fraction of max BS power allocated to overhead channels (paging, etc.).
Base Station maximum Broadcast Power		Scalar	dBm	maximum Broadcast Power
Base Station maximum traffic channel fraction		Scalar	-	Fraction of the maximum allowable broadcast power (per traff. chan. per BS). The maximum allowable traffic channel power is compared to the calculated transmit traffic channel power levels with respect to the Ec/Ior link level data for iterative adjustment in the DL power control.

8.3.7 CDMA capacity

The capacity of the simulated system (i.e. how many mobiles per cell should be generated in the system) is dependent on all other settings and cannot always be easily deducted from these. Therefore SEAMCAT has a feature that allows for automatic determination of capacity. This is also known as simulation of non interfered capacity and is enabled by default.

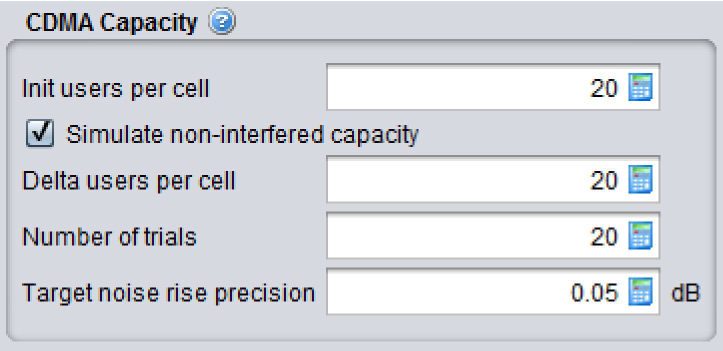

Figure 191: CDMA UL system - Determination of the optimum number of UEs (CDMA capacity)

In CDMA UL, the number of optimised users is being re-calculated for each event. It is recommended to run the "simulate non-interfered capacity" so that SEAMCAT can provide a "best" optimised value, this will optimise the computation time afterwards. If you are using another number you risk to create an overhead in your computation time without any change in the output results.

Figure 192: CDMA DL system - Determination of the optimum number of UEs (CDMA capacity)

Table 31: CDMA Capacity settings parameters (UL and DL)

Description	Symbol	Type	Unit	Comments

Simulate non interfered capacity	-	Boolean	-	Toggles automatic capacity finding. If the option **Simulate non-interfered capacity** is checked, then the system will automatically simulate the 'optimal' number of the mobiles for given system configuration (type of system, bandwidth, cell sizes, etc). The optimum finding algorithm is developed to establish the loading that would correspond to approx. 80% of maximum system capacity. If this option is unchecked, you are free to set a constant user-defined average number of mobile users per cell especially if the optimal capacity for the current scenario is known (this is often the case when running consecutive simulations with the same system) there is no need to simulate – as the simulation process can be quite lengthy. When this checkbox is disabled SEAMCAT uses the value entered in 2 – “Users per cell” as the capacity per cell.

Init users per cell	-	Scalar	-	If capacity simulation is enabled this indicates the starting point of the simulation. Selecting the right starting point can speed up the capacity finding. If capacity simulation is disabled the value in this field is the actual value used by SEAMCAT. SEAMCAT does NOT change this input value into the result of the simulation! Users per cell is equal to UE per Base Station. SEAMCAT consider each Base station as its own cell.
Delta users per cell		Scalar	-	When SEAMCAT tries to find the optimal capacity it adjust the number of UEs per cell starting with this value. A proper value here can speed up capacity finding.
Number of trials		Scalar	-	When finding the optimal capacity SEAMCAT runs this (i.e. Number of trials) many snapshots of every value of UEs per cell before deciding whether or not the current value is the optimal capacity. Generally larger numbers mean greater precision but also longer time needed by the algorithm.
Target noise rise precision		Scalar	dB	**Uplink only** – the precision used when comparing the noise rise of the filled system with target noise rise set under the “CDMA Uplink” panel

Tolerance of initial outage		Scalar	%	**Downlink only** – The tolerance of initial outage is the percentage of UEs that can be dropped before SEAMCAT determines that the tested number of UEs cannot fit into the system (i.e. 20 user_per_cell * 19 BS = 380 UEs, if 5% or less of 380 UEs are dropped, the system is considered able to handle/service 20 UEs per cell). SEAMCAT will adjust the value of UEs per cell untill a value is found which in 80% of the specified number of trials is able to handle the tested number of UEs per cell.This parameter allows for UEs in “extreme” pathloss situations to be “ignored” from the optimal capacity finding.

8.3.8 Propagation Model

You can choose the suitable propagation model to be applied when calculating signal loss along the transmitter and the receiver path. A choice and settings of propagation models are presented in ANNEX 17:.

8.4 Positioning

See section 7.5, common to CDMA and OFDMA on the positioning of BSs and MSs.

8.5 CDMA Link level data

8.5.1 CDMA link level system mapping

Power control is a crucial mechanism in CDMA mobile radio networks, which needs to be modeled in SEAMCAT. It is a complex process involving various layers of signaling, measurement and modulation/demodulation procedures. It is not feasible to model signaling, link and chip level details of CDMA power control in network level simulations performed by SEAMCAT due to the complexity and CPU time constraints. Hence, it is necessary to adopt the two-step approach employed widely in the industry for the simulation of CDMA based systems.

The first step utilizes link level simulations that model fast fading channels, power control procedures and actual chip level algorithms to generate outputs that map channel power requirements to link quality (e.g. frame erasure rate, FER). Such simulations involve the knowledge of intricate details of the CDMA signaling procedures and modulation/demodulation methods.

Major CDMA vendors develop link level simulations and contribute their results to the standard bodies. Since the link level results are independent of most system level variations (cell sizes, amplifier ratings, antenna types, etc.), they are applicable to a wide variety of network configurations. The second step in the simulation of CDMA involves system level simulations that actually model the CDMA network on a macro scale. Since the required channel power vs. link performance data is available from the link level results, transmit power levels for CDMA channels can be calculated and utilized in the system level modelling of a CDMA network.

The approach described above enables the reuse of link level data to model various network configurations. Furthermore, through the use of the link level data, an accurate power control model is implicitly included in the system level simulations that run at moderate complexity.

The built-in CDMA Link level Data used in DL and UL can be found in Section 13.4.6. SEAMCAT allows you to load your own library too.

8.5.2 CDMA DL Power Control Methodology (VOICE ONLY)

Figure 193 presents the dependency between the condition of a user in the network (the so called geometry), mobile speed and soft handover state of the UE that are needed to map a particular link quality to the channel power requirement.

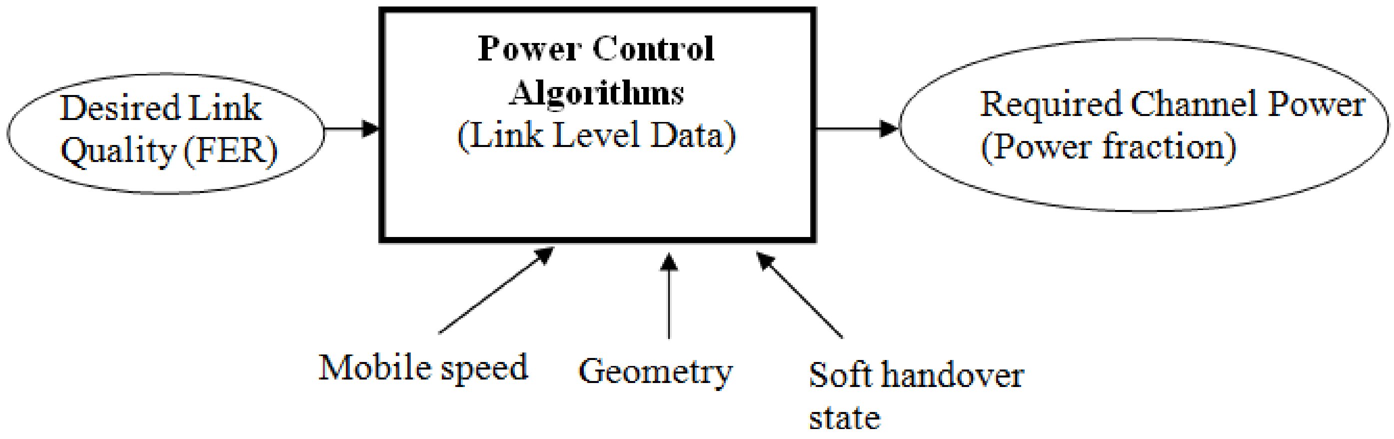

Figure 193: Power Control Module (high level)

All these factors determine the appropriate mapping of a particular link quality to the channel power requirement. For example, stationary users may require less power than moving users to attain the same link quality. Similarly, users connected to several BS’s at the same time (soft handover) may require less power than users connected to a single BS to achieve the same link quality. Furthermore, users in favorable locations (high geometry) may again require less power than users that are in unfavorable locations (low geometry). Hence, link level data includes different mappings (look up tables) between link quality and required power for different mobile speeds, geometries and soft handover states. Furthermore, in order to remove the dependency on the total BS power (may vary from system to system), the power requirements are reported as normalized power fractions (fraction of the total BS power).

Consequently, the link level data is used in modelling power control in a variety of conditions such as different mobile speeds, geometrical user distributions, soft handover characteristics and amplifier output power ratings. In CDMA Downlink, the link level is a function of Ec/Ior.

8.5.3 CDMA uplink Power Control Methodology in SEAMCAT (VOICE ONLY)

Performance characteristics of individual links to be used in the power control module of SEAMCAT are generated a priori from link level simulations. This usually includes several mappings between requested link quality (e.g. block error rate, BLER) and required transmit power of mobile stations/base stations. For generating such mappings in form of “look up tables”, link level simulations involve multipath fading, physical layer transceiver algorithms, e.g. modulation/demodulation and coding/decoding, as well as power control procedures. Different mulipath fading channels (e.g. the ITU channel models) are used to model various configurations, e.g. indoor, outdoor, pedestrian, vehicular, etc.

In CDMA UL, the sum of received C/I values in two sectors should meet the C/I requirements specified by the link level simulation data. In CDMA Uplink, the link level is a function of Eb/No.

8.6 CDMA Downlink - simulation algorithm

8.6.1 Simulation Methodology

The main goal of the downlink power control in SEAMCAT is to calculate the total BS output power and the success rate (% of calls with no link quality degradation) for a given snapshot of the system. BS output power is a key parameter in the scenarios where CDMA is the interferer. Success rate, on the other hand, is crucial in CDMA victim scenarios. One possible way to analyze the impact of other system interference on CDMA is to compare the success rates in the presence and absence of external interference.

A snapshot of the mutually existing systems is modeled at each event generation in SEAMCAT. Hence, at each event generation the power control algorithm should also be run for the CDMA cell, whether it is the victim or the interferer. This is illustrated in Figure 194. The setup block is inherited from the higher layers of SEAMCAT and consists of initializing the system parameters. The next step involves the generation of traffic for power control, calculation of appropriate path losses within the CDMA cell layout and determination of soft handover states. Power control is then performed by utilizing the link level data via an iterative process. Finally, necessary outputs are generated and fed into the interference calculation modules in SEAMCAT.

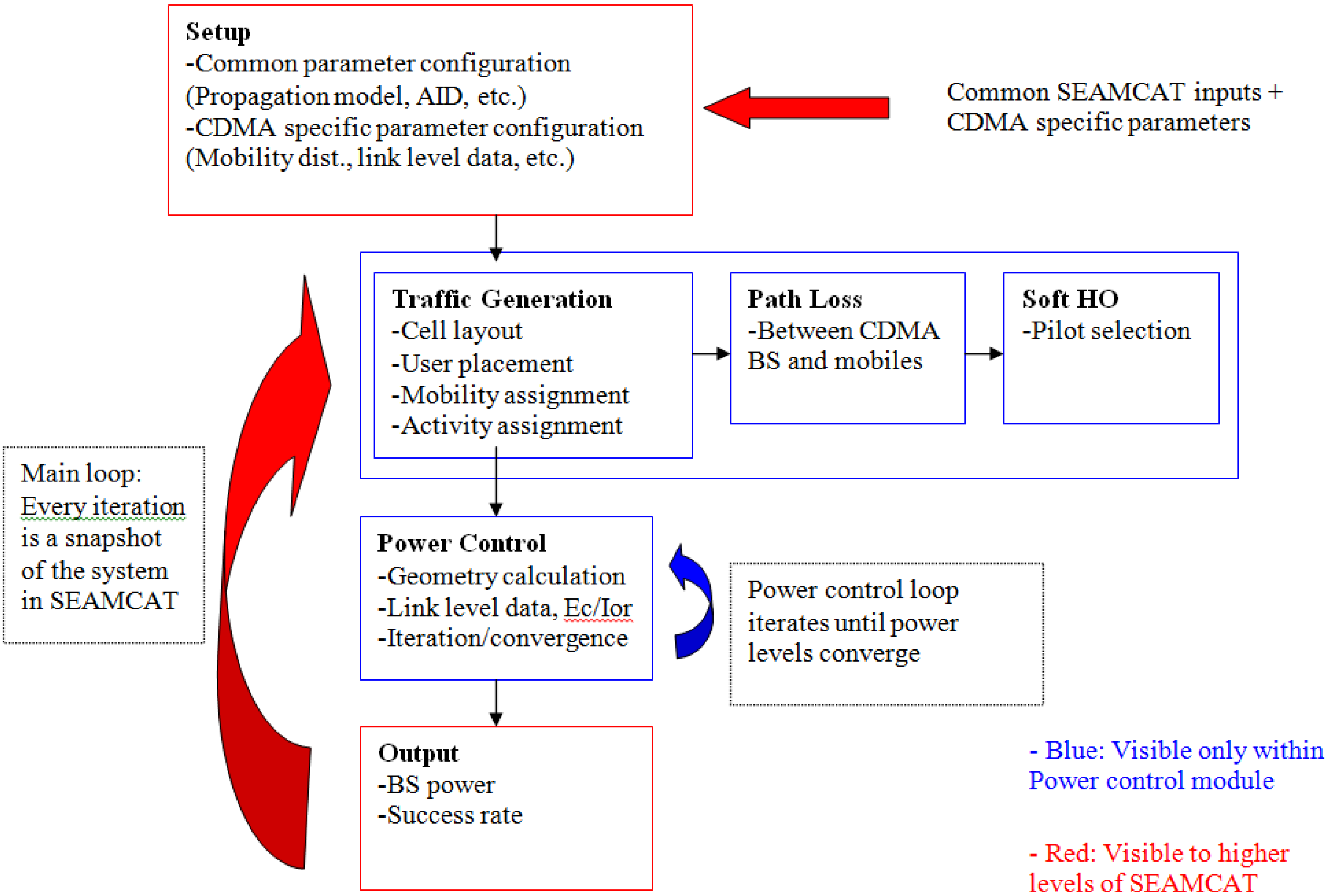

Figure 194: DL Power Control Simulation Methodology – Overview

For simplicity, the CDMA downlink power control methodology is described for omni-cells. However, extension to multi-sector cells is straightforward. In a multi-sector configuration, each sector should be treated in the same way a cell is treated in the omni configuration.

8.6.2 Traffic Generation

While the BS output power and the outage ratio is likely to be calculated for a single CDMA cell, accurate modelling of power control requires the consideration of inner-system interference generated by the surrounding tiers of CDMA cells. The significance of other cell interference in CDMA requires that at least two tiers surrounding the cell of interest be considered. However, BS power and outage statistics will only be collected from the center cell, which has the most accurate interference background (two surrounding tiers). Cells surrounding the center cell will not be visible to the higher levels of SEAMCAT and will only be used to generate the inner-system other-cell interference background for the center cell (Figure 195).

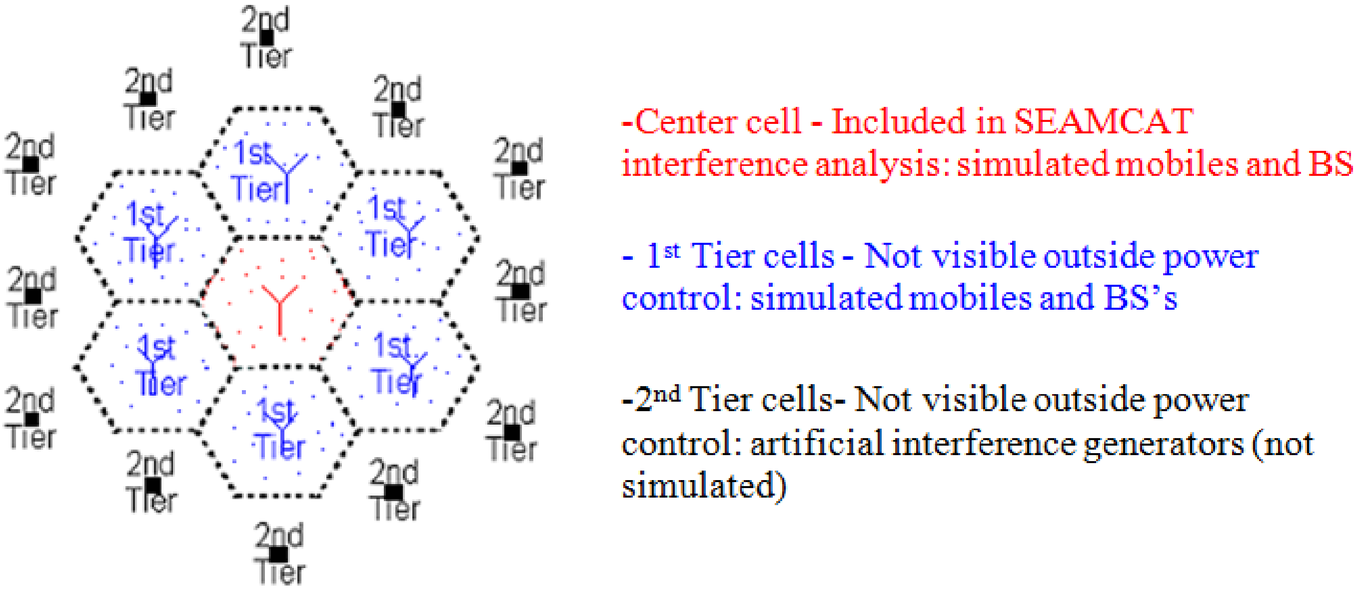

Figure 195: Cell layout for power control

The power control simulation time increases with the number of cells for which power control algorithm is run. One way to reduce the simulation time is to simulate only the center cell and the first tier around it with actual power control algorithms and use artificial interference generators for the second tier as shown in Figure 195. More specifically, the BS's in the center cell and the first tier go through the power control algorithms and calculate the precise power they need to transmit. Whereas, the BS's in the second tier are assigned an output power level to generate interference into the center cell and the first tier. If the output power level set for the second tier is reasonable, this approach will speed up the simulation considerably without sacrificing much from accuracy. Possible methods to determine the appropriate artificial interference level will be addressed later in the paper. Nevertheless, if more accurate results are desired, the second tier can also be simulated using actual power control. In that case, a third tier with artificial interference generators would further increase accuracy by presenting the second tier with a more realistic interference background. However, given the considerations on complexity, the layout shown in Figure 195 presents the most appropriate balance between simulation speed and accuracy.

Since higher levels in SEAMCAT consider only a single CDMA cell, the cell layout shown in Figure 195 may need to be generated separately in the power control module. It is expected that the UE placement be done consistently with SEAMCAT's existing algorithms. However, once the UEs are placed, their mobility assignment should also be done. Actual mobility of the UEs cannot be simulated easily in a static simulation, but the effects of mobility on the channel power can be modeled in a limited sense. While the UEs will be treated at fixed locations within each snapshot, each will be assigned a speed to determine their channel conditions (fast fading), which will be used in the determination of their channel power requirements. This allows the flexibility to simulate various system configurations (fixed, highway, pedestrian, etc.).

8.6.3 Soft Handover

A user may simultaneously be connected to multiple BS's in CDMA based systems (soft handover). Since soft handover affects the amount of power transmitted by each BS to a certain user, it is necessary to determine whether the UE is served by a single BS or multiple BS's. The actual determination of the soft handover state of a user and the corresponding channel power requirements may get complicated. Hence, a simplified soft handover algorithm is presented next, which captures the essence of soft handover effects while avoiding implementation of complex algorithms.

Base stations that are connected to a user are included in the "active set" of that user. A base station is initially selected to be in the "active set" based on the strength of its pilot signal versus the interference background. Each base station broadcasts a certain fixed percentage of its maximum power on the pilot channel. The interference background consists of the non-orthogonal energy received on the other channels of the base stations within the active set and the total broadcast power of the base stations that are not in the active set. The BS selection criterion, "pilot Ec/Io" is then defined as

$$\left(\frac{E_c}{I_0}\right)_i = \frac{pilot\_frac \times P_{Max,i}/W}{FN_0 + \sum_{all j} P_j/W + I_{ext}/W} \quad \text{(Eq. 34)}$$

with the following definitions:

- *Ec* is the chip energy received from ith BS;
- *Io* is the spectral density of total received interference;
- *pilot_frac* is the fraction of BS power allocated to pilot;
- $P_{max,}I$ is the maximum receivable power from ith BS (max BS transmit power*path loss);
- *W* is the system bandwidth;
- *Pj* is the total received power from jth BS;
- *F* is the mobile station noise figure;
- *N0* is the thermal noise power density;
- I_{ext} is the external interference (out of system).

Based on this selection criterion, the following simplified soft handover algorithm can be employed to assign soft handover states to each user:

For each user:

1. Add the BS with the strongest corresponding Ec/Io to the active set;

2. Add the BS with the second strongest corresponding Ec/Io to the active set if its Ec/Io is within 4 dB of the strongest Ec/Io.

Then the soft handover state of a user becomes the number of BS’s in its active set, which is either one or two. Note that in actual systems, the active set of a user may have more than 2 BS’s. However, in order to develop a unified methodology that can simulate various implementations of CDMA based systems and to avoid overwhelming complexity, this simplified approach is suggested. Several standards (including UMTS) present similar methodologies for simulations.

8.6.4 Power Control

As far as SEAMCAT is concerned, the actual CDMA power control algorithm looks merely like a black box that maps link quality to channel power. However, the mapping is not simply one-to-one. Depending on the conditions of the mobile user, the same link quality can map to different channel power requirements. A key parameter that determines the condition of a user is called the "geometry". The higher the geometry, the more favorable the UE's condition is. The geometry is defined as:

$$G = \frac{P_{active}}{N_0 + P_{other} + I_{ext}} \qquad \text{(Eq. 35)}$$

with the following definitions:

- P_{active} is the total power received from BS's in the active set;
- *No* is the thermal noise;
- P_{other} is the total power received from BS's not in the active set;
- I_{ext} is the external Interference (out of system).

The fractional power levels found in the link level data are defined for each user (channel) as:

$$\frac{E_c}{I_{or}} = \frac{P_{traff\_active}/W}{P_{total\_active}/W} = \frac{P_{traff\_active}}{P_{total\_active}} \qquad \text{(Eq. 36)}$$

with the following definitions:

- P_{traff_active} is the total received traffic channel power from BS's in the active set
- P_{total_active} is the total power received from BS's in the active set

P_{total_active} is the sum of the total received power from the BS's in the active set including their pilot, overhead and all traffic channels. Whereas P_{traff_active} includes only the traffic channel power that is received from the BS's in the active for the particular user. In other words, a user's Ec/Ior shows the fraction of the total received power that is used for voice communication with that user. Based on this definition, the amount of traffic channel power received from a BS for a particular user can be derived from the Ec/Ior requirements reported in the link level data.

If user has only 1 BS in the active set (simplex), the power received from the BS is:

$$Ptraff = Ptotal_active x Ec/Ior \qquad \textit{(Eq. 37)}$$

If user has 2 BS's in the active set (2-way soft handover), power received from one of the BS's is then:

$$Ptraff = (Ptotal_active x Ec/Ior)/2 \qquad \textit{(Eq. 38)}$$

Note that symmetry between the two soft handover legs (links with BS's in the active set) is assumed. Therefore, when a user is connected to two BS's, it receives equal power from each link. The determination of the traffic channel power levels for each user cannot be done in a single step. The inherent assumption in equations 37 and 38 is that Ptotal_active is known. However, Ptotal_active itself is the sum of the pilot, overhead and all traffic channel power levels received from the BS's in the active set. Therefore, an iterative process is required to determine the individual traffic channel received power levels.

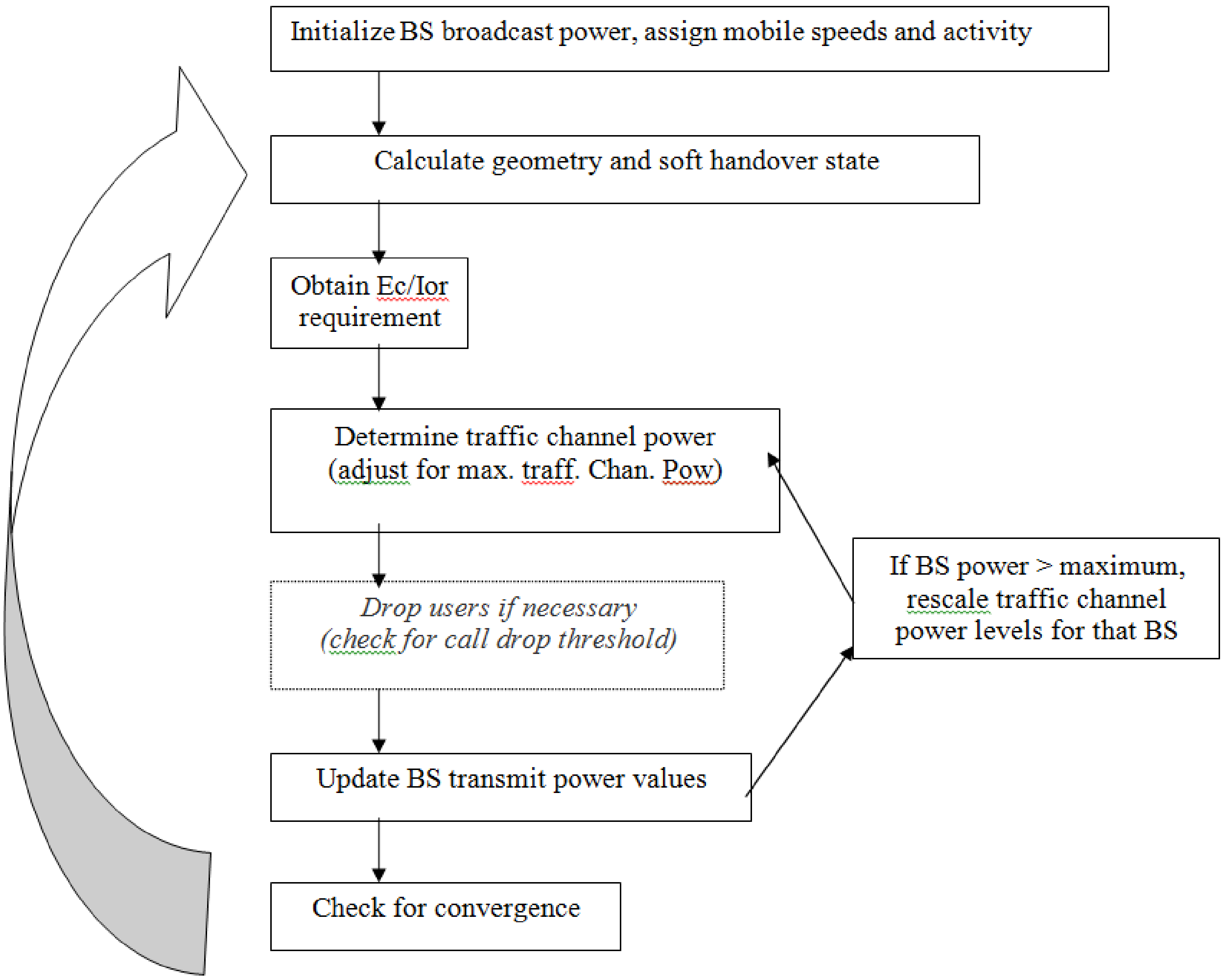

Figure 196: Power Control Loop

Figure 196 shows how the power control loop operates. The initial step is to initialize each BS in the cell layout (figure 1) by assigning total broadcast power levels. A figure around 70% of maximum BS power is appropriate. Note that for the simulated BS's, the total BS power will be updated at each iteration by the power control loop. After enough iterations, the power levels will converge to the correct values.

Once the initialization is complete, geometry and soft handover state for each user can be calculated based on the initial values of the BS broadcast levels. Then the Ec/Ior requirement for each active user can be obtained from the link level data using its mobile speed assignment, calculated geometry and soft handover state. Equations 37 and 38 can then be used to get the received traffic channel power levels for each user. Path loss information can then be used to determine the corresponding transmit channel power levels. However, the calculated transmit traffic channel power levels should be checked against the maximum allowable traffic channel power and transmit/receive levels should be adjusted if necessary. As a result of such an adjustment, a user may not meet its Ec/Ior requirement. Based on a "call drop threshold", such a user may be removed from the system if it meets the following criterion:

$$AchievedEc/Ior < Ec/Iorrequirement - Calldropthreshold(dB) \quad \text{(Eq. 39)}$$

The call drop threshold is set such that dropping a call is limited to extreme circumstances (thresholds less than 2dB are not recommended) and kept mostly as a safety measure to avoid a single user hogging the BS resources. In an actual system, calls are not dropped at the instant they fail to meet their link quality target. The system will tolerate quality degradation up to certain durations and at the same time avoid a single user to sacrifice the overall system performance by consuming all the BS resources (max. traff. chan. pow. setting). In fact, for systems that employ sufficient control of maximum traffic channel power, call drops may be avoided completely within the power control loop. Eventually, users not meeting their Ec/Ior target will be evaluated when the success rate of the system is calculated.

Once the transmit traffic channel levels are calculated, the broadcast power of each BS should accordingly be updated. If the total broadcast power of a BS turns out to be greater than its maximum allowable level, all traffic channels served by that BS should be scaled down so that the maximum BS power constraint is met. The scaling factor that should be applied to the traffic channel power levels can easily be calculated as:

$$Scaling = \frac{P_{\max} - (pilot\_frac \times P_{\max}) - (overhead\_frac \times P_{\max})}{P_{calculated} - (pilot\_frac \times P_{\max}) - (overhead\_frac \times P_{\max})} \quad \text{(Eq. 40)}$$

where:

- P_{max} is the maximum allowable BS power
- $P_{calculated}$ is the actual calculated BS broadcast power (including pilot and overhead).

Scaling is only done if $P_{calculated} > P_{max}$ and it is done only on the traffic channels; pilot and overhead power levels remain at a constant percentage of the maximum allowable BS power. For channels that go through the scaling, achieved E_c/I_{or} levels may not match the required E_c/I_{or} levels. Therefore, call drop criterion (if used) shown in equation 6 should also be checked after the scaling. The process is outlined in Figure 199.

This process describes a single iteration of the power control loop. After all the traffic channel power levels are determined and the BS levels are updated, the process should be repeated (with the new, more accurate BS broadcast levels). Convergence of the traffic channel power levels should be checked at the end of each iteration. The loop can be terminated once the traffic channel power of every simulated user in the network converges to the desired precision.

Signaling and other errors in power control are considered in the link level simulations. System level simulations do not consider additional errors and assume that each user is served with the required power level that is determined from link level data, provided that the BS has enough power to do so and the maximum traffic channel limit is not exceeded.

8.6.5 Success rate

The power control loop terminates when every BS broadcast power converges and traffic channel power level for every user is calculated. Therefore, both the BS output power and the success rate for the cell of interest (center cell in Figure 198) can be calculated. BS output power is the sum of the power in pilot, overhead and all traffic channels. Success rate is the percentage of calls that do not suffer quality degradation. The following process can be used to calculate both output metrics:

i. Power control loop is terminated (traffic power converges for every user)

ii. Final BS transmit power levels are calculated (sum of all traffic, pilot and overhead)

iii. Total BS broadcast power for the cell of interest is determined

(For each active user in the cell of interest)

iv. Final geometry is calculated based on BS power levels calculated in ii.

v. Traffic E_c/I_{or} target is determined based on geometries calculated in iv.

vi. Achieved E_c/I_{or} is calculated based on BS power levels calculated in ii.

vii. Success criterion is checked

$$\left(\frac{E_b}{N_r}\right)_{\text{achieved}} \overset{?}{\geq} \left(\frac{E_b}{N_o}\right)_{\text{target}} - \text{ Success Threshold (dB)} \qquad \text{(Eq. 41)}$$

viii. Success rate is determined for the cell of interest

Success Threshold is usually a small figure such as 0.5dB. Users who miss their E_c/I_{or} targets by more than the threshold suffer link quality degradation. Note that if call drops occurred within the power control loop, they should also be considered when success rate is determined:

$$\text{Success Rate} = \frac{\text{\#users meeting success criterion}}{\text{Total\#of active users including call drops}} \qquad \text{(Eq. 42)}$$

8.7 CDMA Uplink - simulation algorithm

The center cell site only is used to calculate the effects of interference. In spite of this fact, it is essential to consider the intra-system interference caused by other cells in the cluster for an accurate modelling of power control. The precise transmit power of all active mobile stations in the wrap-around cluster has to be calculated in the uplink power control loop.

8.7.1 Power Control

In CDMA networks, closed-loop fast transmit power control (TPC) is supported in uplink. The base station estimates the signal-to-interference ratio (C/I), measured in bit energy-to-noise density ratio E_b/N_0, and compares it to a target value (E_b/N_0_*target*). If the estimated C/I is below E_b/N_0_*target*, the base station commands the mobile station to increase the transmit power; if the measured C/I is above E_b/N_0_*target*, it commands the mobile station to lower its power. The fast transmit power control works at a frequency of f Hz (1500 Hz for WCDMA and 800 Hz in CDMA2000 1x), thus the TPC commands are transmitted at 1/f s time intervals (0.667 ms for WCDMA and 1.25 ms for CDMA2000 1x).

In reality, the fast TPC is not ideal because of issues such as

- inaccuracies in the C/I estimates;
- transmit power control signaling errors;
- delay in the transmit power control loop.

Links level simulations take these errors into account and reflect their impacts on the link quality figures in the look up tables to be input to the power control module of SEAMCAT. Therefore, we assume a simple C/I based fast closed-loop TPC of traffic channels for uplink in the following.

In the uplink, each mobile station perfectly achieves the target C/I, Eb/N0_target, during the power control loop convergence, assuming that the maximum transmit (TX) power, max_MS_Tx_Pw, is not exceeded. Those mobile stations not able to achieve Eb/N0_target after convergence of the power control loop are considered in outage.

The local-mean Signal-to-interference power ratio in the uplink, $(C/I)_{UL}$, is calculated by multiplying the received signal power S by the processing gain G, and dividing the result by the total interference power I_{total}

$$\left(\frac{C}{I}\right)_{UL} = \frac{G \cdot S}{I_{total}} \qquad \text{(Eq. 43)}$$

with

$$I_{total} = (1-\beta) \cdot I_{\text{int}\,ra} + I_{\text{int}\,er} + I_{out} + N_0 \qquad \text{(Eq. 44)}$$

I_{intra} is the intra-cell interference power, i.e. the interference generated by those mobile stations served by the same base station as the considered mobile station. I_{inter} is the inter-cell interference power from other radio cells. I_{out} is the interference power coming from the interfering system. N_0 is thermal noise (as well as spurious interference) contained in the receiver bandwidth, *W*, and b is an interference reduction factor due to the use of interference mitigation signal processing techniques in the uplink, e.g. Multi User Detection. No such interference mitigation technique is assumed in these considerations, therefore b = 0.

Assuming a mobile station power control range in the order of *MS_PC_Range* dB; the minimum TX power is therefore *max_MS_Pw_Tx – MS_PC_Range* dBm.

8.7.2 Soft and Softer Handover

The handover model proposed is a simplified soft handover. We assume that all base stations transmit with the same pilot power in downlink. Therefore, P_{L_fading} (path loss plus the shadow fading) is the only criterion for selecting the base stations belonging to the active set of a mobile station.

We assume that active set for a mobile station consists of two base stations; the base station with the strongest signal, i.e. the lowest P_{L_fading}, and the base station with the second strongest signal if its signal strength is within *Handover_Margin* dB of the strongest signal (in other words its P_{L_fading} is within *Handover_Margin* dB of the lowest P_{L_fading}).

In the case that base stations with omni-antenna are used at the cell sites, selection combining among the base stations in active set is performed and the base station with the strongest signal is selected as the serving base station of the mobile station. In the event of base stations with tri-sector antenna, similar procedure is applied, if the two sectors in the active set belong to different cell sites, else a maximal ratio combining is realized by summing the received signal powers. In the later case, the sum of received C/I values in two sectors should meet the C/I requirements specified by the link level simulation data. Because during softer handover, the mobile station is usually in the overlapping coverage area of two adjacent sectors of the base station, it is reasonable to assume that it has symmetric links to both sectors in the active set. As a consequence, each sector needs to fulfill one half of the C/I requirement.

8.7.3 Voice Activity Factor

The voice activity factor is the measure of how long the non-silence period is to the overall time for voice communication as it reflects the fact that speech users are silent or speaking. In SEAMCAT, It is assumed that all connected users are speaking constantly during a simulated event. It is therefore set to 1 (i.e. 100%).

8.7.4 System loading

The following procedures can be used for system loading during simulation and preparation of simulation outputs.

System loading

To determine the number of active mobile stations *Act_MS* in the network:

1. Set up:
    1. Average traffic load in terms of a predefined number of users per cluster: *N_UL*
    2. standard deviation of log-normal shadowing $\sigma_{shadowing}$
    3. voice activity factor *Act_Factor (fixed to 100%)*
    4. target maximum noise rise over the thermal noise in the network η_*target*
    5. target C/I (E_b/N_0_*target*) to fulfill service requirement depending on configuration and mobility (provided by link level simulations)
    6. maximum transmit power of mobile station *max_MS_Pw_Tx*
    7. power control range – *MS_PC_Rang*:
    8. In the case that the CDMA uplink is the victim link, add the received power from the interfering system to the thermal noise power
2. For each event:
    1. put down uniformly mobile stations at pseudo-random locations across the network and distribute speed among them
    2. Add a new mobile station in the set of active users in the network

-
    -
        - compute average path-loss from the mobile station to the base station of each cell
        - generate a log-normal pseudo-random value to add to each of the path losses to model shadow fading
        - perform a pseudo-random weighted coin-toss to determine voice activity, where 1 occurs with probability *Act_Factor*
        - compute required received power at the base station to meet E_b/N_0_*target*, given interference from pre-existing mobiles and other sources ($\left(\frac{C}{I}\right)_{UL}$ and I_{total})
        - compute required transmit power of the mobile station
        - adjust the required transmit powers of the all existing mobile stations perturbed by addition of the new mobile station

- continue the adjustment until the convergence of power control loop is achieved. A convergence criterion could be that the variation of two consecutive transmit powers of each mobile station is within a predefined threshold.
- compare the number of active mobile stations, *Act_MS*, with *N_UL*
  - if *Act_MS* ≥ *N_UL* terminate the addition of a new mobile station in the network
  - else measure the average noise rise over the thermal noise η and compare it with the target noise rise limit η_target
    - if η_target is reached, terminate the addition of a new mobile station in the network
    - else add a new mobile station and go to step 2b

8.7.5 Outage calculation

Two conditions are counted as outage.

1. A mobile station, which is not able to transmit the required amount of power to meet the received E_b/N_0_*target* due to maximum power limitations. This mobile is counted as part of the specified traffic load *N_UL*. However, the mobile is assumed to be transmitting no power.
2. In the case of *Act_MS* < *N_UL*, no more mobile stations can be added to the set of active users because of noise rise limits. In this event, *N_UL* - *Act_MS* outages are counted.

For each event, the number of optimised users is being re-calculated

8.7.6 CDMA UL cell selection

For the CDMA UL, there are two algorithms selectable in SEAMCAT:

Recommended algorithm when the interferer is a cellular network or affecting many cells in a network: the noise rise (which is measured per cell) is averaged over the whole network. This way, the UEs with highest power over the whole victim network are removed in order to compensate the noise rise due to external interference (Section 8.7.4).

Recommended algorithm when the interferer affects one or a few cells in a network (e.g. a strong interferer located close to a small part of the victim network): the noise rise is calculated per cell. This algorithm works as follows:

1. The cells with highest noise rise are selected.
2. Recursively, cell per cell, the UEs with highest power in the cell are removed in order to level out the network noise rise (see Annex A15.3 for further details on the algorithm)

This algorithm allows investigating per event how many cells are being affected (see Section 12.5.3).

8.8 Capacity for CDMA system

When starting a simulation involving one or more CDMA systems SEAMCAT will begin by checking if any of the CDMA systems have the “Simulate non interfered capacity” feature enabled (this is the default setting). The purpose of the “Simulate non interfered capacity” feature is to find the non interfered capacity system (i.e. how many mobiles per cell should be generated in the system before the introduction of an external interference) with the current configuration.

For each CDMA system needing to have its optimal capacity simulated the screen shown in Figure 197 and Figure 198 will appear for uplink and for downlink systems respectively.

8.8.1 CDMA Uplink capacity finding

In CDMA uplink, the capacity is found by gradually filling system with users until a certain average noise rise with the specified threshold noise rise is reached. The Noise rise is measured as the linear average of dB values – across all 19/57 base-stations. After every trial SEAMCAT calculates the average noise rise over the total number of trials and if this value is above the threshold restarts the simulation with a lower value of users per cell.

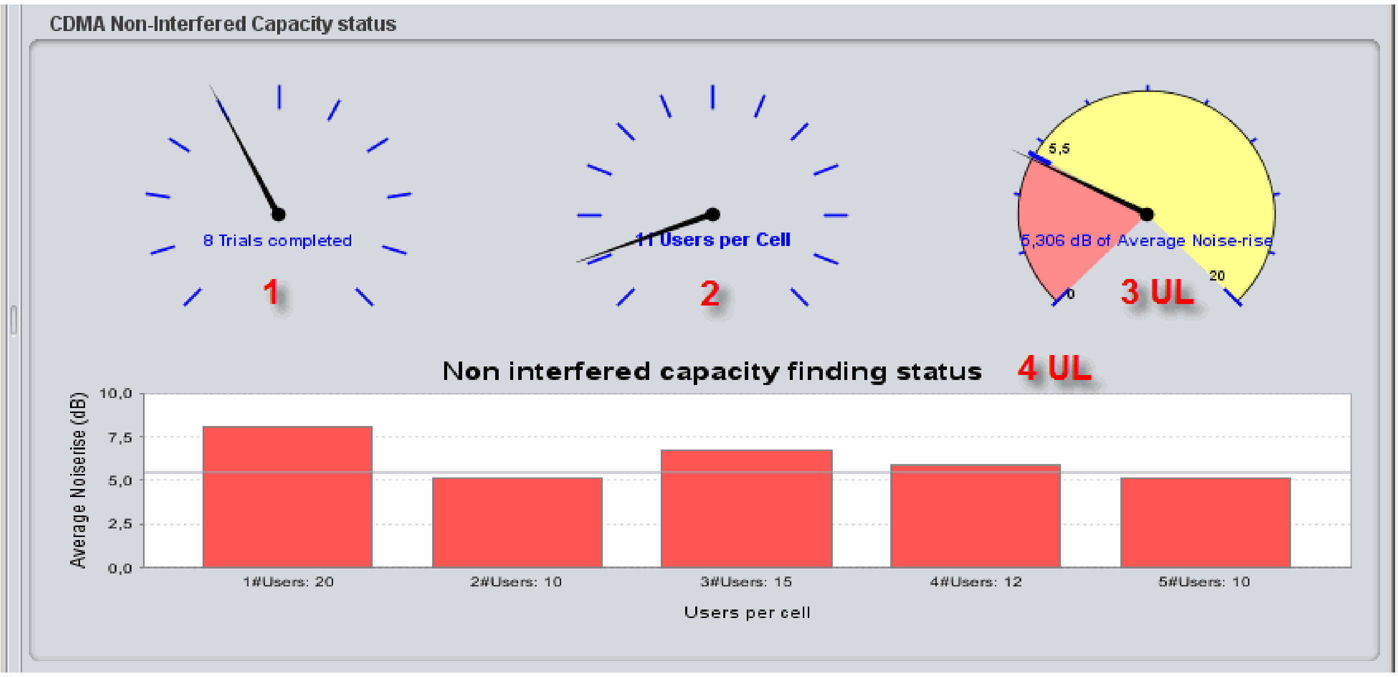

Figure 197: Uplink non-interfered capacity finding

Table 32: Elements of the uplink non-interfered capacity finding screen

ID	Description
1	This dial indicates the number of trials completed with the current capacity. This dial will range from 0 to the number of trials entered as value “4” on Figure 191.
2	This dial indicates the current number of users being tested. Range is dynamic and the dial is mainly intended as an easy visual indicator of values being tested.

3 UL	The needle shows the current value of average noise rise across the trials run. The red area indicates the noise rise is too low (too few users in the system) – the green area is the target noise rise (plus/minus) the tolerance specified. The yellow area indicates the average noise rise is too high (too many users in the system).
4 UL	The bar chart gives information on previous values tested. The Y axis is the average noise rise and the X axis is the number of users per cell being tested.

8.8.2 CDMA Downlink capacity finding

In CDMA downlink, the capacity is found by gradually filling system with users while measuring system outage. For every number of users a certain number of trials are run and then the number of “successful” trials is compared to a predefined success criterion. Only the number of trials is configurable by user – success criterion is fixed at 80%. This means that optimal capacity of a downlink system is defined as the capacity which the system is able serve without any outage in 80% of trials. This step can be quite time consuming. See ANNEX 15: to get a detailed description on how SEAMCAT determines “optimal capacity” for DL CDMA– using the values from Figure 192.

SEAMCAT tries to detect when no more trials with a tested value is needed to adjust to the next value. As an example, if 40 users per cell are being tested for 20 trials and the first 5 trials are unsuccessful it is not possible to reach 80% success rate and there is no need to simulate the last 15 trials. Regardless of the result of the last 15 trials SEAMCAT will conclude that fewer users per cell are needed. If more than 80% success rate is reached before all trials are simulated, there is no need to simulate the rest of the trials.

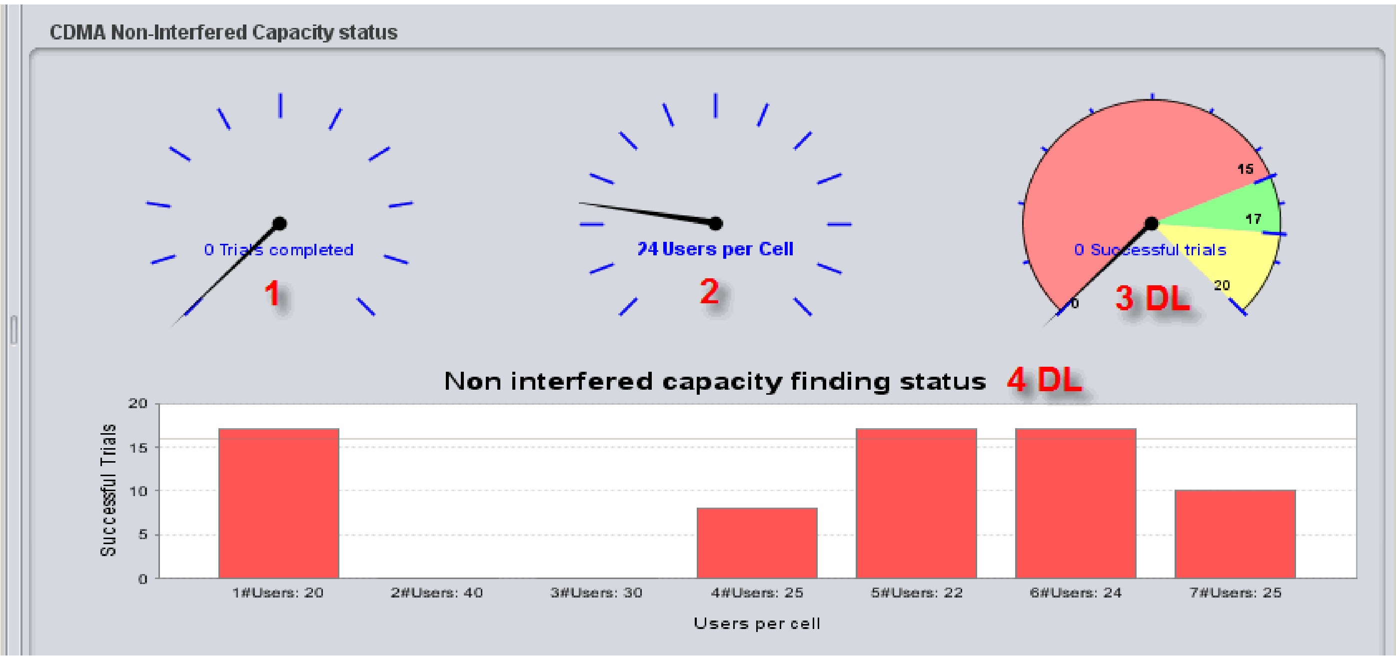

Figure 198: Downlink non-interfered capacity finding

Table 33: Elements of the downlink non-interfered capacity finding screen

ID	Description
1	This dial indicates the number of trials completed with the current capacity. This dial will range from 0 to the number of trials entered as value “4” on Figure 194. SEAMCAT does not always simulate all the trials – target is 80% success and if for example 5 out of 20 have already failed – SEAMCAT does not simulate the rest of the trials.
2	This dial indicates the current number of users being tested. Range is dynamic and the dial is mainly intended as an easy visual indicator of values being tested.
3 DL	The red area indicates that less than 80% has been reached (i.e. too many users in the system – or not all trials yet complete) – the green area is 80% (16 trials with the default settings). The yellow area indicates that more than 80% of the trials are successful (too few users in the system). SEAMCAT stops when this dial stops in the green area after all trials completed.
4 DL	The bar chart gives information on previous values tested. The Y axis is the number of successful trials and the X axis is the number of users per cell being tested.