Benchmarking of mobile network simulator, with real network data
Benchmarking of mobile network simulator, with real network data

Examensarbete utfört i Datatransmission vid Tekniska högskolan i Linköping av

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In the radio network simulator used in this thesis the radio network from a specific operator is modeled. The real network model in the simulator uses a 3-D building database, realistic site data (antenna types, feederloss, ...) and parameter setting from field. In addition traffic statistics are collected from the customer’s network for the modeled area. The traffic payload is used as input to the simulator and creates an inhomogeneous traffic distribution over the area. One of the outputs from the simulator is power per cell.

The purposes of this thesis are to identify simulation accuracy compared to reality and to evaluate and improve the simulation models and the methods used when making a simulation of a real WCDMA network with the Astrid simulator. In cellular systems the transmitted power influences the interference in the network and the interference is in turn affecting the performance. As the transmitted RBS power influences the downlink interference, it is important that the RBS power level is accurate in the simulator. Therefore the simulated RBS power is benchmarked with the real RBS power. The traffic payload from the real network is used as input into the simulator. Based on the traffic payload the simulator generates RBS power as output. The simulated RBS power is then compared with the measured RBS power.

It has been found that the standard parameter setting in the simulator gives in average about 1 W too much RBS power used in the simulations compared to reality. After investigation it was detected that two reasons for the overestimated power are that the common control channels (CCCH) power setting and the feederloss is not set to the same values as in field. With the new CCCH settings and feederloss the simulator overestimates the RBS power with 0.5 W in average. As the traffic today is relatively low the parameters that only affect the dedicated channels can only be used to make small adjustments of the simulated RBS power.
Abstract

In the radio network simulator used in this thesis the radio network from a specific operator is modeled. The real network model in the simulator uses, a 3-D building database, realistic site data (antenna types, feederloss, ...) and parameter setting from field. In addition traffic statistics are collected from the customer’s network for the modeled area. The traffic payload is used as input to the simulator and creates an inhomogeneous traffic distribution over the area. One of the outputs from the simulator is power per cell.

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<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>3G</td>
<td>3rd Generation Mobile Communication System</td>
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<td>3GPP</td>
<td>3rd Generation Partnership Project</td>
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<td>AMPS</td>
<td>Advanced Mobile Phone Service</td>
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<td>ARQ</td>
<td>Automatic Repeat Request</td>
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<td>BCH</td>
<td>Broadcast Channel</td>
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<td>BLER</td>
<td>Block Error Rate</td>
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<td>CCCH</td>
<td>Common Control Channel</td>
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<tr>
<td>CCDF</td>
<td>Complementary Cumulative Distribution Function</td>
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<td>CCH</td>
<td>Control Channels</td>
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<tr>
<td>CDMA</td>
<td>Code Division Multiple Access</td>
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<tr>
<td>CN</td>
<td>Core Network</td>
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<td>CPICH</td>
<td>Common Pilot Channel</td>
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<tr>
<td>DCH</td>
<td>Data Channel</td>
</tr>
<tr>
<td>DS-CDMA</td>
<td>Direct Sequence - Code Division Multiple Access</td>
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<tr>
<td>DCCH</td>
<td>Dedicated Control Channel</td>
</tr>
<tr>
<td>DTCH</td>
<td>Dedicated Traffic Channel</td>
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<tr>
<td>EUL</td>
<td>Enhanced Uplink</td>
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<tr>
<td>FDMA</td>
<td>Frequency Division Multiple Access</td>
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<tr>
<td>GSM</td>
<td>Global System for Mobile Communication</td>
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<tr>
<td>GIS</td>
<td>Geographical Information System</td>
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<tr>
<td>HARQ</td>
<td>Hybrid Automatic Repeat Request</td>
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<tr>
<td>HSDPA</td>
<td>High Speed Downlink Packet Access</td>
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<tr>
<td>ITU</td>
<td>International Telecommunication Union</td>
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<tr>
<td>kbps</td>
<td>kilo bits per second</td>
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<td>MAC</td>
<td>Medium Access Control</td>
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<tr>
<td>MBMS</td>
<td>Multimedia Broadcast/Multicast Services</td>
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<tr>
<td>Mbps</td>
<td>Mega bits per second</td>
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<td>Mcps</td>
<td>Mega chips per second</td>
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<tr>
<td>NMT</td>
<td>Nordic Mobile Telephony</td>
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<td>PedA</td>
<td>Pedestrian A</td>
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<td>PS</td>
<td>Packet Switched</td>
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<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>PSCH</td>
<td>Primary Synchronization Channel</td>
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<td>QAM</td>
<td>Quadrature Amplitude Modulation</td>
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<tr>
<td>QPSK</td>
<td>Quadrature Phase Shift Keying</td>
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<td>R99</td>
<td>3GPP Release 99 traffic</td>
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<td>RA</td>
<td>Rural Area</td>
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<td>RBS</td>
<td>Radio Base Station</td>
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<tr>
<td>RLC</td>
<td>Radio Link Control</td>
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<tr>
<td>RNC</td>
<td>Radio Network Controller</td>
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<td>RRC</td>
<td>Radio Resource Control</td>
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<tr>
<td>SIR</td>
<td>Signal to Interference Ratio</td>
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<td>SHO</td>
<td>Soft Handover</td>
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<tr>
<td>SSCH</td>
<td>Secondary Synchronization Channel</td>
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<tr>
<td>TCP</td>
<td>TEMS Cell Planner</td>
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<tr>
<td>TCPU</td>
<td>TEMS Cell Planner Universal</td>
</tr>
<tr>
<td>TD-CDMA</td>
<td>Time Division - Code Division Multiple Access</td>
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<td>TDMA</td>
<td>Time Division Multiple Access</td>
</tr>
<tr>
<td>TMA</td>
<td>Tower Mounted Amplifier</td>
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<tr>
<td>TTI</td>
<td>Transmission Time Interval</td>
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<tr>
<td>TU</td>
<td>Typical Urban</td>
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<tr>
<td>UE</td>
<td>User Equipment</td>
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<tr>
<td>UMTS</td>
<td>Universal Mobile Telecommunication System</td>
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<tr>
<td>UTRAN</td>
<td>UMTS Terrestrial Radio Access Network</td>
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<tr>
<td>WCDMA</td>
<td>Wideband Code Division Multiple Access</td>
</tr>
</tbody>
</table>
## Contents

1 Introduction .......................................................... 1
   1.1 Background .................................................. 1
   1.2 Problem statement .......................................... 1
   1.3 Thesis scope ................................................. 2
   1.4 Thesis goal ................................................ 2
   1.5 Method ...................................................... 2
   1.6 Thesis outline ............................................. 3

2 Theoretical background ........................................... 5
   2.1 History ..................................................... 5
   2.2 UMTS ........................................................ 5
      2.2.1 WCDMA .................................................. 7

3 Network model ..................................................... 15
   3.1 Simulation tools ............................................. 15
      3.1.1 TEMS Cell Planner Universal ......................... 16
      3.1.2 Elm ..................................................... 16
      3.1.3 Astrid .................................................. 17
   3.2 Models of signal strengths and interference ................. 18
      3.2.1 Pathloss from top of RBS cabinet to RBS antenna ..... 18
      3.2.2 Air pathloss model .................................... 19
      3.2.3 Fading .................................................. 20
      3.2.4 Interference ........................................... 22
   3.3 Field statistics ............................................. 24
      3.3.1 kbits to Erlang conversion .............................. 25
      3.3.2 SHO reduction .......................................... 26
      3.3.3 Service distribution calculation ....................... 26
      3.3.4 Indoor/outdoor calculations ......................... 27
      3.3.5 Average RBS power data ............................... 27

4 Benchmarking between evenly distributed traffic and distribution from real network data .................................... 29
   4.1 Approach ..................................................... 29
   4.2 Simulated network ......................................... 30
   4.3 General simulation configuration ............................ 30
Chapter 1

Introduction

1.1 Background

Research work on WCDMA, which is an air interface used the third generation mobile system (3G), started in early 1990s and in the end of 1999 the first full specification (called 3GPP Release 99) of WCDMA as a 3G technique was completed. Since the Release 99 specification new features have been developed, such as High Speed Downlink Packet Access (HSDPA) and Enhanced Uplink (EUL), to increase the capacity of the network.

Mobile network vendors like Ericsson simulate networks to predict how the new features will affect the network, for example coverage and download speed. Ericsson is using several simulators to be able to foretell how the new feature affects the network and to evaluate the performance of the new feature. One of the simulators is called Astrid, which can simulate real networks by using two other tools, TEMS Cell Planner Universal and Elin. To secure the real network simulators accuracy, the simulator can be benchmarked with real network measurements.

1.2 Problem statement

When simulating a real network a model of the reality can be built up by using the information about the network. In the simulator setup used in this thesis the network model includes such things as geographical information and mathematical models. A mathematical model is an attempt to describe a part of reality. In all of these models there are simplifications, assumptions and estimations. When it comes to complex simulators, such as Astrid, several models are put together. These models have a lot of parameters that can be set to match reality in a specific environment. The problem is to make the mathematical models and assumptions as accurate as possible. Faults in the models may propagates throughout all the simulations.

From the real network there are measurements of the performance and characteristics of the network, for example the load of the network. These measurements
or field statistics are time stamped and gives a detailed picture of the performance of the real network.

Some of these measurements from the real network can be used as input into the simulator to get a better ground to start the simulation upon. As these measurements are time stamped the simulator can therefore use the field statistics to simulate a certain time. The output from the simulator can then be compared with the field statistics to give a picture of the accuracy of the simulated network.

1.3 Thesis scope

This thesis project can be divided in two parts. Both part will only focus on the downlink.

The gain in simulation accuracy when using traffic distribution from field compared to even traffic distribution over the area is investigated in the first part. The second part of this project is to benchmark Astrid with real network data. The field statistics includes both the traffic payload and the power of the Radio Base Station (RBS). In this study the traffic payload will be the input into Astrid and then the simulated RBS power will be compared with the RBS power from the field statistics. The simulator will then be tuned in by changing parameters and assumptions in the model of the real network.

1.4 Thesis goal

The two first levels in the chapter "model improvements: traffic from field (in simulators)" in the "Target specification 2007" (EAB/PT-06:0308) is as below. This is an internal Ericsson goal for the FTJ/G Radio network scenario project.

1. Evaluate the accuracy and added value of including "real network statistics" in to the simulators (Release 99-traffic based, described in section 2.2.1)

2. Evaluate and if needed improve the method used for adding "field statistics", adjust simulator models and parameters settings to align the simulator results with the real network data. (Release 99-traffic based)

The goal of this thesis is to fulfill these two levels for the Astrid simulator. By completion of the two parts presented in 1.3 these goals will be fulfilled.

1.5 Method

The approach of the first part of the thesis is to complete simulations with the traffic distribution from field statistics and simulations with evenly distributed traffic. The results from these simulations will then be compared to see if there is a gain in the simulation accuracy with input from field statistics.

In the second part all simulations will be with the traffic payload from the field statistics as input into the simulator. A simulation with the standard parameter
setting will be completed. The output from the simulator will then be compared with field statistics. From the comparison some approaches will be presented and implemented to improve the simulation model.

1.6 Thesis outline

A theoretical background of the WCDMA is given in chapter 2 together with a brief description of HSDPA. Chapter 3 explains how a simulation is performed with detailed descriptions of the field statistics used and some models used in the simulation. The benchmarking between evenly distributed traffic and traffic distribution from real network data is presented in chapter 4. The benchmarking of the simulator with a real network is found in chapter 5. Other findings are briefly mentioned in chapter 6. In chapter 7 there is an overall conclusion. Finally there are some recommended further work in chapter 8.
Chapter 2

Theoretical background

This chapter explains the theoretical background of the WCDMA.

2.1 History

In the 1980’s the first generation mobile systems were introduced. There were analog networks for speech services. Several standards were used one of them was Nordic Mobile Telephones, NMT, which were using the Frequency Division Multiple Access (FDMA). In FDMA each user has a portion of the total bandwidth during the entire transmission as shown to the left in figure 2.1.

Second generation mobile system, which uses digital transmission, were introduced in the late 1980’s. These networks covered speech and low bit rate data transmission. One example of second generation mobile networks is Global System for Mobile Communication, GSM, which uses a combination of Time Division Multiple Access (TDMA) and FDMA with multiple frequency channels with 8 time slots each. In TDMA each user has its own time slot to transmit as shown in the middle of figure 2.1.

The third generation mobile systems, 3G, support a greater number of users with higher rates then the second generation mobile systems. The goals with 3G are high-quality multimedia and global roaming. In Europe, the 3G air interface is Wideband Code Division Multiple Access (WCDMA). In CDMA systems all users use the total bandwidth of the channel all the time and the users are separated by unique codes. [3] [13]

2.2 UMTS

The Universal Mobile Telecommunication System, UMTS, is often called third generation mobile radio system, 3G. The standards for UMTS have been specified by third-generation partnership project, 3GPP, which is a joint standardization project for Europe, Korea, Japan, USA and China. Members of the 3GPP are companies such as mobile telephony system manufactures and operators.
UMTS networks are at a high-level system point of view divided in three sub-systems, Core Network (CN), UMTS Terrestrial Radio Access Network (UTRAN) and User Equipment (UE), see figure 2.2. The CN routes traffic to external networks. In the UTRAN each Radio Network Controller (RNC) communicates with the CN, controls several RBS (also known as Node B) and is responsible for the control of the radio resource of UTRAN. The main function of the RBS is to perform the radio access in a number of cells (also called sectors), which is a geographical area.

One of the radio access techniques used in UMTS is WCDMA, which is used in for example Europe.
2.2.1 WCDMA

WCDMA uses the direct sequence (DS)-CDMA technique as multiple access method. In the DS-CDMA each user is assigned with a unique code sequence (spreading code). The transmitter multiplies each symbol by the spreading code and the receiver multiplies the received signal with the same spreading code to get the original symbol, see figure 2.3.

![Figure 2.3. Principal of spreading and despreading data](image)

The bits in the spreading code are called chips, in WCDMA the chip rate can be up to 3.84 Mcps. The chip rate is significantly higher than the bit rate. When the transmitter multiplies each bit with the spreading code the power spectral density of the signal is spread out over the frequency spectrum. This is illustrated in figure 2.4. In WCDMA the signal is spread out and transmitted on the 5 MHz signal carrier.

![Figure 2.4. Non-Spread signal and spread signal](image)

In WCDMA all users spread signal is transmitted at the same time, but with
unique codes. The total transmitted signal can be illustrated as in the lower left diagram in figure [2.5]. When the receiver uses the same code as the transmitter the original signal will despread but the other transmitted signals will remain spread over a large bandwidth, as in the lower right diagram in figure [2.5]. As long as the codes are orthogonal to each other the despread signal will despread the wanted signal. In reality the signals are distorted during the transmission due to fading and therefore the receiver can not only despread the wanted signal, some disturbance from other signals are also despread.

![Spreading and despooling](image)

**Figure 2.5.** Spreading and despreading

After the despreading the receiver filters the signal to get the transmitted signal but the other users spread signal is experienced as noise or interference. This means, if the surrounding power level is too high the wanted signal can not be detected. To avoid this, WCDMA uses a power control and it is one of the key functions in WCDMA. If the interference level increases the power control regulate the transmitter to increase the transmission power. This means that the interference level in the system has a direct influence on the power used and vice versa. As the wanted signal is despread and the other signals are remain spread, the despreading gives a gain compared to other signal. This gain is called the processing gain, $G_p$, and can be calculated by using formula [2.1]. Where $R_c$ the chip rate and the $R_b$ is the bit rate.

$$G_p = 10 \cdot \log \left( \frac{R_c}{R_b} \right) \text{ [dB]}$$

(2.1)

In TDMA and FDMA systems adjacent cells do not use the same frequencies, which leads to less interference from other cells. In CDMA systems, on the other
hand, cells can have the same frequency in each cell, frequency reuse is 1. The main reason for this is that the signal power is spread out over the frequency band and therefore it causes less interference.

When a UE moves from one cell to another the UE has to be handed over to another RBS or sector of a RBS. In TDMA and FDMA system, where adjacent cells do not use the same frequency, the UE must drop the connection before a new radio link can be set up. This is referred to as hard handover and causes a short interruption in the connection. When the frequency reuse is 1, as in WCDMA it is possible to use Soft Handover (SHO). During soft handover the UE is connected to more than one RBS or RBS sectors at the same time. As each RBS or RBS sector performs power control of the UE in SHO, the SHO reduces the interference caused by the UE.

In 1999 the 3GPP released its first version of the WCDMA system standardization, called Release 99 (R99), the downlink traffic specified in the R99 was Circuit Switched (CS) 12.2 kbps and 64 kbps and Packet Switched (PS) 64 kbps, 128 kbps and 384 kbps. In later releases other traffics have been specified, for example High Speed Downlink Access (HSDPA) and Enhanced Uplink (EUL), which allow higher bit rates. [8], [13]

**Handover**

As written above, WCDMA uses soft handover when a UE moves from one cell to another but there is hard handover in WCDMA as well. In some cells, where there are a lot of users, there can be more than one frequency carrier. When a UE is handed over to a new frequency hard handover is used, called inter-frequency handover. When a UE moves from an area with WCDMA coverage to another area without WCDMA coverage, for example GSM coverage, hard handover is used, called inter-system handover.

Soft handover can be divided into two parts, soft and softer handover. During softer handover the UE is in the overlapping cell coverage area of two or three adjacent sectors of a RBS. In soft handover the UE is connected to two or more RBS simultaneously. The difference between softer and soft handover is illustrated in figure 2.6. Softer and soft handover is in this thesis normally called only soft handover, SHO.

The RBSs or RBS sectors that are connected to a UE are called the active set of the UE. If a UE is not in soft handover the active set is only one RBS sector.

In figure 2.7 an illustration of a soft/softer mechanism is shown. An additional radio link is connected to the UE when the signal strength is within an add margin, which can be set by the network operator. The UE is then connected to two RBS or RBS sectors until one of the radio link’s signal strength gets below a drop threshold, which is also set by the network operator.

A UE is during SHO assigned to several spreading codes one for each RBS or RBS sector in the active set. The signals from the RBS or RBS sectors in the active set are received by the UE in SHO as additional multipath components. The only difference from multipath reception is that the fingers in the RAKE receiver in the UE need to generate the respective spreading code for each sector or RBS.
Theoretical background

Figure 2.6. Softer and soft handover

Figure 2.7. Soft handover
RAKE receiver separates the individual signals from the multipath reception. The signals from cells that are not in the active set are, as before, seen as interference.

Two main advantages with softer and soft handover are that there is smoother transmission with no momentary interruption during handover and it reduces the interference in the system. One reason to the reduction in interference with SHO is that there are more than one RBS that controls the power of the UE. Disadvantages of softer and soft handover are that it requires a more complex implementation than hard handover and during the handover more network resources are used, such as power resource and spreading code resource.

Power control

As mention before the power control is perhaps the most important function in WCDMA and its main purpose is to reduce the interference in the system. A single overpowered UE could block a whole cell and reduce the capacity in adjacent cells. If one UE is close to the RBS and another UE is on the cell edge, the RBS would only "hear" the closest UE, if there is no power control mechanism.

In WCDMA there are three types of power control loops, fast closed loop-power control, outer loop-power control and the open loop-power control.

The fast power control loop controls the power both for the uplink and downlink and it is updated 1500 time per second. This is faster than a fast fading could possibly happen. The fast power control loop estimates the received Signal to Interference Ratio (SIR) and regulates the SIR towards a SIR target.

The SIR target is controlled by the outer loop power control and it is regulated to achieve a specific blocking error rate (BLER) target. If the SIR target is too high the transmitter uses to much power and there for causes more interference than necessary and if it is too low the receiver will not be able to detect the signal with an accurate BLER. The required SIR depends for example on the multipath profile and the speed of the UE.

The open loop-power control is used to provide an initial power setting in the beginning of a connection of a UE.

Lower protocol layers

When a UE and a RNC or RBS communicates it is necessary that the details of the communication is well defined in protocols. These protocols can be distributed across hierarchically arranged layers, see figure 2.8. The three lowest layers in WCDMA are in this thesis the most interesting and they are called Radio Resource Control layer (RRC), Medium Access Control and Radio Link Control layer (MAC and RLC) and the Physical layer (PHY).

The PHY layer, which is the lowest layer (Layer 1), is responsible for transmitting data over the physical channels including modulation and spreading.

The MAC and RLC layer (Layer 2) is responsible for the decision making with regards to such things as the data speed and channel coding. It delivers data block to the PHY layer over the transport channels.

The RRC layer (Layer 3) is the third layer and responsible for radio resource control including broadcast system information and management of radio connec-
Theoretical background

The channel between the RRC layer and the MAC and RLC layer is called logical channel. In Appendix H there is more information about logical, transport and physical channels.

In each layer extra bits are added, e.g. headers. This means, when bit rates are discussed it has to be defined on what layer and if it is before or after the headers are added.

Channels

In the channels between these three layers and the channels between the transmitter and receiver are mainly two types of channels, dedicated channels and common channels. Dedicated channels are specific for each user while the common channels are shared by all users.

The channel can also be divided in data channels (DCH) and control channels (CCH). The control channels controls the connection and the DCH carries the actual data. The CCH consist of both dedicated and common channels but the DCH consist of only dedicated channels.

The main common control channel (CCCH) is the Common Pilot Channel (CPICH). The CPICH power received by the UE specifies the signal strength from the cell. This means, if the power setting of the CPICH is changed the coverage of the cell will be changed. The power setting of the CPICH is normally 10% of the RBS power but to optimize a mobile network the power setting of the CPICH can be tuned in. Other common control channels are set relatively to the CPICH. Hence if the CPICH power is decreased the power used by the other CCCHs are also decreased.
High Speed Downlink Packet Access - HSDPA

As the demand of higher speed in the mobile network increases a greater capacity will be needed in the WCDMA system. Therefore the HSDPA was introduced in the WCDMA 3GPP’s release 5. HSDPA will provide peak rates of up to 14 Mbps and 2-3 times greater capacity. HSDPA is based on five main technologies, shared-channel transmission, higher-order modulation, link adaptation, radio-channel-dependent scheduling and hybrid ARQ with soft combining.

In HSDPA the users use a shared channel called high speed downlink shared channel (HS-DSCH), which is the actual channel that carries the user data in HSDPA. The shared-channel transmission idea is that the downlink is dynamically shared between packet-data users. The downlink is allocated to a UE only when it actually uses the downlink. In HSDPA Radio-channel-dependent scheduling decides which UE that should use the shared transmission channel. The trade off is between cell throughput and fairness against users. In [7] some different decision making algorithms are described. To get as good throughput as possible the HS-DSCH can, if needed, use all the available power in the RBS after serving R99 traffic as shown in [2.9] Hence HSDPA has dynamical power allocation.

![Figure 2.9. HS-DSCH with dynamic power allocation](image)

In R99 traffic power control is used for compensating for variations in the downlink radio channel, this ensures similar service quality to all UEs. This is not the most efficient way from an overall system-throughput point of view. The overall throughput will be better, if the transmission power is kept constant and UEs with good channel conditions gets higher bit rates than the UEs with bad
channel conditions, see figure 2.10. This is often referred to as link adaptation or rate adaptation and is used in HSDPA.

![Figure 2.10. Rate adaptation](image)

The scheduling and link adaptation decision is made every Transmission Time Interval (TTI), which is in HSDPA 2 ms. With a relatively short TTI the adaption can track rapid variation in the radio channels. To increase the throughput even more, HSDPA supports both 16-Quadrature Amplitude Modulation (16QAM) and Quadrature Phase Shift Keying (QPSK) modulation. 16QAM carries double as many bits per symbol than QPSK but 16QAM is less robust than QPSK. Therefore the 16QAM is only used when the radio-channel conditions so allow. These modulations for HSDPA where standardize in 3GPP’s Release 5, in later releases the HSDPA will also supports 64QAM.

With Hybrid Automatic Repeat Request (HARQ) the UE stores a failed transmission and combine it with the retransmission to increase the probability of successful decoding. Both R99 and HSDPA use HARQ but the main difference between HSDPA and R99 is that the HARQ in HSDPA is implemented on the MAC layer and the in R99 it is implemented in on the RLC layer, which is above the MAC layer in the protocol stack. This leads to a lower retransmission delay for HSDPA than for R99. [4] [9] [14] [15]
Chapter 3

Network model

This chapter describes how the network is modeled. It starts with the tools used, continues with a description of some simulation models and finishes with an explanation of the field statistics handling.

3.1 Simulation tools

There are three tools used in these simulations, TEMS Cell Planner Universal (TCPU or TCP), Elin and Astrid. TCP has information about the network, such as high detailed maps, building database and site data. From the information about the network TCP calculates for example pathloss prediction. Elin is used as an interface between TCPU and Astrid, see figure 3.1.

![Simulation setup](image)

**Figure 3.1.** Simulation setup
Both Astrid and TCP can simulate mobile networks. Astrid is used because it handles future network features that TCP cannot handle at the moment. TCP, Elin and Astrid is described in more detail in sections 3.1.1, 3.1.2 and 3.1.3 respectively.

### 3.1.1 TEMS Cell Planner Universal

TEMs Cell Planner Universal is a commercially available product which is used for designing, implementing and optimizing mobile radio networks. In these simulations TCP is used together with Elin for creating simulation project in Astrid. In TCP there is information about the network like site data, maps and building database. The site data includes for example:

- Location of RBS
- Antenna height, position direction
- Antenna down tilt
- Antenna types
- Feederloss
- RBS maximum power
- Tower mounted amplifier (TMA) information

TCP uses a geographical information system (GIS) called GeoBox. The GIS database stores information about the geographical data, the map resolution and coordinates reference system.

In TCP high resolution maps, 5m-5m and building database is setup to model the real environment. The map resolution area is called a bin and TCP calculates a pathloss to each bin, see section 3.2.2 for a more detailed description of the pathloss calculations. When the real network is modeled in TCP the following data is exported to Astrid via the Elin interface.

- The pathloss prediction from each RBS to each bin
- Network structure with information about locations of the RBS
- Power settings
- Maps

### 3.1.2 Elin

To be able to use the output data from TCP in Astrid the data has to be conformed. This is done by Elin which is a matlab based application. Elin creates an Astrid project in matlab format based on the output data from TCP.
3.1 Simulation tools

3.1.3 Astrid

Astrid is a Matlab-based static simulator, which uses Monte Carlo simulations to gather statistics. In a static simulator, there is no time aspect. Hence the number of users is constant and the users do not move.

A Monte Carlo simulation is an iterative method that uses random input variables to evaluate a deterministic model. For each Monte Carlo iteration, the users are randomly spread out over the area. Results from the iterations, or snapshots, can be averaged to get more statistically valid results. If there is low traffic density, many snapshots are needed, and if there is high traffic density, fewer snapshots can be used to get a statistically valid result.

It is not possible to spread out the users in three dimensions, in this version of Astrid. Instead, all UEs are assumed to be at the same height level, 1.5 m above ground level, but in different geographical positions for each iteration.

Astrid models protocol layers up to the RLC layer. This means that the HS-DPA bit rates in this thesis are at the RLC layer, including the RLC layer header bits.

When simulating a limited area, the cells at the border of the area do not get accurate inter-cell interference. One solution to this problem is to apply wrap around. Wrap around is when copies of the simulation area are placed around the original simulated area. This means that cells at the edge of the simulation area are interfered by the cells on the other side of the simulated area. When simulating real networks, as in this thesis work, where the cells have specific position on the map, wrap around cannot be applied.

Since wrap around is not possible, a smaller area inside the simulated area is identified as the analysis area (also called the active area) and the remaining part of the simulated area is used to get a proper interference level. In the postprocessing of the result, only the active area is filtered out and used in the evaluation.

A bin is a geographical position with the size of the map resolution, 5m×5m. The cell that has the strongest signal in a bin is called the best server cell for that bin.

A cell is active as long as it is best server in any bin inside the "cluster 2" area. Cluster 2 is an Ericsson internal name of an area in the simulation area.

Traffic payload is only distributed over the active cells (or active area). The remaining cells are considered as supportive cells and generate interference. These cells are not used in the evaluation of the result. The supportive cells use a fixed power, which is set relative to the traffic in the active cells.

Before making a simulation in Astrid, some traffic parameters have to be set. These parameters are:

- Traffic density - should be in Erlang/km².

- Indoor/outdoor distribution - how big part of the traffic should be indoor/outdoor.

- Service distribution - what services should be simulated and with what load.

This version of Astrid can simulate the following traffic.
• R99 - Speech, Video and PS traffic defined in 3GPP Release 99, here called R99 traffic, Astrid adds SHO traffic for the UEs in SHO.

• HSDPA - The HSDPA traffic load is set by the HSDPA utilization, explained in Appendix E.

• EUL - Enhanced Uplink

• MBMS - Multimedia Broadcast/Multicast Services

This thesis only focuses on R99 and HSDPA traffic. [6]

3.2 Models of signal strengths and interference

This section describes how the signal’s propagation from the RBS to the UE (downlink) is modeled in this simulation setup. An overview of the signal’s propagation from the RBS to the UE is illustrated in figure 3.2. The signal’s propagation from the RBS to the UE can be divided in three parts. The first part is from the top of the RBS cabinet to the RBS antenna, described in section 3.2.1. The second part is from the RBS antenna to the UE and it is called the pathloss (or air pathloss), described in section 3.2.2. The third part is the fading due to time variations in the environment. The fading is described in section 3.2.3.

Figure 3.2. RBS to UE

3.2.1 Pathloss from top of RBS cabinet to RBS antenna

The signal will be affected by the following during the transportation from the RBS to the output side of the RBS antenna.
3.2 Models of signal strengths and interference

- Feederloss - due to attenuation in the cable, depends on the length and cable type.
- TMA - Tower mounted amplifier, gain in uplink and loss in downlink.
- Antenna gain - Depends on the type of antenna.

3.2.2 Air pathloss model

For simulations of hexagon networks a commonly used air pathloss model is the Okumura-Hata model, which uses the antenna heights of the receiver and transmitter, the environment type and the distance to calculate the pathloss between two points.

This simulation setup uses pathloss model called the urban propagation model instead. The urban propagation model consists of three models, a half-screen model, a recursive micro cell model and a building penetration model. The building penetration model is used for indoor propagation. The other two models are used for outdoor propagation.

The pathloss to a bin is calculated by both the outdoor propagation models and the model with lowest pathloss is chosen. If it is an indoor bin the indoor propagation model is added on the outdoor propagation model. This is illustrated in figure 3.3.

![Diagram of propagation model]

Figure 3.3. Propagation model

**Outdoor propagation model**

In an urban area there are two main paths for the signal to reach the receiver, over rooftops and along streets.

The half-screen model calculates the propagation over rooftops. From the information about the environment and obstacles between the transmitter and the receiver, the half-screen model modulates the obstacles with screens. The screens height is correlated to the obstacles height. The pathloss is then calculated by using a multiple knife-edge approach. Information about knife-edge calculations can be found in [12].

The recursive micro cell model calculates the pathloss between the buildings and along the streets. The pathloss is calculated by determining the illusory distance from the RBS antenna to a bin. Figure 3.4 illustrates an example of different propagation paths along the streets.
Indoor propagation model

In our simulation setup users are placed indoor and outdoor. For indoor positions the pathloss are punished with a pathloss from the indoor propagation model. The model for the indoor pathloss is a linear function, as shown in equation 3.1. Were $L_{in}$ [dB] is the pathloss for the indoor user. $L_{out}$ [dB] is the pathloss at a point just outside the external wall. $W$ [dB] is the penetration loss for the external wall, called the through wall constant or wall loss. $s$ [m] is the distance from the UE to the external wall. $\beta$ [dB/m] is the building penetration slope.

$$L_{in} = L_{out} + W + s \cdot \beta$$

(3.1)

3.2.3 Fading

In addition to the distance dependent pathloss, described so far, the transmitted signal will be attenuated by objects blocking the line of sight. This is called fading and it is the third component in the signal propagation from RBS to UE. Two types of fading are normally modeled in 3G wireless systems, the shadow fading and the multipath fading.

The shadow fading, also called slow fading, is a result of shadowing/attenuation from building, mountains, hills and other objects. The shadow fading is often modeled as a log-normal distribution with a mean set to 0 dB and a standard deviation range from 5-12 dB [17]. Since shadow fading depends on obstacles in the line of sight path it is spatially correlated and the decorrelation distance is in tenth of meters.

The urban propagation model takes obstacles into account when it calculates the distance dependent loss in every bin, every 5x5 meter. Since the shadow fading varies slowly over the geographical distance no additional shadow fading component needs to be modeled to capture the variations within the bins. If the bin sizes had been larger a log-normal shadow fading component would be needed.
When it comes to the multipath fading, it depends on objects in the line of site path of the signal but now the fading is due to a number of reflections on local surfaces, like part of buildings or smaller objects. A wireless system can be thought of as a collection of rays taking different paths between the transmitter and receiver, giving raise to so called multipath fading.

The received signal will be a sum of copies of the transmitted signal. The copies of the transmitted signal reaches the receiver at different time, with different pathloss and phase due to varying distance and reflections. This leads to that signals from different users are not orthogonal to each other at the receiver. The multiple components of the signal may generate constructive or destructive interference. Small movements, in order of half wavelengths, can change the constructive interference into destructive interference or vice versa. Therefore the decorrelation distance for multipath fading is order of half wavelength.

When the multipath fading is modeled a standardized so called channel model is used to describe how the channel will transform the transmitted signal. In this thesis three channel models will be used, Typical Urban (TU), Rural Area (RA) and Pedestrian A (PedA). TU and RA is standardized by 3GPP and PedA by the International Telecommunication Union (ITU). The speed of the UE influence the fast fading and therefore the TU and RA is dependent of the speed. To denote the speed that the channel model represents the speed is added in the end of the name, for example TU3, which means 3 km/h.

![Figure 3.5. Channel model 3GPP Typical Urban, multipath intensity profile](image)

3GPP Typical Urban 3 or TU3 is a channel model for urban environment. In figure 3.5 the multipath intensity profile is shown. [2]
In figures 3.6 and 3.7 the multipath intensity profile for Pedestrian A (PedA) and Rural Area (RA) is shown. The RA and PedA has fewer taps then the TU, and this leads to that the TU transforms the signal more than RA and PedA. Even if the multipath intensity profile for PedA and RA is not equal to each other they are practically similar in a performance estimation point of view, according to [5].

![Figure 3.6. Channel model Pedestrian A, multipath intensity profile](image)

### 3.2.4 Interference

As described in section 2.2.1 a target for the outer loop power control in WCDMA is the SIR target. The SIR target regulates how strong the signal should be when it reaches the receiver. The power of the signal at the receiver depends on the transmitted power and the pathloss. Hence, the interference depends on the pathloss and the power used by other users.

The SIR target is defined as the energy per bit divided by the interference energy, $\frac{E_b}{I_0}$, after the RAKE-combining in the UE. RAKE-combining is when the receiver combines the multipath signals, which reduce the interference. As different UEs are not equally good on RAKE combining the $E_b/I_0$ value depends on the UE.

The $E_c/N_0$ is a measure of the coverage in the WCDMA system and is therefore used when planning a network. In contrast to $E_b/I_0$ the $E_c/N_0$ is defined at the antenna in the UE, before the RAKE-combining. $E_c$ is the energy of the signal
3.2 Models of signal strengths and interference

The relation between $E_b$ and $E_c$ is described by equation \ref{eq:3.2} where $G_p$ is the processing gain.

$$E_c = E_b - G_p$$

\hspace{1cm} (3.2)

The $E_c/N_0$ and the $E_b/I_0$ or $E_c/I_0$ is modeled in the simulator as in equation \ref{eq:3.3} and \ref{eq:3.4}.

$$\frac{E_c}{N_0} = \frac{E_c}{I_{or} + I_{oc}} = \frac{E_c}{I_{or}(1 + \frac{I_{oc}}{I_{or}})} = \frac{E_c}{I_{or}} \cdot \frac{1}{1 + G^{-1}}$$

\hspace{1cm} (3.3)

$$\frac{E_c}{I_0} = \frac{E_c}{\alpha \cdot I_{or} + I_{oc}} = \frac{E_c}{I_{or}(\alpha + \frac{I_{oc}}{I_{or}})} = \frac{E_c}{I_{or}} \cdot \frac{1}{\alpha + G^{-1}}$$

\hspace{1cm} (3.4)

As shown in figure \ref{fig:3.8} the $I_{or}$ is the interference from own cell and $I_{oc}$ is the interference from other cell plus the background noise. $G = \frac{I_{oc}}{I_{or}}$ is called the geometry factor and it is the relation between interference from own cell and interference from other cells. On the cell boarder $G$ is normally lower than close to the RBS. $\alpha$ is called the nonorthogonality factor and describes the nonorthogonality between signals due to fast fading.
3.3 Field statistics

The field statistics, which are supplied by the costumer, includes a lot of data but the data used in this thesis is:

- Traffic payload [kbits] – from RNC counters
- Number of SHO-links [-] – from RNC counters
- RBS power [dBm] – from the RBS counters

Traffic payload is the actual bits that pass through a sector of an RBS. The RNC traffic payload is collected per cell and represents the total kbits that pass through the cell during a certain entity. If a user is in SHO it sends the same data to all cells in the active set. As a consequence the traffic from a UE can be logged as payload in up to 3 cells.

The RBS power data presents how much power each RBS consumes and the data for the SHO-links shows how many RBS or RBS sectors each UE in the network is connected to.

In the field statistics the data is specified for each cell. Data from the network is collected all the time but every 15 minutes they are summarized and stored in a xml-file. To get more manageable set of data these data are often summarized to hourly.

Before using field statistics in the simulator it has to be converted to match the Astrid parameter and result. The following preprocessing has to be completed before the data can be used.

- Convert the traffic load from kbits to Erlang per cell
- Reduce traffic because of SHO
3.3 Field statistics

- Calculate the service distribution
- Calculate the indoor/outdoor distribution
- Average RBS power data

The two first bullets are illustrated in figure 3.9.

3.3.1 kbits to Erlang conversion

The unit for the traffic payload from the field statistics counters is kbits, the name of the counters are presented in Appendix F. This means that the field statistics shows the downloaded kbits during an hour per cell. As traffic payload in Astrid should be in Erlang per km$^2$ the field statistics traffic payload has to be converted.

By using the following formula 3.5 kbits during an hour, $R$, can be converted to Erlang, $E$. When the number of Erlang is known it is trivial to calculate the Erlang per km$^2$ if the area size is known.

$$E = R \cdot \frac{1 + DTX_{gain}}{kbps_{tot} \cdot 3600}$$ (3.5)

The $DTX_{gain}$ is a gain due to that the radio channels between the RBS and the UE does not transmit all the time, which leads to less interference and an increase in capacity. In speech for example the UE does not need to transmit as much data when the user is quiet compared to when the users talks. The $DTX_{gain}$ is calculated by using the activity factor described below. There are two dedicated channels between the RBS and the UE, the Dedicated Traffic Channel (DTCH) and the Dedicated Control Channel (DCCH). The transmission speed of the DTCH depends on the service but the transmission speed of the DCCH is 3.4 kbps for all services.

The activity factor tells how big part of the total connection time the UE is actually active. In this thesis the activity factor of the DTCH is assumed to be 50% for speech and 100% for all other services, for DCCH the activity factor is assumed to be 10% for all services. These activity factors give the $DTX_{gain}$ shown in table 3.1.

The $kbps_{tot}$ is the total kbps transmitted over the DTCH and DCCH for each service. The $kbps_{tot}$ are also shown in table 3.1.
<table>
<thead>
<tr>
<th>Service</th>
<th>$kbps_{tot}$</th>
<th>$DTX_{gain}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speech</td>
<td>$12.2 \text{ kbps} + 3.4 \text{ kbps} = 15.4 \text{ kbps}$</td>
<td>102%</td>
</tr>
<tr>
<td>Video</td>
<td>$64 \text{ kbps} + 3.4 \text{ kbps} = 67.4 \text{ kbps}$</td>
<td>5%</td>
</tr>
<tr>
<td>PS64</td>
<td>$64 \text{ kbps} + 3.4 \text{ kbps} = 67.4 \text{ kbps}$</td>
<td>5%</td>
</tr>
<tr>
<td>PS128</td>
<td>$128 \text{ kbps} + 3.4 \text{ kbps} = 131.4 \text{ kbps}$</td>
<td>2%</td>
</tr>
<tr>
<td>PS384</td>
<td>$384 \text{ kbps} + 3.4 \text{ kbps} = 387.4 \text{ kbps}$</td>
<td>1%</td>
</tr>
</tbody>
</table>

Table 3.1. $DTX_{gain}$

### 3.3.2 SHO reduction

The Astrid simulator adds SHO traffic for the users in SHO. As the downloaded kbits, to UE in SHO, in the field statistics are logged in several cells the traffic payload from the field statistics has to be reduced before it is used in Astrid.

A measure of how much traffic added due to SHO is the SHO-factor. The SHO-factor is the average number of additional radio links per UE. The field statistics contains data of how many UEs, in each cell, that are connected to 1, 2 or 3 cells, the name of the counter are presented in Appendix. From this a SHO-factor can be calculated by using a method presented in [16].

The traffic can now be reduced by the SHO-factor. The SHO-factor in Astrid, which is a result from the simulations not a parameter, might not be equal to the SHO-factor from the field statistics. This means that Astrid will not add as much traffic as is removed from the traffic in the field statistics. To compensate for this the traffic load is multiplied by quotient, $K$, in equation 3.6 before it is used in Astrid

$$K = \frac{1 + \text{SHO}_{factor_F}}{1 + \text{SHO}_{factor_A}}$$  \hspace{1cm} (3.6)

### 3.3.3 Service distribution calculation

The traffic load in the field statistics are divided into CS 12kbps, CS 64kbps, PS 64kbps, PS 128kbps and PS 384kbps. The distribution between the services has to be specified as input to the Astrid simulator. To calculate the distribution between the services the following steps are used.

1. Calculate number of Erlang per service
2. Calculate the percentage of total Erlang for each service

As described in section 3.1.3 many iterations of the Monte Carlo process have to be made if there are few users to get a statistical valid result. In all simulation in this thesis, 20 snapshots have been used. There are few users who use the PS services. Instead of using more snapshots, which is time-consuming, all the PS traffic is assumed be PS 64kbps. This means that the traffic is distributed between

\[\text{During the thesis a improvement of this method was identified, described in chapter } 6\]
3.3 Field statistics

CS 12.2kbps, CS 64kbps and PS 64kbps. CS 64kbps is also a small part of the total traffic so it is probably negligible.

3.3.4 Indoor/outdoor calculations

Indoor traffic and outdoor traffic has to be split up in Astrid, but how much of the total traffic should be indoor traffic and how much should be outdoor traffic? The customer having the real network uses the assumption that the traffic density is 4 times higher per km$^2$ in the indoor area than the outdoor area per cell. Therefore this assumption is used in these simulations. Formulas for this method are presented below. Where $A$ is the area and $E$ is the traffic in Erlang or if it is a km$^2$ in the subscript then is Erlang per km$^2$.

$$E_{\text{out/km}^2} = \frac{E_{\text{tot}}}{4 \cdot A_{\text{in}} + A_{\text{out}}}$$  \hspace{1cm} (3.7)

$$E_{\text{in/km}^2} = 4 \cdot E_{\text{out/km}^2}$$  \hspace{1cm} (3.8)

$$E_{\text{in}} = E_{\text{in/km}^2} \cdot A_{\text{in}}$$  \hspace{1cm} (3.9)

$$E_{\text{out}} = E_{\text{out/km}^2} \cdot A_{\text{out}}$$  \hspace{1cm} (3.10)

The assumption that the traffic is 4 times larger indoor than outdoor can be discussed if it is correct or not but it will be used in the simulations in this thesis, unless something else is specified.

3.3.5 Average RBS power data

The counters RBS power is in the field statistics divided in to intervals of 0.5 dBm, the name of the counter is presented in Appendix F. The power used in each cell is measured every 4th second and the field statistics tells how many of this measurements that are in each interval. To make an average of the power used by each cell over an hour each sample in an interval is assumed to be in the middle of the interval. The average power per cell is then converted from dBm to W to match the simulated RBS.
Chapter 4

Benchmarking between evenly distributed traffic and distribution from real network data

The traffic load deployed in Astrid can either be specified for the whole area or for each cell. Earlier the simulations have been completed with the traffic load specified for the whole area. When the traffic is specified for the whole area the Erlang per km$^2$ is equal in all cells, called even traffic. This lead to that large cells have large amount of traffic and small cells have small amount of traffic.

In the field statistics the traffic payload is specified for each cell. This can be used to specify the traffic payload per cell in the simulator. This means that the Erlang per km$^2$ is different in different cells, this is called uneven traffic. The uneven traffic gives a more realistic traffic distribution over the area than with even traffic.

In this chapter the gain in simulation accuracy, of using uneven traffic as input into Astrid compared to even traffic, is investigated.

4.1 Approach

When comparing the results between uneven traffic and even traffic it is important that the total amount of traffic is equal in both simulations. To achieve equal total traffic the uneven traffic simulation will be made first and the total amount of traffic from this simulation is then used in the even traffic simulation. The bit rates for HSDPA will be used to measure the gain in simulated accuracy with uneven compared to even traffic.
4.2 Simulated network

The simulation network in this study is called the City A project and it is an Astrid project with 304 cells and 107 of them are active cells. All of the 304 cells do not exist in reality but those which do not exist are by the customer planned to be alive in the feature. This together with some problems for the customer to collect the field statistics lead to that the field statistics only includes data for 67 of the 107 active cells.

In those 67 cells the average measured traffic is 2.103 Erlang/cell. To the remaining 40 active cells the average of 2.103 Erlang/cell are applied. With this average over 107 cells the total traffic within the active area are 225.05 Erlang ($E_{tot}=225.5$ Erlang). It would of course be better to use a project where all the simulated cells exist and it would have been field statistics for all cells but City A was the best existing project at this time. Collection of new data and updates of projects were ongoing.

The active area in City A project contains 240309 bins and with the bin size of 25m$^2$ the active area is:

$$A_{Active} = \frac{240309 \times 25}{10^6} = 6.0077 \text{ km}^2$$

Of these 240309 bins there are 109471 indoor bins and 130838 outdoor bins.

$$A_{in} = \frac{109471 \times 25}{10^6} = 2.7368 \text{ km}^2$$

$$A_{out} = \frac{130838 \times 25}{10^6} = 3.2710 \text{ km}^2$$

To be able to compare the results from simulations with even and uneven traffic the total traffic has to be equal. By using $A_{in}$, $A_{out}$ and $E_{tot}$ in equations 3.7 and 3.8 the indoor and outdoor traffic load can be calculated. The outdoor traffic and indoor traffic become 15.83 Erlang/km$^2$ and 63.32 Erlang/km$^2$ respectively for the even simulation.

As a change in traffic also changes the power consumed it can be interesting to see how big difference it is in traffic load per cell between even and uneven traffic. A histogram of the difference in Erlang per cell is shown in figure 4.1 and the most of the cells have less then 1 Erlang in difference when uneven traffic is used instead of even.

4.3 General simulation configuration

The general simulation configuration in the simulation in this chapter is:

- 5 meter map resolution with 3D building data base
- Realistic network site data (positions, feeder losses, antenna tilts, power settings...)
- Power setting
4.4 Simulations results

In this section the results from simulations for the City A project with even and uneven traffic are compared. The HSDPA bit rate depends on the available HSDPA

- Nominal power 17.4 W, 5.5 W for micro cells
- CPICH 10% of nominal power
- BCH -1.5dB, ref CPICH
- PSCH -0.2dB, ref CPICH
- BCH -2.1dB, ref CPICH

- Path loss prediction with the Urban propagation model
  - Best of Half screen and Micro cell model
  - The indoor model use 12 dB wall loss and 0.8 dB/m building penetration slope

- Channel model, TU and PedA
- UE antenna height 1.5 m
- UE category 6

**Figure 4.1.** Histogram of difference in Erlang per cell between even and uneven
power. As the power used by the R99 traffic will be different when using uneven traffic instead of even traffic the available HSDPA power will also be different.

The figures 4.2 and 4.3 shows the complementary cumulative distribution function (CCDF) of the mean HSDPA rate over the area for even and uneven traffic with HSDPA utilization, of 5%, 25% and 50%. The HSDPA utilization is explained in Appendix E.

The HSDPA channel model in figure 4.2 is Typical Urban 3 and in figure 4.3 it is Pedestrian A. In both figures maximum number of codes is 5 and the UE category is 6, for more information about UE categories see Appendix G.

In both the Typical Urban 3 and Pedestrian A simulations the even traffic gives little bit less bit rates than the uneven traffic but the rates are almost equal.

As described before the HSDPA traffic can use if needed all the available power in the RBS. In figure 4.4 the available HSDPA power for even traffic is plotted and for uneven traffic the available HSDPA power is shown in figure 4.5. In both figure 4.4 and 4.5 the channel model is typical urban and the HSDPA utilization is 5%. There are two cells in both figures that have much less available HSDPA power then the other. The reason for this is that these two cells are micro cells, with less total power then the other cells.

The average available HSDPA power is for both even and uneven traffic 12.9 W but there are small differences in the HSDPA bit rate.

In figure 4.6 a CCDF of the available HSDPA power, for all cells except the micro cells, is shown and as the plot shows the available HSDPA power for uneven traffic is more evenly distributed, than for even traffic. This means the R99
4.4 Simulations results

Figure 4.3. C.C.D.F of mean HSDPA rate, Pedestrian A, 5 coder, UE category 6

Figure 4.4. Available HSDPA power with even traffic, average 12.9 W
34 Benchmarking between evenly distributed traffic and distribution from real network data

Figure 4.5. Available HSDPA power with uneven traffic, average 12.9 W

Figure 4.6. CCDF of the available HSDPA power
power also is more evenly distributed over the cells for uneven traffic. Network planners strive to place the antenna sites to achieve good coverage but they also do small cells where they believe there will be a lot of traffic to get the traffic evenly distributed over the cells. This indicates that the simulated network is well planned.

4.5 Summary of results

Due to that there were only payload data for 67 of 107 cells and the remaining 40 cells got an average traffic load the results gives only a hint of the actual result of using uneven traffic instead of even traffic as input into Astrid. It would of course been more reliable if there would have been data for all the cells.

In the City A project network with payload data for 63% of the cells there is no gain of using uneven traffic instead of even traffic with today’s traffic load. The resulting HSDPA bit rates will be almost equal. In the future when the traffic load has increased it can be more difference between the results with even and uneven traffic. This means that in the future there will probably more gain in simulation accuracy of using uneven traffic.

To get rid of the problem with the nonexisting cells a new project, City 2007 D, was created with out these nonexisting cells. It would be interesting to see if there would be larger difference in the HSDPA bit rates with the City 2007 D project, where all cells are alive. This is matter for further studies.
Benchmarking between evenly distributed traffic and distribution from real network data
Chapter 5

Benchmarking of RBS power between simulation result and field data

In this chapter Astrid will be benchmarked with real network data from customer’s network in a European city. The traffic payload from field is used as input traffic into Astrid and the simulated power of the RBSs are then compared with field statistics for the RBS power, which is synchronized in time with the field statistics for the traffic payload.

5.1 Approach

The measured RBS power and traffic payload is synchronized in time, meaning that they are measured during the same time interval. The measured traffic payload per cell will be used to configure the traffic demand in the Astrid simulator. During the simulation Astrid generates RBS power, based on the traffic payload per cell. The simulated RBS power will than be compared with the measured RBS power, to estimates accuracy in the simulator. If the simulated RBS power is not close enough to the measured value an investigation will be completed to identify the main reasons for the difference in RBS power. From this investigation some possible explanations to the power difference will be suggested and evaluated. It will be an iterative process to tune in the RBS is modeled more accurately. With a more accurate simulated RBS power, the pathloss, interference and thus the overall simulation result is more likely to be more accurate than before.

5.2 Simulated network

As explained in chapter 4 the City A project has more cells than in reality. To be able to compare the real network with the simulated network a new project was
Benchmarking of RBS power between simulation result and field data

created, called City D, where the nonexisting cells are removed. City D project consist of 228 cells and 85 of them are active. The simulated area and the analyzed area is the same as in the City A project. When comparing the traffic payload with the cells in City D an additional RBS was identified as nonexisting, including two active cells and one supportive cell. To remove the nonexisting cell in the City D project would imply that the whole chain of creating a new project has to be redone. This was something we wanted to avoid to start with.

For the RBS power data, the data collection is more difficult than for the RNC data, and it was only possible to get RBS data for 50 of the 85 active cells.

In the traffic payload data, there were data for all existing cells except for one. The customer, who supplies the field statistics, had problems to get the traffic payload data from this cell.

What traffic payload should be applied to the cells without traffic payload data? For the two active cells that do not exist in reality there are two main options. One way is to use the average traffic payload but then the total number of users in the system would be larger in the simulations than in reality and therefore the interference level might be larger than in reality. Another way is to set the traffic payload to 0, this might lead to a lower interference level than in reality.

The second option is used in this simulations since the cell do not exist. There is one active cell that do exist in reality but do not have traffic payload data and for this cell an average traffic payload is applied.

5.3 General simulation configuration

The general simulation configuration in the simulation in this chapter is presented below. These are the values used unless other values are specified.

- 5 meter map resolution with 3D building database
- Realistic network site data (positions, feeder losses, antenna tilts, power settings...)
- Power setting
  - Nominal power 17.4 W, 5.5 W for micro cells
  - CPICH 10% of nominal power
  - BCH -1.5 dB, rel. CPICH
  - PSCH -0.2 dB, rel. CPICH
  - SSCH -2.1 dB, rel. CPICH
- Path loss prediction with the Urban propagation model
  - Best of Half screen and Micro cell model
  - The indoor model use 12 dB wall loss and 0.8 dB/m building penetration slope
- $E_b/I_0$ targets, for TU
5.4 Initial simulation results

- 7.2 dB, CS 12.2
- 7.1 dB, CS 64
- 6.4 dB, PS 64

- Channel model, TU
- UE antenna height, 1.5 m
- Traffic distribution, indoor traffic per km² = 4-outdoor traffic per km²
- Average SHO-compensation

5.4 Initial simulation results

Figure 5.1. Difference in RBS power, simulated - real, channel model TU3

To get a first overview of how accurate the simulated RBS power is compared to the real RBS power a simulation was made with the general simulation configuration as described in section 5.3, which is a commonly used setting in Astrid. In the figure 5.1 the difference between the simulated and the real RBS power is shown. In most of the cells the measured RBS power is lower than the simulated RBS power. The mean of the difference is 1.1 W and the standard deviation is 0.83 W. The ideal would be to have the mean of 0 W and a standard deviation of 0 W.
Figure 5.2. CCDF of the difference in RBS power, initial setting

In figure 5.2 the CCDF of the difference in RBS power is shown together with the ideal CCDF and it shows that the simulator generally overestimates the RBS power given a certain traffic load.

5.4.1 Rural area vs. Typical Urban

In the parameter setting used in the first simulation the channel model was Typical Urban. Orthogonality measurements, have during 2006 been performed in urban and dense urban areas. The measurements are presented in [11]. One of the outcomes was that the TU3 model is too pessimistic. Instead a Rural Area model would be more accurate. Therefore the channel model was changed to a Rural Area. The changes from the initial simulation configuration in 5.3 are:

- Channel model RA
- $E_b/I_0$ target, for RA
  - 7.1 dB, CS 12.2, (initial value 7.2 dB)
  - 6.7 dB, CS 64, (initial value 7.1 dB)
  - 6.2 dB, PS 64, (initial value 6.4 dB)

In figure 5.3 the difference in RBS power is shown. Some cells have decreased their simulated power, for example cell 49, and some have larger simulated power with RA compared to TU, for example cell 16. In figure 5.4 the CCDFs of the
5.4 Initial simulation results

**Figure 5.3.** Difference in RBS power, simulated - real, channel model RA3

**Figure 5.4.** CCDF of the difference in RBS power, Rural Area
Benchmarking of RBS power between simulation result and field data

simulation with initial setting and with Rural Area as channel model is shown. This plot shows that the RA is a little bit better than TU in this simulation environment. The average difference has decreased, the mean difference is now to 1.0 W and the standard deviation 0.78 W. This means, the simulator gives a more accurate result when the RA is used instead of TU. Therefore from now on all the simulations in this thesis were made with the RA as channel model.

5.4.2 Reasons for two deviating cells

In both figures 5.1 and 5.3 there are two cells, cell number 22 and 39, that deviate from the other cells. Both of them have more than 1 W too low simulated power.

Figure 5.5 shows a map with the RBSs over the simulated area and cluster 2 area is marked. The two cells with low simulated power are marked with a rectangle and a triangle. One of them (cell 22, triangle) is in the outer region the simulated area. This means that cell 22 has less surrounding cells in the simulator than in reality. Cell 22 has therefore too little interference from other cells in the simulator. Cell number 39 (rectangle) is not on the edge of the simulated area, it has many surrounding cells. Other reasons have to be found to explain the too low simulated power.

![Figure 5.5. Map over simulated network, cluster 2 area](image)

The, in reality, nonexisting RBS is the RBS marked with a circle, its cells
therefore have no traffic, as explained in section 5.2. This might lead to that the adjacent cells do not have an accurate interference level. Cell 39 is pretty close to the nonexistent RBS and this might be a reason for the low simulated power. To get rid of the problem with the nonexistent cells a new project was created without these three cells, two of them are active cells. The new project (City D no1630) therefore has 225 cells with 83 active cells. With this new project the difference in RBS power is as shown in figure 5.6, mean 1.0 W and standard deviation 0.76 W. The mean and the standard deviation is almost unchanged and cell 39 has only a little bit more simulated power. The new project did not affect cell 39 as much as expected. At the time of writing no explanation found to why Astrid underestimates the RBS power in cell 39, further studies are needed. The City D no1630 project is used in the subsequent simulations.

![Difference in RBS power, simulated - real, City D no 1630](image)

Figure 5.6. Difference in RBS power, simulated - real, City D no 1630

As the simulated power for cell 22 and 39 is less than the in reality, their contribution to interference to adjacent cells are not enough.

### 5.5 Reasons for overestimated RBS power and simulation result

The average simulated power was about 1 W too high and to investigate the size of the loss needed to get an accurate average simulated power an extra loss component was implemented in the simulator. With the extra loss component set to -1.5 dB the average difference in RBS power was 0.05 W. In figure 5.7 the difference in
RBS power for each cell is presented. This indicates that it is in average of about 1.5 dB too much power used in the link budget.

![Figure 5.7. Difference in RBS power, simulated - real, loss -1.5 dB](image)

What can be the reason for the 1.5 dB? After some discussion and brainstorming six areas where identified that can contribute to the over estimated RBS power. The overestimated RBS power is probably not due to one of these areas, it is more likely to be a combination.

**SHO compensation** — In the calculations of the SHO compensation, described in 3.3.2, the SHO-factors have been the average SHO-factor for all cells. As the SHO-factor varies between each cell it would probably be more accurate to use cell specific SHO-factors in the SHO compensations. This is investigated in 5.5.1.

**Indoor propagation model** — If a correlation between the difference in RBS power and indoor area can be found then the indoor propagation model and indoor/outdoor traffic distribution might not be accurate. The indoor model might have too high through wall constant or building penetration slope. This is investigated in 5.5.2.

**Indoor/outdoor traffic distribution** — A correlation between the difference in RBS power and indoor area can also indicate that the indoor/outdoor traffic distribution assumption might overestimate the indoor traffic and underestimate the outdoor traffic. This is investigated in 5.5.3.
5.5 Reasons for overestimated RBS power and simulation result

**UE sensitivity** – If there is a correlation between the amount of traffic and the difference in RBS power it might indicate that simulator uses too much RBS power for each user. The UE sensitivity can be change in the simulator by changing the required $E_b/I_0$ target and if the $E_b/I_0$ target is decreased each UE need less power from the RBS to detect the signal properly. The values of the $E_b/I_0$ target in Astrid come from a systems guideline. As mobiles gets better and better on detecting the signal the required $E_b/I_0$ target gets lower. This means that these guidelines are often pessimistic compared to reality. If this $E_b/I_0$ target is lowered the RBS power decreases because the UE does not need as powerful signal as before. With lower RBS power the interference, $I_0$, will also decrease. Hence signal strength $E_b$ will be decreased even more to reach the $E_b/I_0$ target. This is investigated in 5.5.4.

**Height of UE** – In the pathloss prediction all the UE antennas are assumed to 1.5 m above the ground but this is of course not the case in reality. Many users are not on ground level when using their UE. Studies have shown that the pathloss decreases if the UE antenna height increases. Therefore an increase in the UE antenna height in the pathloss prediction might contribute to decrease the simulated power. This is investigated in 5.5.5.

**Common control channel setting** – All of the above five theses focus on the dedicated channels but the reason that Astrid overestimates the power might be due to the common channels. This is investigated in 5.5.6.

### 5.5.1 Evaluation of SHO compensation

The SHO compensation, described in section 3.3.2 uses an average SHO-factor when calculating the quotient, $K$, in equation 3.6. A more accurate way might be to use cell specific SHO-factors for both the field statistics and Astrid, therefore a simulation was performed with cell specific SHO compensation. The changes from the initial simulation configuration in 5.3 are:

- **Channel model RA**
- **$E_b/I_0$ target**, for RA
  - 7.1 dB, CS 12.2, (initial value 7.2 dB)
  - 6.7 dB, CS 64, (initial value 7.1 dB)
  - 6.2 dB, PS 64, (initial value 6.4 dB)
- **Individual SHO-compensation**

In figure 5.8 the difference between the simulated and real RBS power is presented, the mean is 0.9 W and the standard deviation is 0.77 W. The simulated RBS power is reduced when cell individual SHO compensation is used compared to an average SHO compensation, but the changes are small compared to what is needed to get an accurate power level. The CCDF in figure 5.9 also shows that
Figure 5.8. Difference in RBS power, simulated - real, individual SHO

Figure 5.9. CCDF of the difference in RBS power, individual SHO
there is only a small difference compared to the simulation with the initial setting in section 5.3. The main part of the difference comes from the channel model change from Rural Area instead of Typical Urban. Individual SHO-compensation is used in subsequent simulations.

5.5.2 Evaluation of indoor propagation model

If there is a correlation between indoor/outdoor area distribution and the RBS power it might indicate that the parameter setting need to be changes for the indoor propagation model, described in section 3.2.2. In figure 5.10 the distribution between indoor and outdoor area is shown. By comparing figure 5.10 with figure 5.6 a correlation between the indoor/outdoor area distribution and the difference in RBS power can be seen for the cells 14, 15, 21, 25, 34 and 49. These cells have large indoor part and high difference in RBS power. There are cells that do not have this correlation, for example cell 41.

![Figure 5.10.](image)

The overestimated RBS power is, as explained in the beginning of section 5.5, most likely a combination several identified areas. Therefore correlation between indoor/outdoor area distribution and the difference in RBS power is strong enough to justify a test of the change of the parameters in the indoor model.

To investigate if the indoor model is accurate a simulation with a smaller through wall constant was completed. As there is 1.5 dB in average too much loss used in the link budget the through wall constant, $W$ in equation 3.1 was change from 12 dB to 10 dB. Changes from the initial simulation configuration in 5.3 are:
Benchmarking of RBS power between simulation result and field data

- Channel model RA
- Indoor model, wall loss 10 dB, (initial value 12 dB)
- $E_b/I_0$ target, for RA
  - 7.1 dB, CS 12.2, (initial value 7.2 dB)
  - 6.7 dB, CS 64, (initial value 7.1 dB)
  - 6.2 dB, PS 64, (initial value 6.4 dB)
- Individual SHO-compensation

![Difference in RBS power, simulated - real](image)

Figure 5.11. Difference in RBS power, simulated - real, wall loss 10 dB

The most of the users are indoors, and therefore they are affected by this through wall constant change, which should lead to a significant change in the simulated RBS power. The result from this simulation is shown in figure 5.11 and in figure 5.12. The average difference in RBS power is now 0.9 W and standard deviation is 0.72 W and the CCDF differs not too much from the base case. The main part of the difference between the RBS power in this simulation and in the initial case is due to change of channel model. The simulated RBS power did not decrease as much as expected. This shows that the indoor model has only a small impact on the simulated power with today’s traffic load.
5.5 Reasons for overestimated RBS power and simulation result

5.5.3 Evaluation of indoor/outdoor distribution

The indoor propagation model could not reduce the simulated RBS power as much as necessary to get an accurate simulated RBS power. Could the assumption that the indoor traffic is 4 times larger per km$^2$ than the outdoor traffic be changed to get a reduction in the simulated RBS power? As all indoor users have an extra pathloss compared to outdoor users, the simulated RBS power should decrease if more users are outdoors. A reasonable assumption is that the indoor traffic per km$^2$ is larger than for outdoor. To see if the indoor/outdoor traffic distribution can reduce the simulated RBS power an extreme case is simulated, with the indoor and outdoor traffic per km$^2$ equal to each other. Changes from the initial simulation configuration in 5.3 are:

- Channel model RA
- $E_b/I_0$ target, for RA
  - 7.1 dB, CS 12.2, (initial value 7.2 dB)
  - 6.7 dB, CS 64, (initial value 7.1 dB)
  - 6.2 dB, PS 64, (initial value 6.4 dB)
- Traffic distribution, indoor traffic per km$^2$ = outdoor traffic per km$^2$
- Individual SHO-compensation

Figure 5.12. CCDF of the difference in RBS power, wall loss 10 dB
Benchmarking of RBS power between simulation result and field data

Figure 5.13. Difference in RBS power, simulated - real, indoor-outdoor 50-50

Figure 5.14. CCDF of the difference in RBS power, indoor-outdoor 50-50
5.5 Reasons for overestimated RBS power and simulation result

As seen in figures 5.13 and 5.14 the indoor/outdoor distribution can not reduce the simulated power as much as necessary. The mean difference is 0.9 W for this simulation and the standard deviation is 0.79 W. The main part of the difference between the RBS power in this simulation and in the initial case is due to change of channel model. The indoor/outdoor traffic distribution has also a small impact on the simulated RBS power.

5.5.4 Evaluation of $E_b/I_0$ target

If there is a correlation between the amount of traffic and the difference in RBS power, it might indicate that the simulator uses too much RBS power for each user. In figure 5.15 the amount of Erlang per cell is shown. By comparing figure 5.15 with figure 5.6 it can be seen that some cells have much traffic and also too high simulated RBS power, for example cell 21, 38, 44 and 49, but there are exceptions from this theory, e.g. cell 40. The same line of argument as in section 5.5.2 leads to that there is strong enough correlation between traffic load and difference in RBS power to justify a change in the $E_b/I_0$ target.

![Figure 5.15. Erlang per cell](image)

As discussed in the beginning of section 5.5 the $E_b/I_0$ targets in Astrid are from guidelines and this might be a little bit pessimistic compared to reality. To investigate if the pessimistic $E_b/I_0$ target can be a reason to the too high simulated RBS power, a simulation is made with the $E_b/I_0$ target for voice traffic, CS 12.2kbps was decreased with 1 dB. Changes from the general simulation configuration in 5.3 are:
52 Benchmarking of RBS power between simulation result and field data

- Channel model RA
- $E_b/I_0$ target
  - 6.1 dB, CS 12.2, (initial value 7.2 dB)
  - 6.7 dB, CS 64, (initial value 7.1 dB)
  - 6.2 dB, PS 64, (initial value 6.4 dB)
- Individual SHO-compensation

![Graph showing difference in RBS power, simulated - real](image)

**Figure 5.16.** Difference in RBS power, simulated - real, $E_b/I_0$ target = 6.1

In figure 5.16 the difference in RBS power from this simulation is shown. In this simulation the standard deviation is 0.74 W and the mean difference is 0.9 W. The difference has decreased but far from enough to get an accurate RBS power level in the simulations and the CCDF in figure 5.17 is still close to the initial CCDF. Again, the main part of the difference between the RBS power in this simulation and in the initial case is due to change of channel model.

5.5.5 Evaluation of height of UE

In reality the traffic is distributed in three dimensions, users make calls not only on ground floors but also higher up in the buildings. In this version of Astrid the users can not be spread out in 3D, instead all users are at the same level. In the simulation area in this case there are many tall buildings and it is not unusual with building with 5 or more floors. Most buildings in the simulated area are
5.5 Reasons for overestimated RBS power and simulation result

Figure 5.17. CCDF of the difference in RBS power, $E_b/I_0$ target = 6.1

between 12-22 m high. From this the average UE height is estimated to be 8 m above ground level. In this simulation the changes from the general simulation configuration in 5.3 are:

- Channel model RA

- $E_b/I_0$ target, for RA
  - 7.1 dB, CS 12.2, (initial value 7.2 dB)
  - 6.7 dB, CS 64, (initial value 7.1 dB)
  - 6.2 dB, PS 64, (initial value 6.4 dB)

- UE antenna height 8 m, (initial value 1.5 m)

- Individual SHO-compensation

The result from this simulation is shown in figure 5.18. The average difference in RBS power in this simulation is 0.9 W and standard deviation is 0.76 W. The UE antenna height did not make a major impact on the simulated RBS power as can be seen in the CCDF in figure 5.19. Again, the main part of the difference between the RBS power in this simulation and in the initial case is due to change of channel model.
Figure 5.18. Difference in RBS power, simulated - real, UE antenna height 8 m

Figure 5.19. CCDF of the difference in RBS power, UE antenna height 8 m
5.5 Reasons for overestimated RBS power and simulation result

5.5.6 Evaluation of common control channel settings

The channels in the downlink can be divided into dedicated channels and common channel. The dedicated channels are specific to each user. Therefore the power used in the RBS for these channels depends for example on the number of users. For the common channels the RBS uses the same power no matter what. The earlier attempts to decrease the RBS power by only changing the RBS power used in the dedicated channels but there might be the common channels that are modeled to use too much power.

The channels can also be divided in data channels (DCH) and control channels (CCH). The data channels, which transport the actual data, are all of them dedicated channels, the control channels are both dedicated and common channels.

![Figure 5.20. Control Channel (CCH) power](image)

In figure 5.20 the simulated CCH power is plotted and in figure 5.21 the simulated DCH power is plotted. As these plots show the control channels use much more power. The average power used by the DCH is only 0.5 W and the mean power for the CCH is 3.4 W. Out of the simulated CCH the common channels use 3.1 W. This means the dedicated channels use in average 0.8 W. Even if all the dedicated channels would have been removed (=no users in the network) the simulated power would have been too high. The earlier attempts to reduce the simulated power have all been focusing on the dedicated channels and the reason to that the RBS power has not been reduced as much as expected is that the dedicated channels are such a small part of the total power. It would probably been better to start to investigate if it is the dedicated or common channels that
use the largest part of the RBS power, and then been working from the result of the investigation.

Figure 5.21. Data Channel (DCH) power

<table>
<thead>
<tr>
<th>Channel</th>
<th>Power relative CPICH</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCH</td>
<td>-1.5 dB</td>
</tr>
<tr>
<td>PSCH</td>
<td>-0.2 dB</td>
</tr>
<tr>
<td>SSCH</td>
<td>-2.1 dB</td>
</tr>
</tbody>
</table>

Table 5.1. Power setting for CCCH, from simulator

The power setting in the simulations for the CPICH has so far been 10% of the total RBS power. The other common control channels (CCCH) have had the setting as in table 5.1. In the real network on the other hand the CCCH power setting is as in table 5.2. If the CPICH power is unchanged (10% of the total RBS power) and the simulation CCCH power setting is changed to the real network setting, the total simulated CCCH power will decrease with about 0.4 W. This result is obtained by using equation D.1 in Appendix D for the two CCCH power settings.

During the control of the CCCH settings we realized that the feederloss in the simulator is not equal to the feederloss in the real network. In several cells there are more than 1 dB difference between the feederloss in the simulator and in reality but in average the feederloss in the real network was only 0.1 dB less than
Table 5.2. Power setting for CCCH, from from field

<table>
<thead>
<tr>
<th>Channel</th>
<th>Power relative CPICH</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCH</td>
<td>-3.1 dB</td>
</tr>
<tr>
<td>PSCH</td>
<td>-1.8 dB</td>
</tr>
<tr>
<td>SSCH</td>
<td>-3.5 dB</td>
</tr>
</tbody>
</table>

the average feederloss in the simulator. Therefore a simulation with the following changes from the general simulation configuration in 5.3 was completed.

- Channel model RA,
- Power setting
  - BCH -3.1 dB, rel. CPICH, (initial value -1.5 dB)
  - PSCH -1.8 dB, rel. CPICH, (initial value -0.2 dB)
  - SSCH -3.5 dB, rel. CPICH, (initial value -2.1 dB)
- $E_b/I_0$ target, for RA
  - 7.1 dB, CS 12.2, (initial value 7.2 dB)
  - 6.7 dB, CS 64, (initial value 7.1 dB)
  - 6.2 dB, PS 64, (initial value 6.4 dB)
- Changed values for feederloss, cell individual
- Individual SHO-compensation

The difference in RBS power, from the simulation with the new feederlosses and new CCCH setting (CPICH unchanged), is shown in figure 5.22. The average difference in RBS power is now 0.5 W and the standard deviation is 0.78 W. The simulated power is more accurate with the right common control channel setting (CCCH) and the accurate feederloss but the deviation is unchanged. The CCDF in figure 5.23 is now considerably closer to the ideal than in the initial simulation.

5.6 Summary of results

With the general simulation configuration, presented in section 5.3, the simulator overestimated the RBS power with about 1 W in average.

In a study presented in [11] shows that city centers are more behaving like a Rural Area channel model compared to Typical Urban. The simulation result in section 5.4.1 confirms the study results in [11], in regards to power consumption.

One of the reasons to the overestimated the RBS power was that the CCCH settings in the simulator were not equal to the CCCH setting in the real network. With the right CCCH setting and Rural Area as channel model the simulator
58 Benchmarking of RBS power between simulation result and field data

Figure 5.22. Difference in RBS power, simulated - real, with new CCCH settings

Figure 5.23. CCDF of the difference in RBS power, new CCCH and feederloss
overestimates the power with about 0.5 W. The simulated RBS power is considerably closer to the ideal with the new CCCH and feederloss setting than the initial simulation.

In figure 5.24 a summary of the simulation results are shown and it shows that the mean difference in RBS power has decreased but the standard deviation is almost unchanged. Further studies are recommended to decrease the mean value even further and to decrease the standard deviation.

![Summary of simulation results](image)

**Figure 5.24.** Summary of the results, 1. Initial settings, 2. Rural Area, 3. Individual SHO-comp, 4. Wall loss = 10 dB, 5. Indoor traffic = Outdoor traffic, 6. $E_b/\text{I}_0$ target(voice) = 6.1 dB, 7. UE height = 8 m, 8. New CCCH and feederloss

As the traffic payload today is relatively low the parameters that only affect the dedicated channels can only be used to make small adjustment. The parameters that only affect the dedicated channels will be hard to tune as they use relatively low power and changes in these parameters only gives small changes in the RBS power. The tuning of these parameters might be easier when the traffic load is heavier and changes give a larger impact on the simulated RBS power. This is a matter for further studies.
Benchmarking of RBS power between simulation result and field data
Chapter 6

Other findings

When converting the traffic payload from kbits to Erlang the payload has to be divided by the SHO-factor to get an accurate number of Erlang. As described in section 3.3.2 the traffic payload is multiplied by a quotient, $K$ in equation (3.6), of the SHO-factor from the field statistics and Astrid to get the right amount of traffic into Astrid. This gives that the traffic payload is first divided and then multiplied by the SHO-factor from the field statistics. Therefore the field statistics SHO-factor calculation is unnecessary and the SHO-factor from reality is not needed in the traffic payload calculations.
Chapter 7

Conclusion

The assignment for this master thesis was to evaluate and benchmark the simulator Astrid with real network data. This includes improving the simulation model and evaluating and improving the methods. In particular there were two parts of this thesis. In addition a benchmark of different Astrid versions was completed, the result from this study is presented in Appendix A.

In the first part of the study simulations were made with even and uneven traffic distribution and the HSDPA bit rates were then compared. As there was missing traffic payload data to almost 40% of the cells, further studies are needed to conclude if there is worth the effort of using traffic distribution from field statistics instead of evenly distributed traffic.

The second part of the thesis project was to benchmark the simulated RBS power with the real RBS power to get an accurate power and interference level in the simulations. Measurement in [11] shows that Rural Area is a better channel model then Typical Urban in city centers, the simulations results confirms this. With today’s traffic load the main part of the power used by the RBS is the common control channels (CCCH) and in this simulation project the CCCH was not update to the same values as in the real network and therefore causing in average about 0.4 W extra RBS power. With the right CCCH settings the simulator overestimates the RBS power with about 0.5 W. As the traffic payload today is relatively low the parameters that only affect the dedicated channels can only be used to make small adjustment.
Chapter 8

Further work

The following are recommendations for further studies.

- In this thesis a study of the gain in simulation accuracy when using traffic distribution from field statistics compared to evenly distributed traffic was completed. The simulated network had only field statistics for 60% of the cells. This leads to inaccuracy in the result. Therefore a study of the same kind is recommended to be completed but with a network where there are field statistics for all cells. The recommended study should conclude if there is worth the effort of using traffic distribution from field statistics instead of evenly distributed traffic.

- With today’s traffic load the common control channels use the largest part if the RBS power, hence the dedicated traffic channels use a small part of the RBS power. Therefore the parameters that only affect the dedicated channels are hard to tune today. Therefore the same kind of study as is chapter 5 is recommended to be completed when the traffic payload has increased. The recommended study could work with combinations of the areas discussed in section 5.5 to get the simulated RBS power as close to the real RBS power as possible.
Further work
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Appendix A

Benchmarking of Astrid version 1.0.17

Before starting with the actual thesis work a comparison between Astrid versions 1.0.17, 1.0.4 and new is completed. Astrid version 1.0.17 is relatively new version and the reason for doing this benchmarking is to see if the updates from earlier versions give some changes in the final results. Another reason for doing this is that I should get used to handle the simulator. Astrid version new was the first version of Astrid and therefore the oldest of these three versions. The general simulation configuration for these simulations is as follow.

- 5 meter map resolution with 3D building data base
- Realistic network site data (positions, feeder losses, antenna tilts, power settings...)
- Path loss prediction with the Urban propagation model
  - Best of Half screen and Micro cell model
  - The indoor model use 12 dB wall loss and 0.8 dB/m building penetration slope
- UE antenna height, 1.5 m
- Traffic - HSDPA only

In the figures A.1-A.4 below there are plots from simulations with only HSDPA traffic in different scenarios. There are simulations with two types of channel models, Typical Urban 3 and Pedestrian A.

One thing that differs between version 1.0.17 and the other two versions is the parameter HS_UEcat, which specifies the UE category in version 1.0.17; see Appendix G for more information about UE categories. The UE category specifies what kind of modulations that can be used. In Astrid versions new and 1.0.4 there is instead a parameter called HSmod that can be set to QPSK or 'QPSK and
16QAM'. Astrid has a parameter called HSmaxc and it tells maximum number of HSDPA codes the system. In the simulations with HSmaxc=5 the UE category 6 is used and with HSmaxc=15 the UE category 10 is used. Both of these UE categories support both QPSK and 16QAM and therefore HSmod='QPSK & 16QAM' for all these simulations with version 1.0.4 and new.

These four figures shows that simulator new gives higher bit rates than the other two and version 1.0.4 gives little bit lower rates than version 1.0.17. The main reason to the high bit rates in simulator new is that the feeder loss is missing in the geometry factor calculations. This bug was fixed in version 1.0.2. The small differences in bit rates between version 1.0.17 and 1.0.4 is probably due to small bug fixes and updates in methods used in the simulator. As all plots in figure A.1 - A.4 shows the version 1.0.17 gives almost the same results as version 1.0.4.

Figure A.1. HS rate with Typical Urban and 5 codes
Figure A.2. HS rate with Pedestrian A and 5 codes

Figure A.3. HS rate with Typical Urban and 15 codes
Figure A.4. HS rate with Pedestrian A and 15 codes
Appendix B

Astrid parameters

Some of the parameters used in Astrid be explained in the chapter

<table>
<thead>
<tr>
<th>Astrid parameters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>sp.simHS</td>
<td>Indicating whether HSDPA is simulated</td>
</tr>
<tr>
<td>sp.simUL</td>
<td>Indicating whether the uplink is simulated</td>
</tr>
<tr>
<td>ap.dl_ebio_target</td>
<td>Sets the $E_b/I_0$ target in the downlink, (depends on channel model and velocity)</td>
</tr>
<tr>
<td>sc.serv_channel</td>
<td>Sets the channel model used for R99 traffic</td>
</tr>
<tr>
<td>sc.serv_veloc</td>
<td>Sets the velocity of the UEs</td>
</tr>
<tr>
<td>ap.HSutil</td>
<td>Variable for the average HSDPA power utilization</td>
</tr>
<tr>
<td>ap.HSffmap</td>
<td>Sets the channel model for HSDPA traffic</td>
</tr>
<tr>
<td>ap.HS_UEcat</td>
<td>Sets the UE category for HSDPA</td>
</tr>
<tr>
<td>ap.HSvel</td>
<td>Sets the HSDPA user velocity</td>
</tr>
<tr>
<td>ap.HSmaxc</td>
<td>Maximum number of codes available in the system</td>
</tr>
<tr>
<td>ap.sho_maxlinks</td>
<td>Maximum number of SHO-links</td>
</tr>
<tr>
<td>ap.sho_margin</td>
<td>Sets SHO window</td>
</tr>
<tr>
<td>mp.demand.service</td>
<td>Sets the simulated services</td>
</tr>
<tr>
<td>mp.demand.load_factor</td>
<td>Describes the distribution between simulated services</td>
</tr>
<tr>
<td>mp.mix.demands</td>
<td>Sets the demanded mix of the traffic</td>
</tr>
<tr>
<td>mp.mix.scale_factors</td>
<td>Sets Erlang per km²</td>
</tr>
</tbody>
</table>

Table B.1. Parameters in Astrid
Appendix C

Simulation parameter setting

Parameter settings of the some interesting parameters used in the simulations are presented in this Appendix.

<table>
<thead>
<tr>
<th>Parameter setting</th>
<th>Parameter setting in Appendix A</th>
</tr>
</thead>
<tbody>
<tr>
<td>sp.simHS = 1</td>
<td>sp.simUL = 1</td>
</tr>
<tr>
<td>sp.simUL = 1</td>
<td>ap.HSvel = 3.6 km/h</td>
</tr>
<tr>
<td>ap.HSvel = 3.6 km/h</td>
<td>mp.mix.demands = [], means no R99 traffic</td>
</tr>
</tbody>
</table>

Table C.1. Parameter setting in Appendix A

<table>
<thead>
<tr>
<th>Parameter setting</th>
<th>Parameter setting in chapter 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>sp.simHS = 1</td>
<td>sp.simUL = 0</td>
</tr>
<tr>
<td>sp.simUL = 0</td>
<td>ap.HSvel = 3.6 km/h</td>
</tr>
<tr>
<td>ap.HSvel = 3.6 km/h</td>
<td>mp.demand.service = [1 2 3], means CS 12.2, CS 64 and PS 64</td>
</tr>
<tr>
<td>mp.demand.service = [1 2 3], means CS 12.2, CS 64 and PS 64</td>
<td>mp.demand.load_factor = [0.8784 0.0008 0.1208]</td>
</tr>
<tr>
<td>mp.demand.load_factor = [0.8784 0.0008 0.1208]</td>
<td>mp.mix.demands = [22 23], means indoor and outdoor</td>
</tr>
</tbody>
</table>

Table C.2. Parameter setting in chapter 4
<table>
<thead>
<tr>
<th>Parameter setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>sp.simHS = 0</td>
</tr>
<tr>
<td>sp.simUL = 0</td>
</tr>
<tr>
<td>sc.serv_channel = Typical Urban</td>
</tr>
<tr>
<td>sc.serv_veloc = 3 km/h</td>
</tr>
<tr>
<td>ap.dl_ebio_target = 7.2 dB, CS 12.2kbps</td>
</tr>
<tr>
<td>ap.dl_ebio_target = 7.1 dB, CS 64kbps</td>
</tr>
<tr>
<td>ap.dl_ebio_target = 6.4 dB, PS 64kbps</td>
</tr>
<tr>
<td>mp.demand.service = [1 2 3], means CS 12.2, CS 64 and PS 64</td>
</tr>
<tr>
<td>mp.demand.load_factor = [0.9597 0.0003 0.04]</td>
</tr>
<tr>
<td>mp.mix.demands = [1 2], means indoor and outdoor</td>
</tr>
<tr>
<td>Through wall constant = 12 dB</td>
</tr>
<tr>
<td>Indoor slope = 0.8 dB/m</td>
</tr>
</tbody>
</table>

*Table C.3. Initial parameter setting in chapter*
Appendix D

Model of Common Control Channels

The simulated common control channels are the common pilot channel (CPICH), the broadcast channel (BCH), the primary synchronization channel (PSCH) and the secondary synchronization channel (SSCH). As mentioned before the CPICH channel is typically set to 10% of the nominal RBS power and the others CCCH are set relatively to the CPICH. The CPICH channel is used all the time but the other CCCHs are not. To get a good simulated CCCH, each channel has an activity factor, \( \alpha \), (this is not only applied to CCCH). In table D.1 the activity factor used in these simulations for the CCCH is shown.

<table>
<thead>
<tr>
<th>Channel</th>
<th>( \alpha )</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPICH</td>
<td>1</td>
</tr>
<tr>
<td>BCH</td>
<td>0.9</td>
</tr>
<tr>
<td>PSCH</td>
<td>0.1</td>
</tr>
<tr>
<td>SSCH</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Table D.1. Activity factors for CCCH

The total power used by the CCCH is then calculated by using the equation D.1, where \( P \) denotes power and \( R \) is the power relative the CPICH power.

\[
P_{CCCH} = P_{CPICH} \cdot (1 + R_B \cdot \alpha_B + R_P \cdot \alpha_P + R_S \cdot \alpha_S)
\]  

(D.1)
Appendix E

HSDPA utilization

The HSDPA utilization reflects the time the HSDPA channels are in use. For example if HSDPA utilization is the used in 3 minutes during an hour the HSDPA utilization is 5%, as figure E.1.

![Diagram showing HSDPA utilization](image)

**Figure E.1.** HSDPA utilization

The HSDPA utilization can also be explained by using the interference. If for example a UE hears interference from 10 surrounding cells but there is only one of those that is using HSDPA at the same time as the UE. Then the HSDPA utilization is 10%.
Appendix F

Field statistics counter

<table>
<thead>
<tr>
<th>Counter</th>
</tr>
</thead>
<tbody>
<tr>
<td>pmDlTrafficVolumeCs12</td>
</tr>
<tr>
<td>pmDlTrafficVolumeCs64</td>
</tr>
<tr>
<td>pmDlTrafficVolumePs64</td>
</tr>
<tr>
<td>pmDlTrafficVolumePs128</td>
</tr>
<tr>
<td>pmDlTrafficVolumePs384</td>
</tr>
</tbody>
</table>

Table F.1. Field statistics counter used for traffic payload calculations

<table>
<thead>
<tr>
<th>Counter</th>
</tr>
</thead>
<tbody>
<tr>
<td>pmSumUesWith1Rls1RlInActSet</td>
</tr>
<tr>
<td>pmSumUesWith1Rls2RlInActSet</td>
</tr>
<tr>
<td>pmSumUesWith1Rls3RlInActSet</td>
</tr>
<tr>
<td>pmSumUesWith2Rls2RlInActSet</td>
</tr>
<tr>
<td>pmSumUesWith2Rls3RlInActSet</td>
</tr>
<tr>
<td>pmSumUesWith3Rls3RlInActSet</td>
</tr>
</tbody>
</table>

Table F.2. Field statistics counter used for SHO calculations

<table>
<thead>
<tr>
<th>Counter</th>
</tr>
</thead>
<tbody>
<tr>
<td>pmTransmittedCarrierPower</td>
</tr>
</tbody>
</table>

Table F.3. Field statistics counter used for RBS power
Appendix G

User Equipment Categories

The HSDPA UE categories available in Astrid version 1.0.17 are presented in table G.1.

<table>
<thead>
<tr>
<th>UE category</th>
<th>Supported modulation</th>
<th>Max codes</th>
<th>Max rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>QPSK &amp; 16QAM</td>
<td>5</td>
<td>3650</td>
</tr>
<tr>
<td>6</td>
<td>QPSK &amp; 16QAM</td>
<td>5</td>
<td>3650</td>
</tr>
<tr>
<td>7</td>
<td>QPSK &amp; 16QAM</td>
<td>10</td>
<td>7300</td>
</tr>
<tr>
<td>8</td>
<td>QPSK &amp; 16QAM</td>
<td>10</td>
<td>7300</td>
</tr>
<tr>
<td>9</td>
<td>QPSK &amp; 16QAM</td>
<td>15</td>
<td>10216</td>
</tr>
<tr>
<td>10</td>
<td>QPSK &amp; 16QAM</td>
<td>15</td>
<td>14383</td>
</tr>
<tr>
<td>12</td>
<td>QPSK</td>
<td>5</td>
<td>1825</td>
</tr>
</tbody>
</table>

Table G.1. UE categories
Appendix H

Logical, Transport and Physical Channels

Logical channels define what type of data that is transferred and are classified into two groups, control channels for the transfer of control information and traffic channels for transfer of user information. The control channels are:

- **BCCH** - Broadcast Control Channel, a downlink channel for broadcasting system control information.
- **PCCH** - Paging Control Channel, a downlink that transfers paging information.
- **DCCH** - Dedicated Control Channel, a channel that transfers dedicated control information between a UE and the RNC.
- **CCCH** - Common Control Channel, a channel for transmitting control information between the network and UEs.

The traffic channels are:

- **DTCH** - Dedicated Traffic Channel, a channel dedicated to one UE, for the transfer of user information.
- **CTCH** - Common Traffic Channel, a downlink channel for transfer user information to all or a group of specified UEs.

The transport channel defines how and with what characteristics, data is transferred. Transport channels are divided in common channels and dedicated channels, where the common channels can be used by any user at any time and the dedicated channel is reserved for a single user. The only dedicated transport channel is the dedicated channel, DCH, which carries all the information intended for a given user. The common transport channels are:
• BCH - Broadcast Channel, a channel that transmits information specific to
  the network or for a given cell.
• FACH - Forward Access Channel, a downlink channel that carries control
  information to terminals.
• PCH - Paging Channel, a downlink channel that transmits relevant data to
  the paging procedure.
• RACH - Random Access Channel, an uplink that carries control information
  the UE, such as request to set up a connection.
• CPCH - Common Packet Channel, an uplink channel that is an extension
  to the RACH channel that carries packet-based user data.
• DSCH - Downlink Shared Channel, a channel that carries dedicated user
  data and/or control information.

The physical channels define the exact physical characteristics of the radio
channel and they are divided into common channels, dedicated channels and indi-
cation channels. The common physical channels are:
• P-CCPCH - Primary Common Control Physical Channel, a channel that
  broadcasts system information.
• SCH - Synchronization Channel, a channel used for synchronization.
• S-CCPCH - Second Common Control Physical Channel, a channel that
  transmits idle-mode signaling and control information to UE.
• P-CPICH - Primary Common Pilot Channel, a channel that sends the scram-
  bling code of the cell.
• PRACH - Physical Random Access Channel, a uplink channel that among
  others carries access requests.
• PDSCH - Physical Downlink Shared Channel, a channel that carries dedi-
  cated user data and/or control information.
• PCPCH - Physical Common Packet Channel, a channel that is specifically
  intended to carry packet data.

The dedicated channels are:
• DPDCH - Dedicated Physical Data Channel, a channel that transmits ded-
  cated data.
• DPCCH - Dedicated Physical Control Channel, a channel that transmits
  control signals, such as power control.
• AICH - Acquisition Indication Channel, a channel that acknowledges the
  RBS has acquired a UE random access attempt.
• PICH - Page Indication Channel, a channel that informs a UE if it should monitor the page channel.

• CSICH - CPCH Status Channel, a downlink channel that carries the status of the CPCH.

• CD/CA-ICH - Collision Detection/Channel Assignment Indicator Channel, a downlink channel that indicates whether the channel assignment is active or inactive.

In the MAC and RLC layer the logical channels are mapped onto the transport channels and in the physical layer the transport channels are mapped onto the physical channels, the mapping is described in [8] and [10]. This is only R99 channels, if for example HSDPA technique is applied some additional channels are required.
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