Mikko Mattila

THE TESTABILITY REQUIREMENTS FOR A WCDMA BASE STATION

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Bachelor's Thesis
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Degree program in Information Technology
Oulu University of Applied Sciences

PREFACE

This Bachelor's Thesis was made for Elektrobit Wireless Communications Ltd. in Oulu. The supervisor of this Thesis was Principal lecturer Lea Hannila from Oulu University of Applied Sciences, Raahe campus and the mentor was Senior design engineer Antti Malinen from Elektrobit Wireless Communications Ltd.

I want to say thanks to Specialist Juha Mankinen from Elektrobit Wireless Communications Ltd, who discovered the topic of this thesis and Manager Mikko Miettinen, who was my contact person in Elektrobit Wireless Communications Ltd.

Oulu 18 February 2013

Mikko Mattila

TIIVISTELMÄ

Oulun seudun ammattikorkeakoulu, Raahen kampus
Tietotekniikan koulutusohjelma

Tekijä: Mikko Mattila
Opinnäytetyön nimi: Testattavuusvaatimukset WCDMA-tukiasemalle
Työn ohjaajat: Antti Malinen (EB), Lea Hannila (OAMK)
Työn valmistumislukukausi ja -vuosi: Kevät 2013 Sivumäärä: 27 + 17

Opinnäytetyön tarkoituksena oli määrittää testattavuusvaatimukset WCDMA-tukiasemalle. Vaatimuksilla varmistetaan mahdollisten virheiden löytyminen ja näin ollen testaustyön nopeutuminen. Vaatimukset kattavat WCDMA-tukiasemajärjestelmän L1 (fyysinen kerros)- ja L2 (MAC-kerros) -protokollakerrokset, jotka on määritelty 3GPP-standardissa. Työn tilaajana toimi Elektrobit Wireless Communications Ltd.

Opinnäytetyössä tutkittiin 3GPP-standardin määrittelemiä ominaisuuksia WCDMA-tukiasemalle, joita käytettiin pohjana mittauksille. Mittausten luonnosteluun käytettiin Microsoft Excel – ohjelmaa, josta valmiit mittaukset siirrettiin Web-pohjaiseen JIRA–vaatimustenhallintaohjelmaan.

Opinnäytetyön tuloksena WCDMA-tukiasemalle määriteltiin 3GPP-standardiin perustuvat testattavuusvaatimukset, joita tehdessä tutustuttiin WCDMA-järjestelmään ja 3GPP-standardiin. Vaatimukset jaettiin JIRA-vaatimustenhallintajärjestelmässä neljään mittausluokkaan, joiden ominaisuuksilla tutkitaan tukiaseman toiminnallisuutta. Mittausluokat ovat reaaliaika-, HSDPA-, HSUPA- ja yleiset mittaukset. Osa mittauksista voidaan tehdä reaaliaikaisesti ja osa kirjoitetaan lokitiedostoon, josta tulokset analysoidaan jälkikäteen. Mittausten lisäksi vaatimuksissa määriteltiin, miten mittaukset esitetään graafisessa käyttöliittymässä, jota toteutetaan parhaillaan. Vaatimuksia voidaan pitää myös pohjatyönä LTE-tukiaseman testattavuusvaatimuksille.

Asiasanat:

Testattavuus, WCDMA, L1/L2, reaaliaika, HSDPA, HSUPA

ABSTRACT

Oulu University of Applied Sciences, Raahe Campus
Degree Programme in Information Technology

Author: Mikko Mattila
Title of thesis: The testability requirements for a WCDMA base station
Supervisors: Antti Malinen (EB), Lea Hannila (OAMK)
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The purpose of this Bachelor's thesis was to drive and define testability requirements for a WCDMA base station. The requirements will ensure that the needed testability features are defined so that the visibility to software maturity increases and the testing effort in terms of time decreases. The testability features will cover the L1 (physical) and L2 (MAC) layers defined by the standardization for WCDMA base station systems. This bachelor's thesis was made for the Elektrobit Wireless Communications Ltd.

The thesis work was carried out by investigating the WCDMA base station features defined by a 3GPP standardization, they were used as a basis for the measurements. The draft version was made into a Microsoft Excel sheet, where the complete measurements were mapped to a Web-based requirement and error management software called JIRA.

As a result of this thesis, 3GPP standardization based testability requirements were defined for the WCDMA base station and during the thesis work a WCDMA-system and a 3GPP standardization got introduced. The requirements were divided into four measurement categories in a requirement and error management system called JIRA. The measurement categories are Real-Time, HSDPA, HSUPA and General measurements. These features are needed for investigating the WCDMA base station functionality. Some of the measurements can be performed in real time when performing test cases and some measurements can be written to a log file for analyzing the results afterwards. A GUI definition was described as well as a measurement definition. The GUI implementing work is presently ongoing and the requirements can be a background work for LTE base station's testability requirements.

Keywords:

Testability, WCDMA, L1/L2, Real-Time, HSDPA, HSUPA

CONTENTS

1 INTRODUCTION

This bachelor's thesis was made for Elektrobit Wireless Communications Ltd. Elektrobit Ltd (brand name EB) was founded in Oulu, Finland in 1985. The company is divided into two business segments; EB Automotive business segment, which offers embedded software and hardware solutions for automotive industry and EB Wireless business segment which offers solutions for wireless technologies. (Elektrobit, date of retrieval 30.5.2012)

The aim of this thesis was to define WCDMA base stations testability requirements at Physical (PHY) Layer (L1) and Data Link (L2) Layer levels. WCDMA (Wideband Code Division Multiple Access) is a radio interface, which is used in UMTS's (Universal Mobile Telecommunication System) third generation (3G) mobile cellular technology networks based on the GSM standard. WCDMA defines signal modulations and communications between mobile devices and base stations.

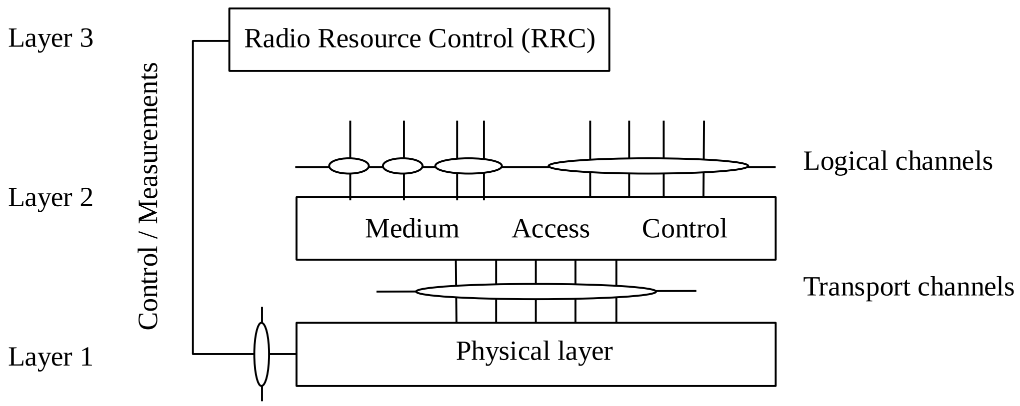

FIGURE 1 Radio interface protocol architecture around the physical layer (Elektrobit, Internal source, date of retrieval 7.6.2012)

The theoretic data transmission speed in 3G is up to 84 Mbps, when a dual cell and MIMO (Multiple Input, Multiple Output) are used. The data transmission capacity is more flexible than the previous generation, which is better known as 2G. WCDMA has two supported basic techniques. FDD (Frequency Division Duplex) gives opportunity to use 250 speech channels at the same time. This technique is based on the fact that downlink and uplink have own 5MHz frequency bands used by devices and base stations. A 1920-1980 MHz frequency band is dedicated to downlink and a 2110-2170 MHz band to uplink. TDD (Time Division Duplex) uses the same frequency band both ways. The transmission works alternately and enables only 120 channels at the same time, but it requires only half of the bandwidth compared to FDD. 1900-1920 MHz and 2020-2025 MHz bandwidths are allocated to TDD technique (Wikipedia, W-CDMA, Date of retrieval 10.6.2012, Granlund, K. 2001, 117-122 & Holma, H. & Toskala, A. 2002, 3-5).

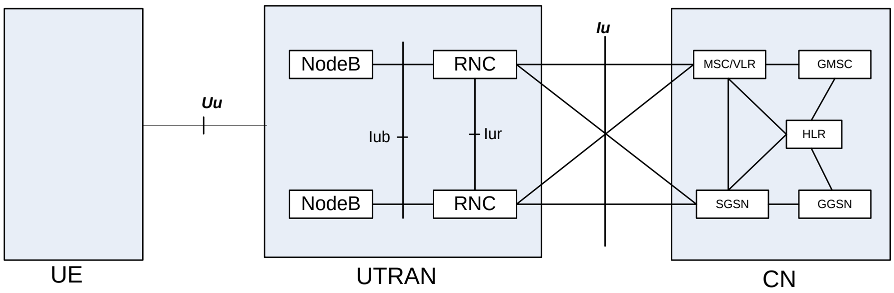

FIGURE 2 UMTS and UTRAN high-level system architecture (Elektrobit, Internal source, date of retrieval 7.6.2012)

Figure 2 shows a UMTS and UTRAN high-level system architecture. UMTS has three distinct elements and two interfaces. These elements are UE (User Equipment), UTRAN (UMTS Terrestrial Radio Access Network) and CN (Core Network) and interfaces are Uu and Iu. UE is a user device, which is used for radio communication over the air for example a mobile phone. UTRAN is the radio network in the UMTS network and UTRAN is connected to UE over the Uu (air) interface. UTRAN consists of two elements; NodeB (UMTS Base Station) and RNC (Radio Network Controller). NodeB takes care of the data flow converting between Iu and Uu interfaces and also radio resource management. RNC is an owner and controller of radio resources. RNC is also the service access point, which provides UTRAN services to CN (3GPP TS25.401, date of retrieval 10.6.2012, Elektrobit 2012, date of retrieval 7.6.2012).

In Rel'99 dedicated channels are used to carry a user data transmission. The dedicated channel in downlink is Downlink Dedicated Physical Channel (Downlink DPCH), where the downlink data is transmitted. The user data and time multiplexing for physical control information are applied by downlink DPCH. In uplink dedicated channels the user data transmission contains one or more Dedicated Physical Data Channels (DPDCH) with a variable Spreading Factor (SF) and a single Dedicated Physical Control Channel (DPCCH). The DPDCH's control information like Transmission Power Control (TPC), Transport Format Combination Indicator (TFCI), Feedback Information (FBI) and Pilot bits are transported in DPCCH (3GPP TS25.401, date of retrieval 10.6.2012).

Common channels in Rel'99 are; Broadcast Channel (BCH) for system and cell specific information, Forward Access Channel (FACH), Paging Channel (PCH) for transporting, Common Packet Channel (CPCH), Common Pilot Channel (CPICH) used in downlink and scrambled with cell-specific scrambling code, Synchronization Channel (SCH) for a cell search operation used in downlink, Random Access Channel (RACH) used in uplink and Acquisition Indicator Channel (AICH) for indicate the RACH signature reception, which is used in downlink. (Holma, H. & Toskala, A. 2002, 101-104 & Elektrobit 2012, date of retrieval 7.6.2012)

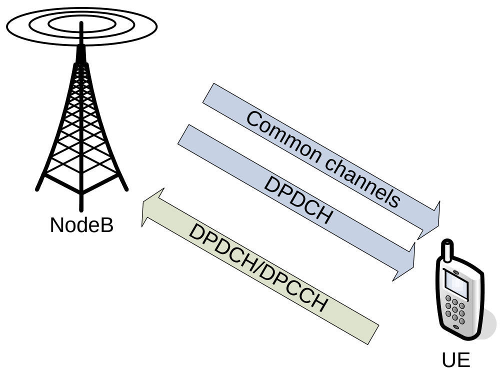

FIGURE 3 WCDMA rel'99 user data transmission (Elektrobit 2012, date of retrieval 7.6.2012)

High-Speed Downlink Packet Access (HSDPA) has come along the release 5, when it was introduced in 3GPP. The main idea of HSDPA was to increase a downlink (DL) packet data throughput. With HSDPA also came new channels called High-Speed Downlink Shared Channel (HS-DSCH) and High-Speed Shared Control Channel (HS-SCCH) in downlink and High-Speed Dedicated Physical Communications Channel (HS-DPCCH) in uplink. Subsequent to HSDPA also came new features, like Adaptive Modulation and Coding (AMC), Hybrid Automatic Repeat request (HARQ), 2ms Transmission Time Interval (TTI), Advanced Packet Scheduling (PS) and an enhanced multi code operation (3GPP TS25.308, date of retrieval 10.6.2012 & Elektrobit 2012, date of retrieval 7.6.2012).

In HSDPA, code and power resources are shared with all users, who are active. That is why more channels are needed. High-Speed Downlink Shared Channel (HS-DSCH) supports Adaptive Coding and Modulation (AMC), which allows that a transmission format can dynamically change in every 2 milliseconds. Also, instead of Quadrature Phase Shift Keying (QPSK), a 16QAM modulation can be used in a good radio channel condition. To enable higher data rates, the 1/3 turbo code may be punctured down. If all codes are allocated to a single UE, up to 15 codes with a fixed spreading factor of 16 can be received, depending on the UE capabilities. (3GPP TS25.308, date of retrieval 10.6.2012 & Elektrobit 2012, date of retrieval 7.6.2012)

Data decoding enabling control information on HS-DSCH and data combining to perform a physical layer is carried through High-Speed Signaling Control Channel (HS-SCCH). Codes to de-spread modulation info, Hybrid-ARQ (HARQ) related information and an ARQ process number are carried on HS-SCCH, whereas HARQ's following feedback signalling and channel based scheduling support are transmitted in uplink of High-Speed Dedicated Physical Control Channel (HS-DPCCH). For example, Channel Quality Information (CQI) informs a communicative channel condition to the scheduler and HARQ ACK/NACK information tells to the sender if the decoding process was successful and if not. If it was not, it requests retransmission. (3GPP TS25.308, date of retrieval 10.6.2012)

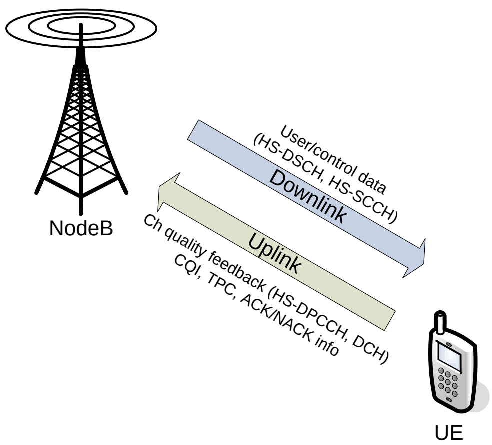

FIGURE 4 HSDPA Channels (Elektrobit 2012, date of retrieval 7.6.2012)

High-Speed Uplink Packet Access (HSUPA), also known as E-DCH (Enhanced uplink Dedicated Channel) in 3GPP, was introduced in the release 6. The purpose of HSUPA is to increase uplink data rate. New features in HSUPA are for example a fast NodeB based scheduling, L1 HARQ and Shorter TTI (2ms/10ms). Subsequent to HSUPA there were also introduced new channels; E-DPDCH and E-DPCCH in uplink and E-AGCH, E-HICH and E-RGCH in downlink, which are seen in Figure 5. (3GPP TS25.319, date of retrieval 10.6.2012 & Elektrobit 2012, date of retrieval 7.6.2012)

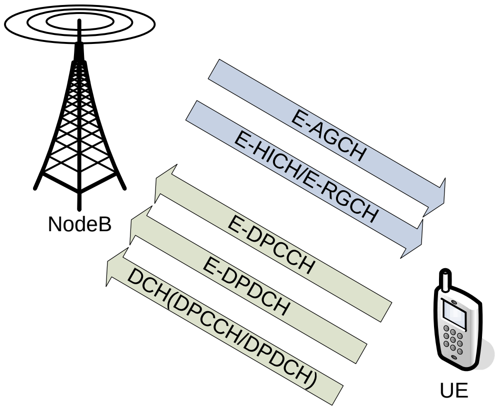

FIGURE 5 HSUPA Channels (Elektrobit 2012, date of retrieval 7.6.2012)

For the dedicated data transmission, where the data priority and power headroom are transported during data transmission scheduling information like a buffer status, there is a channel E-DPDCH (E-DCH Dedicated Physical Data Channel). E-DPCCH (Dedicated Physical Control Channel) is used for E-DPDCH’s detection and decoding with the associated control data. There is Happy Bit, which informs if the UE has enough resources for transmission. E-HICH (E-DCH HARQ Indicator Channel) is used to transmit HARQ feedback information. NodeB sends an acknowledgement (ACK) if transmitted E-DPDCH TTI is received correctly and a negative acknowledgement (NACK) if TTI is received incorrectly. E-RGCH (E-DCH Relative Grant Channel) indicates an E-DCH transmit power level to the UE. E-AGCH (E-DCH Absolute Grant Channel) is a shared channel, which tells UE how its transmit power level should be regulated (3GPP TS25.319, date of retrieval 10.6.2012 & Elektrobit 2012, date of retrieval 7.6.2012).

2 DEFINITION

The planning and working of the thesis were started by thinking the needs of the project and it was urgent to drive congruent testing methods to the project. Also, the topic "Testability requirements for a WCDMA base station" was assigned. It was important to drive these testing requirements to mitigate project testing and of course to save time and costs.

The purpose of this bachelor's thesis was to drive and define testability requirements for a WCDMA base station and more specifically L1 and L2 layers. The testability features will cover the L1 and L2 layers according to the 3GPP standardization. The testability requirements are defined in order to improve the overall effectiveness of integration and verification testing of a base band software. In practice, these requirements will ensure that the needed testability features are defined so that the visibility of the software maturity increases and the testing effort in terms of time decreases. The testability features will cover the L1 and L2 layers defined by the 3GPP 25-series standardization for WCDMA base station systems. L1 (physical layer, often termed PHY) is the lowest and L2 (MAC layer) is the second lowest layer of the three-layered radio interface.

Measurements are categorized in four classes; Real-Time, HSDPA, HSUPA and General -measurements. Some of the features are needed only afterwards from a log file, not real-time. Because the bandwidth is limited, it is impossible to get all data in real time. Real-Time Measurements consists mainly of a release '99 of 3GPP and these features can be measured real time. This parent feature contains cell information, power control, RACH, receiver and channel information measurements. An HSDPA feature contains measurements related to MAC-HS PDU transmission, flow control, schedulers and HS-DSCH data transmission and reception. HSUPA feature contains both HSUPA Trace and HSUPA real time measurements related to Cell & DCH Uu Load, received compensated C/I, variables, grant reduction reason and E-DCH reception and transmission. "General measurements" contains features, which are not directly related to real-time, HSDPA or HSUPA. "General measurements" is the parent feature, which contains for example a DSP memory and user information measurements.

3 ENVIRONMENT

The testing environment is reviewed in this chapter. WCDMA is one piece of this project and L1 and L2 levels are two lowest levels of UMTS three leveled protocol architecture. Figure 6 shows the L1/L2 level as a "NodeB BB-module data debug and trace" –box. (Elektrobit 2012, date of retrieval 7.6.2012)

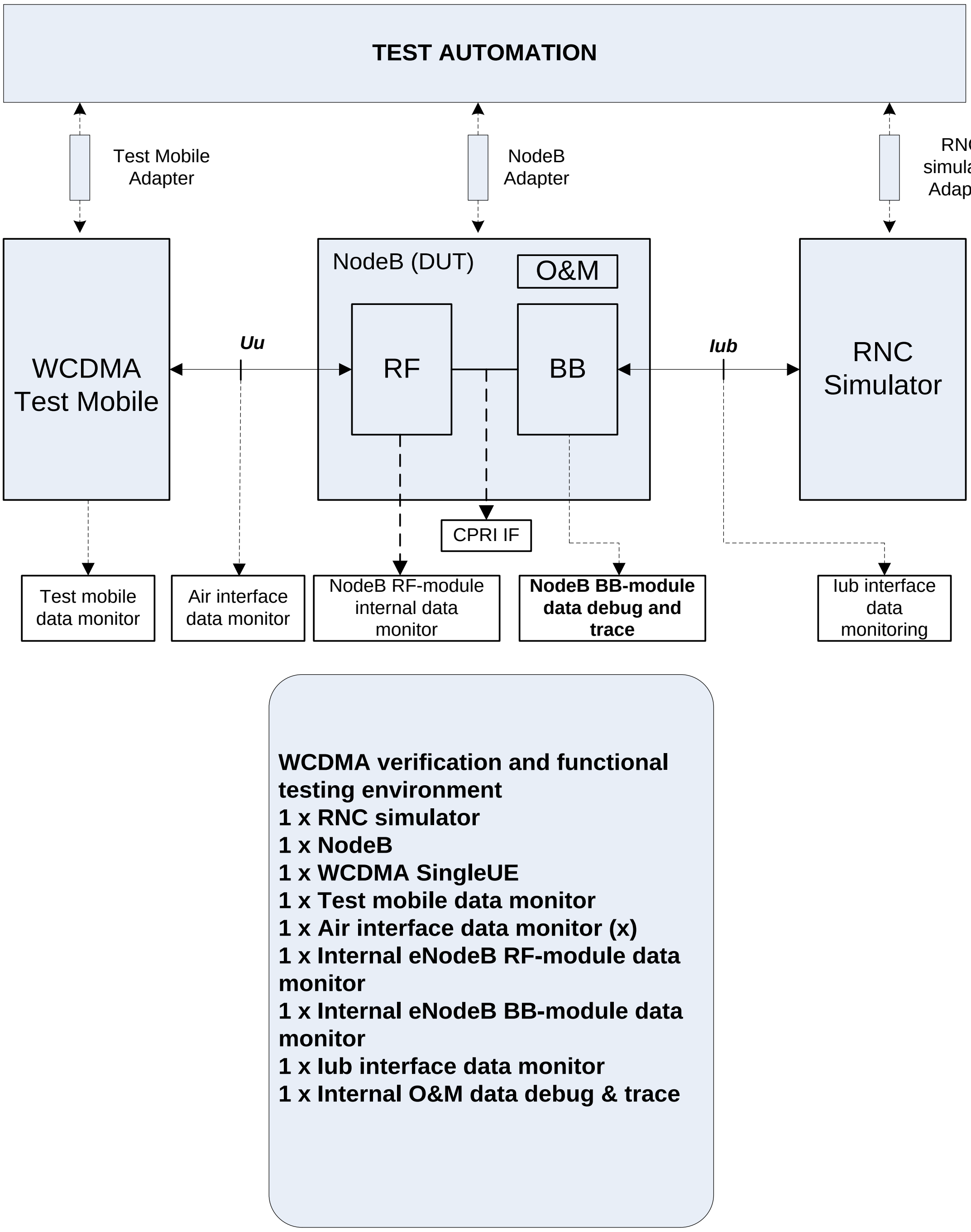

FIGURE 6 WCDMA single-UE testing environment (Elektrobit 2012, date of retrieval 7.6.2012)

3.1 Testing Environment

The measurements in this thesis concentrate on ensuring the early phase testing of selected features in the L1/L2 level functionality. The aim of the testing is mainly on an error debugging and verification. The set up can also be used as a backup for an L3 testing, if the real L3 testing cannot be done. Typical test scenarios in the L1/L2 testing are for example user dedicated and physical layer procedures and E-DCH-, HSDPA, cell setup and common channel configurations.

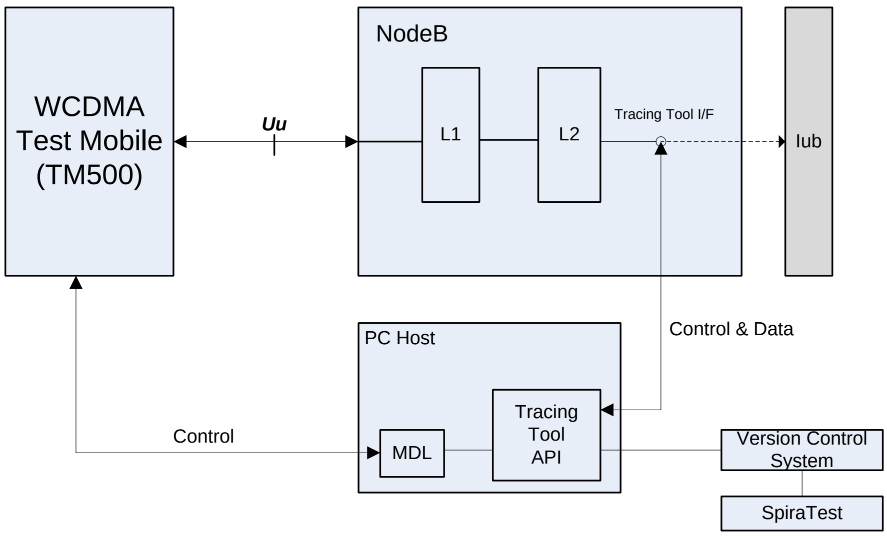

FIGURE 7 L1/L2 Testing Environment (Elektrobit 2012, date of retrieval 7.6.2012)

The NodeB testing environment is running on Linux workstations and the Test Mobile control and logging tool is running on Microsoft Windows. The monitoring points in the testing environment are Uu and Iub. For monitoring an Iub interface is used an open source software called Wireshark and the tracing tool is connected to NodeB via a Tracing-tool interface, which is a message queue based interface. L1 is the physical layer sub-system, which is responsible for the L1 channel processing and it can be split in both Downlink and Uplink. L2 handles all cell and user resources management. Also frame protocols and HSDPA and E-DCH traffic scheduling are handled by an L2 sub system. For example, a CPU load and an overload control are under L2 responsibilities. (Elektrobit 2012, date of retrieval 7.6.2012)

The test mobile in the L1/L2 test environment is Aeroflex TM500. NodeB and TM500 are connected via the Uu interface and it is configured both in the L1 and L2 test modes. TM500 and Tracing tool communicate via a Mobile Data Logger (MDL) application provided by Aeroflex. Test scripts are stored to a version control system and test specifications are stored in a commercial test management tool SpiraTest provided by Inflectra. (Elektrobit 2012, date of retrieval 7.6.2012)

Figure 8 shows WCDMA monitoring points (Elektrobit 2012, date of retrieval 7.6.2012). From the test mobile data monitor can be seen channel information, user/cell performance, BER/BLER, Throughputs, received DL power, transmitted UL power, power control information, PHY/MAC statistics and higher layer information. An air interface data monitor shows radio frequency (RF) measurements, spectrum/signal analyzer, code domain power measurements, common/dedicated channel and user info and air interface protocol info. NodeB RF module internal data monitor shows for example the number of carriers and carrier information and Tx/Rx power and frequency information. Base band (BB) module information shows messages between MAC and PHY (L1/L2), NodeB functionality and Node B Application Part (NBAP) message information. Iub interface info consists of NBAP messages, Radio Resource Control (RRC) analysis, call analysis, Throughput measurements and Iub analysis. (Elektrobit 2012, date of retrieval 7.6.2012)

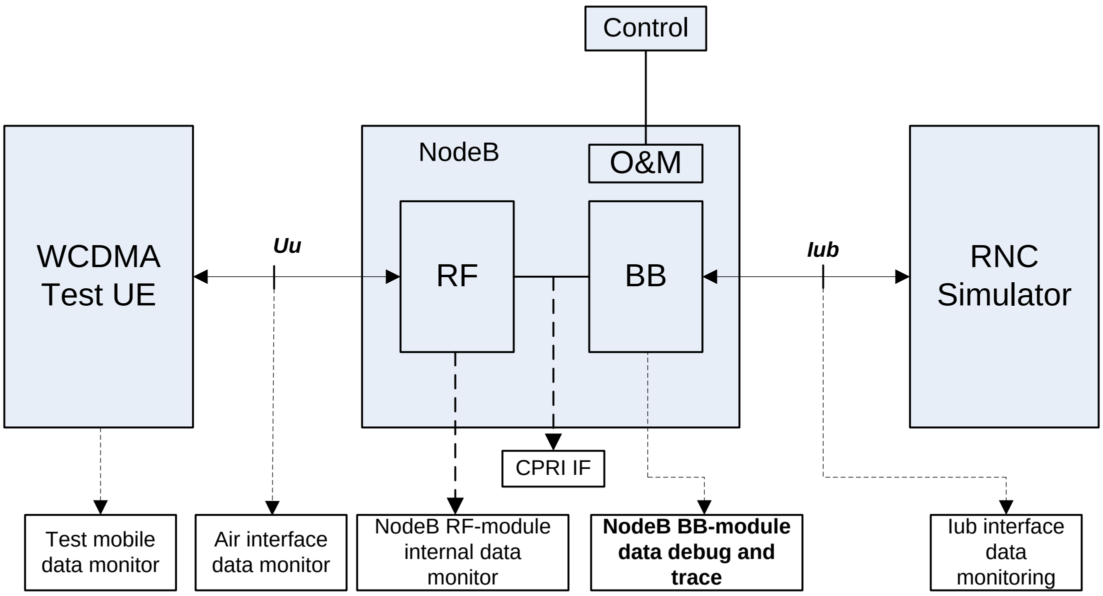

FIGURE 8 WCDMA monitoring points (Elektrobit 2012, date of retrieval 7.6.2012)

3.2 JIRA

The project uses an issue tracking software called JIRA for requirement and error management purposes. JIRA is the commercial issue tracking software (database), developed by Australian company called Atlassian and it can be used via a web browser. The requirements are categorized to four measurement types (Real-Time, HSDPA, HSUPA and General) and three levels (Epic, Parent feature and Child feature). The measurements are handled as features in the JIRA system. (Atlassian, date of retrieval 10.6.2012 & Wikipedia, JIRA, date of retrieval 10.6.2012)

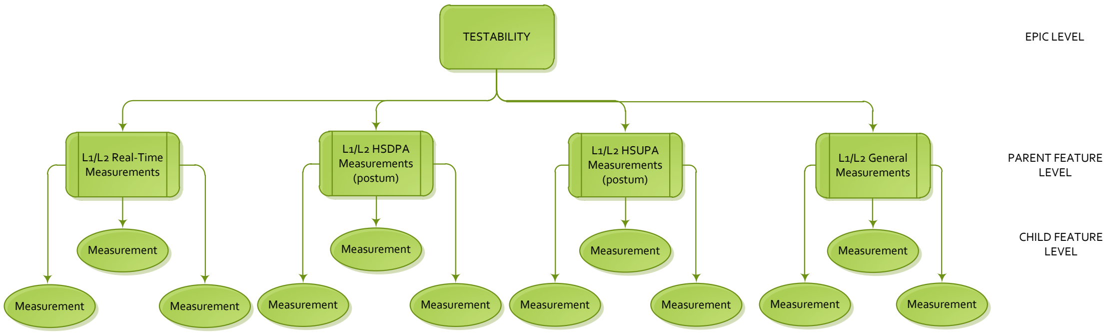

FIGURE 9 Testability levels in JIRA (Mattila, M. 2012)

Testability is the Epic level which is the highest level and parent features are divided into four categories; L1/L2 Real-Time measurements, L1/L2 HSDPA measurements, L1/L2 HSDPA measurements and L1/L2 General measurements. The lowest level is Child Feature level, where the measurements can be found.

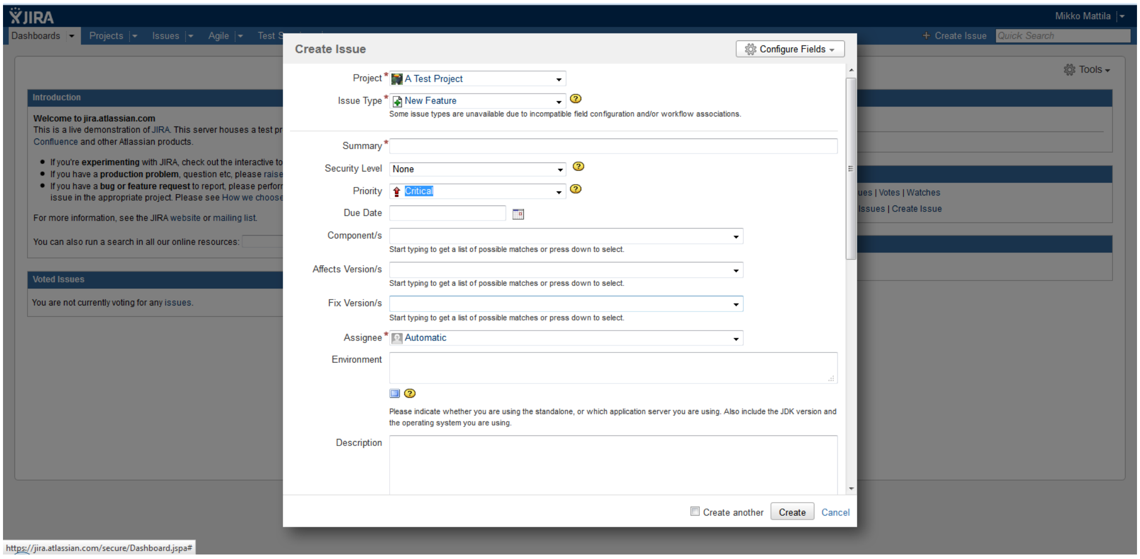

FIGURE 10 Creating an Issue in JIRA (Mattila, M. 2012, Atlassian, date of retrieval 12.8.2012)

Creating a measurement/issue to JIRA occurs by filling a template in the web browser. The required fields are project, issue type, summary, security level, component/s and description. The project field tells to which project an issue/feature belongs. In the issue type field it can be chosen Epic, Feature (in this case the option is a feature for measurements), Feature detail or Error. The summary field tells the topic of the issue. The security level tells whether the feature is internal or external. The internal will be shown only to the project and customer and the external is also shown to partners. The component field shows to which technology the issue belongs (in this case WCDMA). And the description field tells specific information of the feature. There is also a Label field, which helps searching issues and a comment field, where every change made to the issue will be seen. Also, in the history field it can be seen every change that has been made. Every time the issue has been changed, a reporter, assignee and watcher receive an e-mail, where changes can be seen. JIRA gives a unique ID-number (in Figure 11 ID is TST-48593) to every issue, which also helps searching issues.

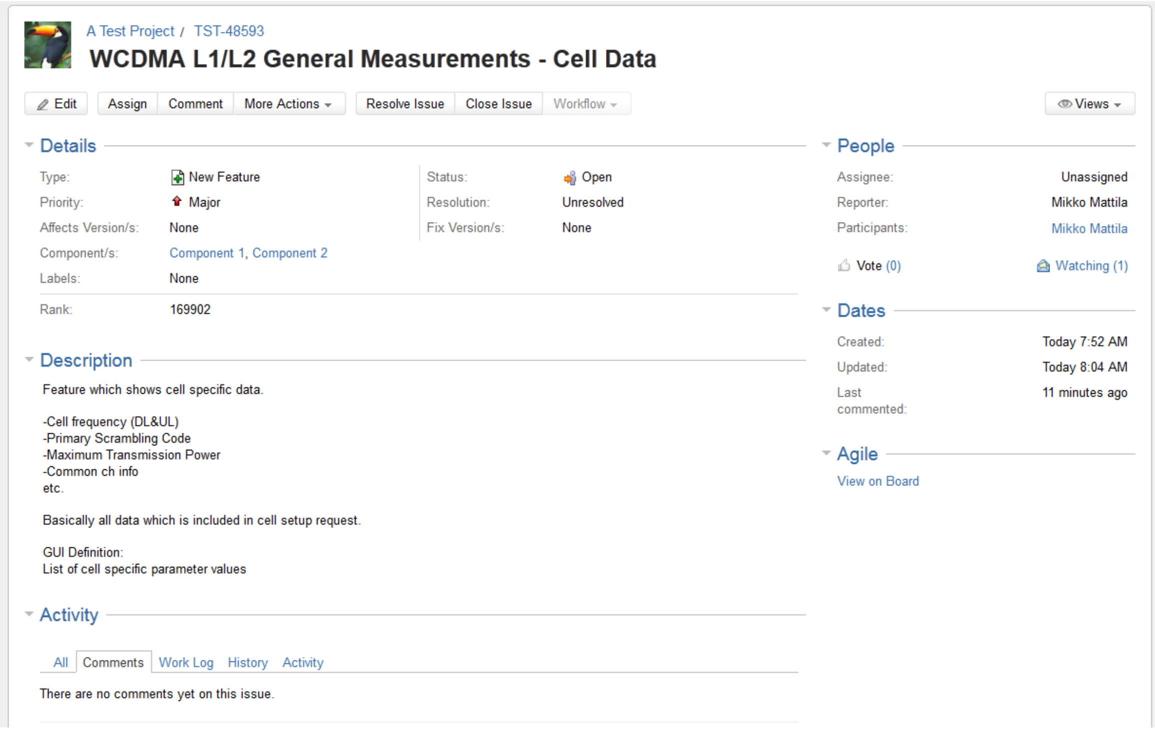

FIGURE 11 An example of the JIRA issue (Mattila, M. 2012, Atlassian, date of retrieval 12.8.2012)

4 IMPLEMENTATION

In this chapter, it is described how the implementation work was accomplished; the implementation process and what kinds of methods were used and arguments, why specific measurements were needed.

The implementation work was started by exploring and studying 3GPP specifications and comparing specifications with the project plan and collecting measurements which were valid to cover the L1/L2 layers testability. The draft version of valid testability requirements were listed to a Microsoft Excel sheet. The implementing work was continued with weekly review meetings and via email if needed. As the requirement descriptions were sufficiently specified, the draft versions of the measurements were mapped to JIRA for an approval. When the measurement was approved of, it was assigned to software developers for a further development. JIRA was the most important tool.

Features were categorized in four classes because it is important to perform some of the measurements in real time when performing test cases and with some measurements it was enough to write the results to a log file and analyze the results afterwards from the log file.

4.1 L1/L2 Real Time measurements

Some of the measurements needed to be performed in real time, while running the tests. For example, a power control is needed for monitoring and adjusting transmission power levels between NodeB and UE. The Power control is an important feature which affects straight to the system capacity. It is important that the user equipment’s transmission power level does not load the system too much, but leads the power control to adjust it to a certain level that the connection is good enough. DPCCH power level is adjusted to every slot by a closed loop power control. (Holma, H. & Toskala, A. 2006. 87)

The Power control also adjusts a SIR (Signal to Interference Ratio) target. With a closed loop power control, NodeB measures continuously the SIR value. If the SIR value is greater than the SIR target, NodeB tells to UE to decrease the transmission power and conversely. The SIR can be calculated using pattern: SIR=RSCP/ISCP*SF. The Received SIR, RSCP (Received Signal

Code Power) and ISCP (Interference Signal Code Power) are measured on the DPCCH physical channel.

While executing tests, it is very important that all parts in the system are synchronized. A Sync status measurement tells with colors, when system is synchronized. The Initial sync shows as yellow color, the In sync state as green, the out of sync as red color and the radio link failure shows as a red slash over the green light. Uplinks sync status is measured both from a Rake receiver and from physical layer point of view.

Synchronizing is also important when analyzing log files. Usually it is necessary to get several measurements at the same time and to synchronize the log files, which is important when finding possible faults. If a timestamp for some reason was not possible to perform, there were other features to get log files in In sync. SFN (System Frame Number) is one feature and it was included in every measurement. When comparing different log files, SFN helps equivalent spot findings. Another feature that was used was CFN (Connection Frame Number) (appendix 1).

4.2 L1/L2 HSDPA Measurements

As mentioned earlier, the main idea of HSDPA was to increase the downlink data throughput and it was one of the HSDPA real time measurements. Throughput is the average rate of successful message delivery over a communication channel. It tells how fast (bit/s) a message is delivered over a communication channel. Throughput was also included in some other measurements, because of its importance, for example throughput was included in an IR RACH preamble measurement.

One of the biggest features is an HSDPA trace, which has a big role in an HSDPA measurements feature. The HSDPA trace is not real time because the volume of data is so massive that it must be analyzed afterwards from a log file. After a few minutes of measuring, there were several gigabytes of log data and several thousands of lines in the log file. Also, as 2 milliseconds TTI (Transmission Time Interval) came along, when HSDPA was introduced, the trace was impossible to analyze in real time. The scheduler provides the HSDPA trace, which includes all scheduling decisions for each TTI for each user. The HSDPA measurement includes for example measurements like MAC-HS PDU transmission, HS-DSCH data transmission and reception measurements (appendix 2).

4.3 L1/L2 HSUPA Measurements

As opposed to HSDPA, the main idea of HSUPA was to increase uplink data throughput and it was one feature in HSUPA too. The Measurement is working almost the same way than in HSDPA, but in uplink.

HSUPA needs its own trace, so there was also specified a HSUPA trace. The HSUPA trace is also written into a log file. The HSUPA trace consists of several measurements. It is important to get information from UE, UE scheduling, scheduled Grant, HARQ (Hybrid Automatic Repeat Request) and Allocation. From the HSUPA trace it can also be inspected cell measurements. Throughput and SFN are also included in the trace. A Scheduler is an important part of HSUPA, so the HSUPA trace includes a lot of scheduling information.

Signal traffic measurements are also important in the base stations testing. As well as SIR, one of the signal measurements is ACK/NACK (Acknowledge/Non-Acknowledge). In this measurement a HARQ process sends the signal and the response includes an ACK or NACK message. ACK means that the signal is passed and NACK means that the signal is failed. The Tracing tool is counting every ACKs and NACKs and performs real time counting in GUI. HARQ, ACK and NACK measurements were included in the HSUPA trace too (appendix 3).

4.4 L1/L2 General Measurements

In the general measurements miscellaneous measurements were collected. They were not related straight to other categories. However, the general measurements were as important as other measurements. “General measurements” includes measurements that are related to the user, data, cell and memory and a CM (Compressed Mode) pattern is also specified in this category (appendix 4).

5 POSSIBILITIES FOR FURTHER DEVELOPMENT

The testability requirements can be developed further by implementing a graphical user interface (GUI). The purpose is that the GUI can be connected remotely to a base station and the testing person can see the results straight from the GUI by real time or the results can be written to a text file to analyze logs afterwards. The testing person can choose the wanted measurement by changing flags from the graphical user interface. The GUI can show diagrams or a text and there will be a real time error log where possible crashes or errors can be seen, and the GUI alarms if an error happens. The purpose is that all results can be seen via a graphical user interface. It helps the testing and verification work and saves time and money. In figure 12 can be seen an example of what a GUI can look like.

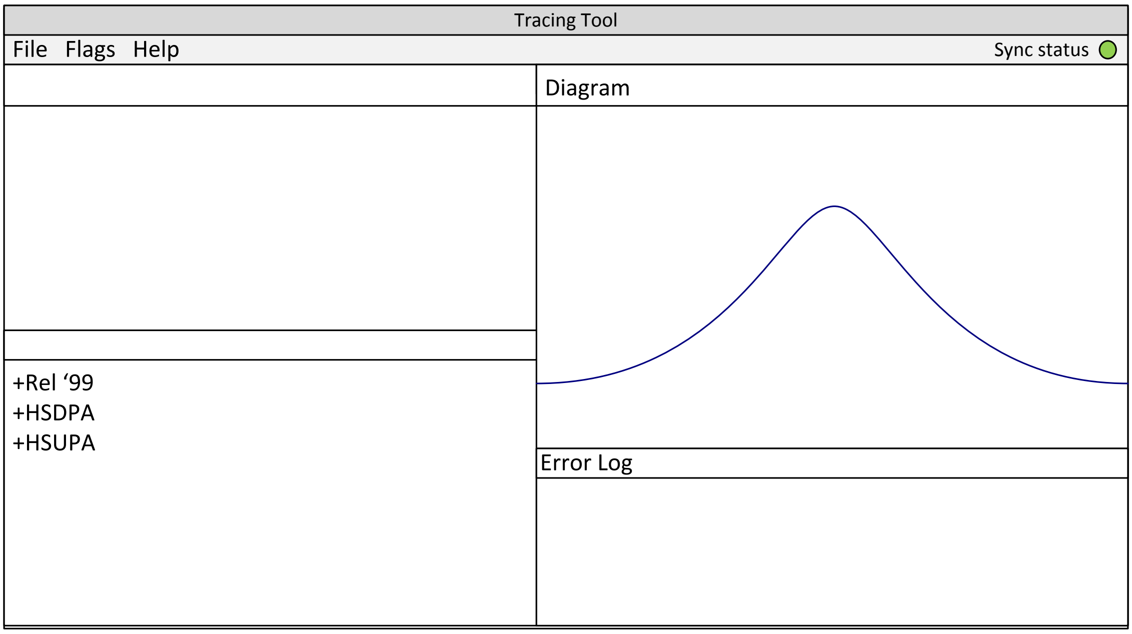

FIGURE 12 An example of tracing tool graphical user interface (Mattila, M. 2013)

6 SUMMARY

Elektrobit Wireless Communications Ltd. commissioned this Bachelor's thesis for project needs. The purpose of this thesis was to drive and define the testability requirements for a WCDMA base station in order to improve the overall effectiveness of the integration and verification testing of a base band software.

The topic was very challenging because during the thesis work, a lot of new information was received. The information was collected from the Internet and literature related to UMTS and from Elektrobit's internal documents. I was introduced first time to a 3GPP standardization and a WCDMA system and it was very interesting.

The main result was that the thesis meets both the project and company needs. The requirements were based on the 3GPP standardization and the measurements were mapped to JIRA for a further development. The measurements were divided into four categories in JIRA; Real-Time, HSDPA, HSUPA and General measurements. These features are needed for investigating a WCDMA base station functionality at the L1/L2 levels. Some of the testability requirements will be tested soon and the rest of them a little bit later.

7 TERMINOLOGY

16/64QAM	16/64 Quadrature Amplitude Modulation
3G	3rd Generation of mobile telecommunications technology
3GPP	3rd Generation Partnership Project
ACK/NACK	Acknowledge/Non-Acknowledge
AG	Absolute Grant
AMC	Adaptive Modulation and Coding
BB	Base Band
BCH	Broadcast Channel
BER	Bit Error Rate
BLER	Block Error Rate
CFN	Connection Frame Number
CN	Core Network
CM	Compressed Mode
CPCH	Common Packet Channel
CPICH	Common Pilot Channel
CQI	Channel Quality Information
DL	Downlink
DPCCH	Dedicated Physical Control Channel
DPCH	Downlink Dedicated Physical Channel
DPDCH	Dedicated Physical Data Channel
E-AGCH	E-DCH Absolute Grant Channel
E-DPCCH	Dedicated Physical Control Channel
E-DCH	Enhanced uplink Dedicated Channel
E-DPDCH	E-DCH Dedicated Physical Data Channel
E-HICH	E-DCH HARQ Indicator Channel
E-RGCH	E-DCH Relative Grant Channel
FACH	Forward Access Channel
FBI	Feedback Information
FDD	Frequency Division Duplex
FP	Frame Protocol
GUI	Graphical User Interface
HARQ	Hybrid Automatic Repeat request

HSDPA	High-Speed Downlink Packet Access
HSPA	High-Speed Packet Access
HSUPA	High-Speed Uplink Packet Access
HS-DPCCH	High-Speed Dedicated Physical Communications Channel
HS-DSCH	High-Speed Downlink Shared Channel
HS-SCCH	High-Speed Shared Control Channel
ISCP	Interference Signal Code Power
Iu	Interface between NodeB and RNC
L1/L2	Layer 1 (Physical Layer)/Layer 2 (MAC Layer)
LTE	Long Term Evaluation
MDL	Mobile Data Logger
MIMO	Multiple Input, Multiple Output
NBAP	NodeB Application Part
NodeB	UMTS Base Station
PCH	Paging Channel
PDU	Protocol Data Unit
PS	Advanced Packet Scheduling
QPSK	Quadrature Phase Shift Keying
RACH	Random Access Channel
RBS	Radio Base Station
REL'99	3GPP Release '99
RNC	Radio Network Controller
RG	Relative Grant
RF	Radio Frequency
RRC	Radio Resource Control
RSCP	Received Signal Code Power
RTT	Round Trip Time
SCH	Synchronization Channel
SF	Spreading Factor
SFN	System Frame Number
SIR	Signal to Interference Ratio
TDD	Time Division Duplex
TFCI	Transport Format Combination Indicator

TPC	Transmission Power Control
TTI	Transmission Time Interval
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
UTRAN	UMTS Terrestrial Radio Access Network
Uu	Air interface between NodeB and UE
WCDMA	Wideband Code Division for Multiple Access

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APPENDICES

Appendix 1. L1/L2 Real Time measurements

Appendix 2. L1/L2 HSDPA Measurements

Appendix 3. L1/L2 HSUPA Measurements

Appendix 4. L1/L2 General Measurements

L1/L2 Real Time measurements **APPENDIX 1**

SIR measurement

This feature shall measure the received SIR (Signal to Interference Ratio), the RSCP (Received Signal Code Power) and the ISCP (Interfering Signal Code Power) on the DPCCH physical channel. The reference point for the measurement shall be the antenna connector. The measurement shall be non-automatic and all three measurement results along with the SIR target shall be reported together to output trace. This measurement feature is used to calculate and support Average Sir and Average Sir Error. The measurement is also used to support periodic NBAP Dedicated Measurement for SIR. Basic observation time: Time slot.

Characteristics for SIR measurement:
Accuracy: +/- 3dB, when -7 dB < SIR < 20 dB (absolute accuracy)
Reporting range: -11 to 20 dB
Reporting resolution: 0.5 dB

Characteristics for average SIR target:
Reporting range: -34 to 38 dB
Reporting resolution: 0.1 dB

Characteristics for RSCP measurement:
Reporting range: -135 to -63 dBm
Accuracy: +/- 5 dB (absolute accuracy)
Reporting resolution: 0.1 dB

Characteristics for ISCP measurement:
Range: -34 to 38 dB
Reporting resolution: 0.1 dB
SIR, RSCP and ISCP shall be measured on the DPCCH channel. The SIR can be calculated with next pattern: SIR=RSCP/ISCP*SF
where:
RSCP = Received Signal Code Power, the received power on one code.

ISCP = Interference Signal Code Power, the interference on the received signal. Only the non-orthogonal part of the interference is included in the measurement
SF = the spreading factor used

Characteristics for SIR error measurement (SIR - SIR target average):
Range: -31 to 31 dB
Accuracy: +/- 3 dB
Reporting resolution 0.5 dB

Trace example:
18:51:33.715 result :<2012-02-09,17:51:23, ULSIR, DPCH, measId=0, cc=0, cfn=23, target=15.000000, sir=15.300000, rscp=100.000000, iscp=-103.600000>
18:51:33.716 result :<2012-02-09, 17:51:23, ULSIR, DPCH, measId=0, cc=0, cfn=23, target=15.000000, sir=15.200000, rscp=-100.000000, iscp=-104.300000>
18:51:33.718 result :<2012-02-09, 17:51:23, ULSIR, DPCH, measId=0, cc=0, cfn=23, target=15.000000, sir=15.400000, rscp=-100.000000, iscp=-103.300000>
18:51:33.726 result :<2012-02-09, 17:51:23, ULSIR, DPCH, measId=0, cc=0, cfn=23, target=15.000000, sir=15.400000, rscp=-100.000000, iscp=-103.700000>

18:51:33.846 targetSir=15.0 dB, measSir=15.3 dB, diff = 0.3 dB
18:51:33.847 targetSir=15.0 dB, measSir=15.4 dB, diff = 0.4 dB
18:51:33.849 targetSir=15.0 dB, measSir=15.3 dB, diff = 0.3 dB
18:51:33.850 targetSir=15.0 dB, measSir=15.2 dB, diff = 0.2 dB
18:51:33.851 targetSir=15.0 dB, measSir=15.4 dB, diff = 0.4 dB

In tracing tool, there shall be histogram, where SIR target and measured SIR is visible.

DL power TX
Downlink Transmission Power measures transmitted carrier power (TCP) per user and code power per cell.

Characteristics;

Transmitted Carrier Power

Measurement period: 100 ms

Accuracy: ± 5%

Range: For 5% ≤ Ptot ≤ 95%

Reporting range: 0 ... 100%

Reporting resolution: 0.5 dB

Transmitted Code Power

Measurement period: 100 ms

Accuracy: ± 3 dB

Range: Over the full range

GUI shows transmission power per cell and user.

Decoding Time

This feature measures how much time is spent decoding one dedicated channel from uplink.

Decoding time shall be shown in tracing tool.

Sync Status

Sync status' feature measures uplinks sync status both from Rake and from physical layer point of view.

In tracing tool, sync status shall be shown as colored light. Initial sync is showing as yellow light, in sync as green, Out of sync as red and Radio link failure as red slash over the green light. For example request message asks user ID and response message tells user id and sync status.

SFN

System Frame Number range is 0 … 4095 and it shall be included in every measurement.

IR RACH preamble

Impulse Response measurement for RACH preambles.

Array size: 27 counters (Measured signal to noise ratio -25 ... 0 dB), Range: 0 to 2^{32-1} bits (max value of a 32 bit parameter)

This function shall measure the one way propagation delay, throughput, for each successful RACH or C-EDCH access. The measurement is triggered by the reception of a RACH message or a C-EDCH message. The measurement is automatic and the measurement result shall be reported Iub downlink in the RACH FP frame. In case of a C-EDCH access the measurement result shall be reported in the first E-DCH data frame that contains correctly decoded transport block(s). The measurement is event triggered

In tracing tool, there shall be 2D Graph, where X-axis shows delay and y-axis shows SIR value.

IR RL preamble
Rake receiver impulse response measurement for Radio Link measures Rake finger data like delay and amplitude.

In tracing tool, there shall be 2D Graph, where x-axis shows delay and y-axis shows SIR value.

RAKE RAW BER (Pilot Bits)
Raw Bit-Error-Ratio calculation over Pilot bits

This function shall measure the bit error rate for a DPCCH physical channel by counting the number of erroneous bits in the pilot bits.

GUI Definition:
Vertical column bar which shows BER 0 ... 100%

Throughput
Throughput measures the average rate of successful message delivery (bit/s) over a communication channel. This feature measures throughput from each user and from entire cell.

In tracing tool, there shall be 2D-Graph, where x-axis shows time and y-axis shows throughput's value.

CQI

This feature measures Channel Quality Indicator feedback from UE. In case of HSDPA CQI, when sending from UE to RBS.

In tracing tool, there shall be histogram, where x-axis shows CQI value and y-axis shows CQI count.

EDCH Scheduled Grant Index

In this feature, DSP takes a sample of the scheduled grant index transmitted to a serving E-DCH user on an E-AGCH. The measurement result for each E-DCH user is identified by means of the users UL scrambling code.

Measurement time shall be 10ms.
Measurement period shall be 10ms.
Report period shall be 100ms.

In tracing tool, there shall be 2D-Graph, where x-axis shows time and y-axis shows throughput and dashed line which shows the last AG (Absolute Grant) value.

Transport Channel BER

This feature shall measure the bit error rate (BER) for a transport channel carried by a DPDCH physical channel by re-encode the decoded data an comparing it with the input data to the decoder.

Characteristics
Range: Convolutional coding 1/3rd with any amount of repetition or a maximum of 25% puncturing: for absolute BER value ≤ 15%. Convolutional coding 1/2 with any amount of repetition or no puncturing: for absolute BER value ≤ 15%. Turbo coding 1/3rd with any amount of repetition or a maximum of 20% puncturing: for absolute BER value ≤ 15%.
Accuracy: +/- 10% of absolute BER
Reporting range: 0 ... 1
Basic observation time: TTI

In tracing tool, there shall be a vertical column bar, which shows BER 0 ... 100%

Transport Channel BLER

This feature shall measure the block error rate (BLER) for a RACH or a DCH transport channel by counting the CRC evaluation results for each transport block.

In tracing tool, there shall be a vertical column bar which shows BLER 0 ... 100%

Closed Loop Power Control

This feature measures uplink and downlink power control commands

Trace example:
[Cfn UlTpcValid UlTpc DlTpcValid DlTpc] : [194 0x7fff 0x2aaa 0x7fff 0x5ddd]
Cfn: 194
UlTpcValid 111 1111 1111 1111
UlTpc 010 1010 1010 1010
DlTpcValid 111 1111 1111 1111
DlTpc 101 1101 1101 1101

- Uplink and downlink TPC bits are needed for every slot.
- TPC valid bitmask is used to indicate presence of TPC bit, for example in case of compressed mode or DPC mode 1
- Measurement period needs to be user defined or started/stopped by start and stop commands

In tracing tool, there shall be 2D Graph, where x-axis shows time/slot/frame and y-axis shows TPC command cumulative value of up or down for both directions uplink and downlink

Round Trip Time

This feature shall measure the round trip time (RTT) to use for location services. The round trip time is defined as the time from sending out a frame of a DPDCH to reception of the first answer on the corresponding DPCCH/DPDCH in the same cell. The reference point for the measurement shall be the antenna connector.

Range: 876.0000 ... 7316.0000 chip,

Accuracy: 0.5 chip,

Tracing tool shows RTT value in milliseconds.

CM GAP

Compressed mode GAP positioning when SF/2 and HLS methods are used

Trace example shows gap positioning (0=No Gap, 1=Gap):

[Cfn RlsSync Frame Sync BER NumRfr Receiver State UlDtxActive CmGapInFrame Channel Info Sir Target] : [254 1 1 0 6 3 0 0 1 1700] [255 1 1 0 6 3 0 0 1 1700]

Tracing tool shall write the trace to a text file.

Throughput

Throughput is the average rate of successful message delivery (bit/s) over communication channel. Throughput shall be measured from each user and entire cell.

In tracing tool, there shall be 2D-Graph, where x-axis shows time and y-axis shows Throughput level.

CQI

This feature measures Channel Quality Indicator feedback from UE

In tracing tool, there shall be histogram, where x-axis shows CQI value and y-axis shows CQI count.

Channel Power

This feature measures downlink's channel HS and NON-HS power

In tracing tool, there shall be 2D-Graph, where x-axis shows time and y-axis shows power value.

ACK/NACK

This feature shall measure expected and received ACK and NACK.

In tracing tool, there shall be counters for both ACK and NACK.

PQL

DSP shall report the PQL (Priority Queue Length) value of the variable for every PQ

HSDPA Trace

Scheduler shall provide a HSDPA trace which includes all scheduling decisions for each TTI for each user (like ACK/NACK, HARQ info, TBS, CQI, SIR, SFN...).

This feature shall include next measurements:

MAC-HS PDU transmission measurement:

MAC-HS PDU Data

User ID Index

Slot Number

HS-PDSCH TRANSMITTED POWER

HS-SCCH TRANSMITTED POWER

NON-HS-POWER

SCCH CODE NUMBER

NUMBER OF PDSCH CHANNEL CODES

HS-PDSCH CHANNEL CODE NUMBER

MODULATION TYPE

HARQ-PROCESS INFO

RED AND CONST VERSION

NEW DATA INDICATOR

DIVERSITY MODE

SCHEDULING ORDER

TB SIZE INFO

STREAM INFO

TB SIZE

TB HEADER SIZE

MAC-HS TYPE

NUMBER OF PRIO QUEUES

64QAM MODE

PRE CODE WEIGHT INDICATOR

MAC-HS / ehs PDU

HS-DSCH data transmission measurement:

HS-DSCH-RNTI

Channelization code set information

MIMO Activation Indicator

64Qam Activation Indicator

MC Activation Indicator

Stream Indicator

Modulation scheme information

Pre coding Weight Information

Transport block size information

H-ARQ process information

New data indicator

MAC-hs header size

PRIO QUEUE ID

SPI

TSN

SI

NUMBER OF MAC-D-PDU

LCH ID

MAC-D PDU SIZE

HS-PDSCH available power

HS-PDSCH allocated power

HS-DSCH-RNTI (UE identity)

Number of HS-PDSCH codes

Available number of HS-PDSCH codes

HS-SCCH allocated power

Number of HS-SCCH codes

Available number of HS-SCCH codes

HS-DSCH data reception measurement:

MIMO Mode Activation Indicator

64QamActivationIndicator

MC Activation Indicator

Received CQI

Expected CQI

CQI reliable

Pre coding Weight Information

HSDPA Trace shall be written to a text file.

Throughput

Same as in HSDPA measurement; Throughput is the average rate of successful message delivery (bit/s) over communication channel. Throughput shall be measured from each user and entire cell.

GUI Definition:
2D-Graph where x-axis shows time and y-axis shows Throughput level

AG (Absolute Grant)

The measurement result for each E-DCH user shall be identified by means of the user's UL scrambling code number. Both D-EDCH and C-EDCH users are measured. The measurement is not applicable to C-EDCH users with CCCH traffic since there are no grants signaled.

The measurement shall be non-automatic.

Range:
0...31 (26)
0xFF: Not applicable

Reporting resolution: 1
Basic observation time: 2 ms

RG (Relative Grant)

Relative Grant related to HSUPA power.

Sample the relative grant sent to each E-DCH user. The measurement result for the E-DCH user is identified by means of the users UL scrambling code. Only every fifth measurement will contain valid data for 2 ms users due to the fact that relative grant in non-serving cell is sent with 10 ms period.
Relative grant for non-serving cell / Radio Link:

Range:

0: DOWN

1: HOLD

0xFF: NOT APPLICABLE

Relative grant for serving cell / Radio Link:

Range: The Relative Grant from the Serving E-DCH RLS can take one of the three values:

0: DOWN

1: HOLD

2: UP

One report contains 10 RG values (for each user if several UEs included). Values are reported once per E-TTI. Reporting period either 20 ms or 100 ms depending on E-TTI. The report contains the UL scrambling code of the E-DCH user, E-TTI and RG values.

Measurement time = 2 ms or 10 ms

Measurement period = 2 ms or 10 ms

Report period = 20 ms or 100 ms

ACK/NACK

Ack/Nack feedback from NodeB, in order to see successful data package receiving (& re-transmission for data packages).

Measurement time = 2ms.

Measurement period = 2ms.

Report period = 20ms.

GUI Definition:

Counter for ACK and counter for NACK

HARQ queues

HARQ (Hybrid Automatic Repeat request) -queues shall be included to HSUPA Trace.

E-DCH Scheduled Grant Index

DSP takes a sample of the scheduled grant index transmitted to a serving E-DCH user on an E-AGCH. The measurement result for each E-DCH user is identified by means of the users UL scrambling code.

Measurement time = 10ms.

Measurement period = 10ms.

Report period = 100ms.

GUI Definition:

2D-Graph; x-axis -> time, y-axis -> Throughput and dashed line which shows the last AG value

RCOI

RCOI shall measure a sample of the Receiver Compensated C/I received on the interface. One sample of RCOI is taken for each E-DCH user.

Compressed Mode

CPM (Compressed mode) shall be measured CPM shall be set to ""Active - No Gap"" if the E-DCH TTI does not overlap compressed mode gaps on UL DPCH, but CPM is active. CPM shall be set to "Active - Gap" if the E-DCH TTI overlaps compressed mode gaps on UL DPCH. If SF reduction is applied and CPM is active, either ""Active - No Gap - SF Reduction"" or ""Active - Gap - SF Reduction"" shall be set. Otherwise CPM shall be set to "Not Active""

DDI

Data Description Indicator shall be measured: DSP receives the Data Description Indicators (DDI) for each E-DCH user.

Range:

0..63

0xFF: not applicable

E-HICH Power

E-HICH sub frame power shall be measured in dBm relative to PCPICH reference power. In case of non-serving RL, the value shall be set to 'not valid'. The reported E-HICH code power is always the E-HICH total code power, meaning that in case of dual TX branches the reported value represents the sum of the two.

Range:
-35, -34.95...+15.0 dB
0xFFFF: Invalid
Reporting resolution: 0.5dB

Normalized CQI value shall be used in the E-HICH power control algorithm. The value shall be set to 'invalid' in case no control was performed.

HSUPA Trace

Scheduler shall provide a HSUPA trace which includes all scheduling decisions for each TTI for each user.

This feature shall include next measurements:

General;
Sfn

UE;
User ID, E-TTI, number of Radio links, RL 1 ID, RL 2 ID , RL 1 Cell-ID, RL 2 Cell-ID, Serving E-DCH RL, max Set of E-DPDCH, E-DCH MAC-d flow count, Maximum number of retransmissions, RSN

UE scheduling info;
Happy bit, scheduling info [3], Highest SPI, Logical channel related

Scheduled Grant info;
Absolute Grant, Relative Grant, Grant reduction reason, Scheduling function, TNL congestion indication, Reconfiguration ongoing flag

HARQ;

HICH info, NACK/ACK ratio or BLER, Resending sequence number, HARQ process allocation 2ms TTI, HARQ process allocation NST 2ms TTI, HARQ process number

Allocation;

used Grant, used TB size (or TB index), spreading factor, scheduled SG, allocated TB size, allocated TB size NST, Total MAC-es guaranteed bit rate, Max numb of bits per MAC-e PDU for NST, E-DCH Max Bitrate, max allowed SG

UE Measurements;

Throughput / UE, Throughput / Flow

Cell Measurements;

RTWP, Throughput / Cell, E-DCH Provided Bit Rate for Cell Portion, Physical layer measurement: Transmitted carrier power, Transmitted carrier power of all codes (not used for HS-PDSCH, HS-SCCH, E-AGCH, E-RGCH or E-HICH transmission), Received scheduled E-DCH power share (RSEPS)

Summary;

CPU load, HW capacity usage, Numb of E-DCH UEs, Numb of DCH UEs, Numb of unhappy UEs, E-DCH numb of scheduled serving UEs, E-DCH numb of scheduled non serving Users, E-DCH scheduled grant of serving UEs, E-DCH scheduled grant non serving UEs, E-DCH scheduled throughput serving UEs, E-DCH scheduled throughput non serving UEs

DCH;

SIR, UL SIR target, TPC bit UL, TPC bit DL

HSUPA Trace shall be written to a text file.

User list with Data and Type

User list with data and type shall list active users. Query per user(s) to see the loaded user data; user type (DCH, HSDPA, HSUPA), Amount of users, Ueid, nbccRefId, Connection type, Connection time.

Cell Data

Feature shall show the cell specific data for example cell frequency (DL and UL), primary scrambling code, maximum transmission power and common channel info. Basically this measurement shows all data which is included in cell setup request.

GUI definition:
List of cell specific parameter values

Memory Consumption

This feature shall report status of available heap memory. Memory utilization report - status of each (shared and local per core) dynamic memory pools / fragment sizes

Output shall show memory's current size and low water mark (minimum free size) locally.

Memory Dump and Analysis

This is feature for memory dumping and decoding and analyzing. Memory dumping tool will be needed for example in software crash debugging or debugging the issues with hanging resources and users.

Traffic Latency measurement

Traffic latency shall be measured both UL and DL. This is DSP internal processing measurement.

Current baseband device allocation

Current baseband device allocation shall be expressed in spreading factors and connection capabilities

CM Pattern

Compressed Mode Pattern(s) query shall be listed. Depending how many patterns have been loaded to RL/NBCC (max. 6 patterns). Following parameter list shall be listed to each pattern.

List example:

TGPID =

TGSN =

TGL1 =

TGL2 =

TGD =

TGPL1 =

UL/DL Mode = UL only, DL only or DL AND DL

DL Compressed Mode Method = SF/2 or HLS

UL Compressed Mode Method = SF/2 or HLS

DL Frame Type = A or B

DeltaSIR1 =

DeltaSIRafter1 =

DeltaSIR2 =

DeltaSIRafter2 =

Optional:

CMC CFN =

TGPRC =

TGCFN =