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# **User Interface of a GSM Capacity Optimisation Tool**

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<p>The capacity requirements for modern mobile networks build on top of technology like GSM/EDGE are increasing as the usage of data services is growing. The lack of visibility of possible problems in bottlenecks in the BSS domain, including Radio, Abis/EDAP, PCU and Gb-interface, can cause degradation to the whole network capacity throughput.</p> <p>A centralised solution to analyse and optimise the different network domains through real network measurement would increase the visibility of the overall edge-to-edge chain of capacity network. From this edge-to-edge analysis, a drilldown further to the actual root cause is also needed. Based on the measurements particular rules can be created for each domain that can help in identifying and correcting the actual problems.</p> <p>Understanding and accepting the user goals and needs help in the creation of user requirements. In this thesis, the user requirements for GSM/EDGE capacity related needs for Nokia Siemens Networks OSS are described. The user requirements can be used to create workflows that can identify gaps related to individual user requirements.</p> <p>The main contribution of this thesis is to clarify issues related to visualisation of complex data associated to configuration and performance management of the network. This requires many different visualisation channels. Logical network structure requires a tree-like view to be able to visualise relationships between different network elements. A view to present geographical information and performance data related to the network elements on map is also needed. The last visualisation channel required needs to present configuration and performance attribute related information in a table like form. The needs and functions of all these views are derived from the user needs related to capacity analysis in different domains. The main emphasis of different views is in the inter-working functions to support the overall workflow of capacity optimisation. The expandability of the solution should also be stressed to allow future capacity network analysis domains like core network, WCDMA and WiMax and even other vendors besides Nokia Siemens Networks.</p>		
<b>Keywords:</b>	GSM, GPRS, EDGE, Network Optimisation, Network Analysis, Automation Visualisation, User Stories, User Centered design (UCD), Usability	



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<p>Kapasiteettivaatimukset moderneissa matkapuhelinverkoissa, kuten GSM/EDGE, kasvavat koko ajan johtuen lisääntyvästä datapalveluiden käytöstä. Näkyvyyden puute mahdollisissa kapasiteettiongelmissa eri BSS:n alueen pullonkaloissa, mukaan lukien Radio, Abis/EDAP, PCU ja Gb-rajapinnat, saattavat aiheuttaa ongelmia koko verkon suorituskyvyille.</p> <p>Keskitetty ratkaisu, jolla voidaan analysoida ja optimoida erilaisia verkon kapasiteettialueita perustuen verkon oikeisiin mittauksiin, lisäksi näkyvyyttä koko verkon yli tapahtuvassa kapasiteettianalysissä. Koko verkkoa tutkittaessa pitää myös olla mahdollista syventää yksittäisen osa-alueen analyysia. Mittausten perusteella voidaan luoda sääntöjä, joilla helpotetaan ongelmien tunnistamista ja korjausta.</p> <p>Käyttäjän tarpeiden ja tavoitteiden ymmärtäminen ja hyväksyminen auttaa käyttäjävaatimusten luonnissa. Tässä diplomityössä on kuvattu käyttäjävaatimuksia GSM/EDGE-verkkojen kapasiteettianalyysiin liittyviin tarpeisiin Nokia Siemens Networks in OSS:ssä. Vaatimuksista voidaan koota tehtäväkuvauksia, jotka auttavat muuten huomaamatta jäävien käyttäjävaatimusten tunnistamisessa.</p> <p>Tämän diplomityön tärkein anti liittyy monimutkaisen kokoonpano- ja suorituskykytiedon visualisointiin. Tällaisen tiedon visualisointi vaatii useita eri esitystapoja. Looginen verkkorakenne vaatii puumaisen rakenteen, jolla voidaan kuvata verkkoelementtien välisiä riippuvuuksia. Tarvitaan myös tapa kuvata maantieteellinen informaatio ja mittausdata samassa näkymässä. Lisäksi tarvitaan keino visualisoida tarkempaa kokoonpano- ja suorituskykytietoa taulukkorakenteena tekstimuodossa. Nämä tarpeet ja toiminnallisuudet kumpuavat käyttäjän tarpeista eri kapasiteettianalyysin osa-alueilla. Erityisesti suunnittelussa on huomioitu eri näkymien välinen yhteistoiminta, jonka tulee tukea koko kapasiteettianalyysiä. Suunnittelussa on painotettu myös mahdollisia tulevaisuuden laajennuskohteita kuten runkoverkko, WCDMA, WiMax sekä muiden valmistajien verkkoratkaisut.</p>	
<b>Avainsanat:</b>	GSM, GPRS, EDGE, Verkon optimointi, Verkon analyysi, Automaatio, Visualisointi, Käyttäjätarinat, Käyttäjakeskeinen tuotekehitys (UCD), Käytettävyys



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## ABBREVIATIONS

<b>3GPP</b>	3G (Third Generation) Partnership Project
<b>AuC</b>	Authentication Center
<b>BS</b>	Base Station
<b>BSS</b>	Base Station Subsystem
<b>CCH</b>	Control CHannel
<b>CCU</b>	Channel Control Unit
<b>CM</b>	Configuration Management
<b>EDAP</b>	EDGE Dynamic Abis Pool
<b>EDGE</b>	Enhanced Data rate for GSM Evolution
<b>EGPRS</b>	Enhance General Packet Radio Service
<b>EIR</b>	Equipment Identity Register
<b>EMS</b>	Element Management System
<b>GERAN</b>	GSM/EDGE Radio Access Network
<b>GPRS</b>	General Packet Radio Service
<b>GSM</b>	Global System for Mobile Communication
<b>GSMK</b>	Gaussian Minimum Shift Keying
<b>GSN</b>	Gateway Support Node
<b>HLR</b>	Home Location Register
<b>IP</b>	Internet Protocol
<b>ISDN</b>	Integrated Services Digital Network
<b>KPI</b>	Key Performance Indicator
<b>ME</b>	Mobile Equipment
<b>MS</b>	Mobile Station
<b>NMS</b>	Network Management System
<b>NSS</b>	Network Switching Subsystem
<b>OMC</b>	Operation and Maintenance Center



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<b>OSS</b>	Operation Support System
<b>PCU</b>	Packet Control Unit
<b>PI</b>	Performance Indicator
<b>PLMN</b>	Public Land Mobile Network
<b>PM</b>	Performance Management
<b>PS</b>	Packet Switched
<b>PSK</b>	Phase Shift Keying
<b>PSTN</b>	Public Switched Telephone Network
<b>QoS</b>	Quality of Service
<b>RNS</b>	Radio Network Subsystem
<b>RNC</b>	Radio Network Controller
<b>TCH</b>	Traffic Channel
<b>TDMA</b>	Time division multiple access
<b>TMN</b>	Telecommunications Management Network
<b>TRX</b>	Transceiver
<b>TS</b>	Timeslot
<b>UI</b>	User Interface
<b>UMTS</b>	Universal Mobile Telecommunication System
<b>UTRAN</b>	UMTS Terrestrial Radio Access Network
<b>VLR</b>	Visitor Location Register
<b>WCDMA</b>	Wideband Code Division Multiple Access





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## 1. INTRODUCTION

*"Know thy users for they are not you."*

Usability dictum

### 1.1 Background

The cellular world is becoming more and more complex as we speak. The existing second generation mobile standard, in Europe Global System for Mobile Communication (GSM), has been supplemented with faster data rates, that is, Enhanced Data rate for GSM Evolution (EDGE) and third generation mobile standard, in Europe Wideband Code Division Multiple Access (WCDMA), is finally taking off. The build-up of fluent and conclusive monitoring and analysing functions for these two systems from the radio interface all the way to core network will be a very difficult task especially for the telecommunication services with different capacity and availability requirements. The increasing data traffic amounts in the networks are creating capacity problems and degradation in the Quality of Service (QoS).

Division between different monitoring and analysing functions in a mobile network is split between the radio and the transmission domains. Another split can be made between radio access network and the core network. Mostly, the tools available at least in the Nokia Siemens Networks Operations Support Systems (OSS) portfolio are also using a similar split in the functionality that they provide. This split creates gap to the overall monitoring and analysis capabilities and can hide certain problems in the network as the overall situation in the network cannot be controlled and monitored sufficiently from a centralised place.

The missing visibility of the possible problems in the network can cause serious bottlenecks that have an affect on the overall capacity throughput of the network. The bottlenecks in the network can lead to significant lose in the operating expenditure. Moreover, due to the lack of centralised solution the costs related to network management and analysis will stay in the current level although pressure to cut costs is all the time present. The lack of centralised solution also contributes to the high capital expenditure as certain parts of the network can be have unutilised parts as the visibility of to the overall situation is not existing.



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## **1.2 Scope of This Thesis**

The scope of this thesis is to explain and categorise the user needs and goals related to capacity analysis. From those needs GSM/EDGE capacity related user requirements for Nokia Siemens Network OSS are created. In these requirements, the goal is to build a viable and easily usable capacity analysis solution fulfilling all the needs found. The main emphasis of this thesis is in the simplicity of visualisation and ease of usage.

Although, the emphasis and scope of this thesis is in the GSM/EDGE networks, still the focus of the created solutions is also kept in extendibility to technologies like WCDMA or WiMax.

## **1.3 Structure of This Thesis**

The study conducted in this thesis starts with a background given in Chapter 1. The following part comprises of a theory section, which is meant to provide general understanding of the topics discussed subsequent chapters. The main characteristics of GSM/EDGE network and its measurement and services capabilities are introduced in Chapter 2. This part is followed by an introduction into mobile network analysis and optimisation possibilities in Chapter 3. After this, quick overview is given to the field of usability and user-centered design in Chapter 4.

The main contribution of this thesis is given thereafter in the succeeding two chapters. Chapter 5 presents the user requirements and workflows related to capacity analysis and Chapter 6 utilised the background information presented in previous chapters and concludes to a proposal for a possible capacity analysis User Interface (UI).

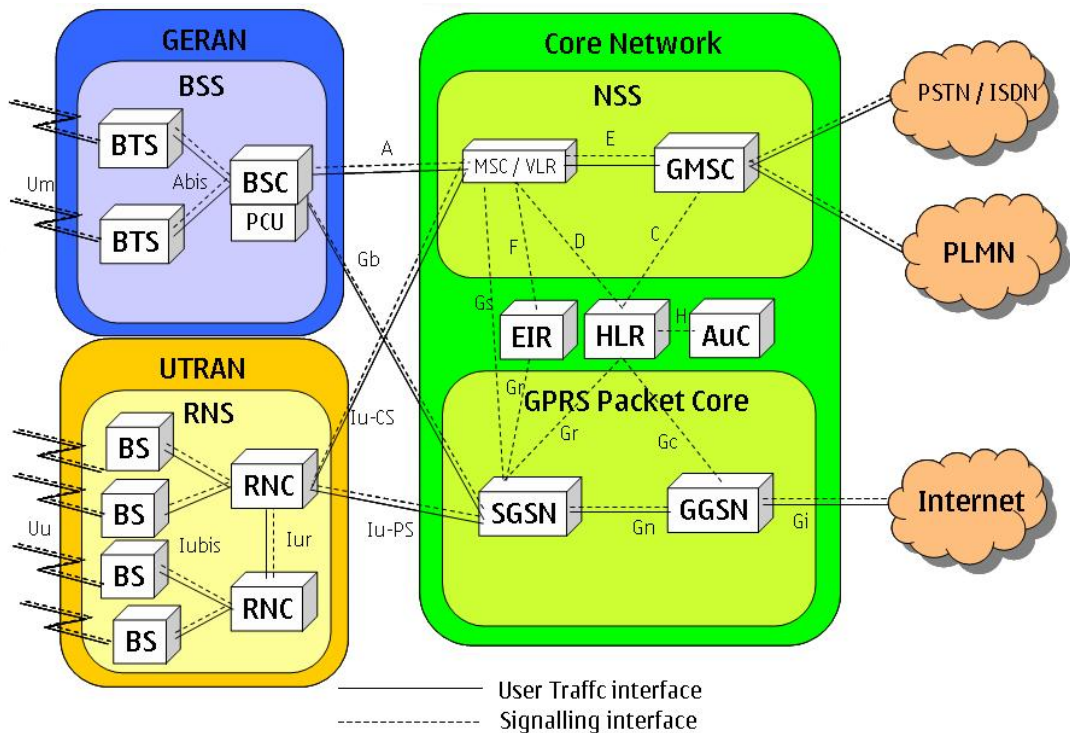
Finally, this master's thesis ends with final conclusions and future research possibilities.



## 2. TECHNOLOGY REVIEW

### 2.1 Introduction

In this chapter the main focus will be on the technical side of the User Interface (UI). Although the main point in this thesis is the UI design and usability, it is still worth while to quickly go through the most important technical points to give some clarification on the complexity of the issues at hand and give some background information from the relevant parts on the decisions made in the UI part. The technology review will concentrate on the main issues concerning GSM and General Packet Radio Service (GPRS) and Enhanced Data rate for GSM Evolution (EDGE). Main points in this chapter will still be in the data flows and measurement gathering that enable the optimisation of different services from the capacity perspective.



**Figure 1: GSM and UMTS network structure [Mou92], [Lai02]**

Figure 1 shows quite well the complexity and the number of different interfaces in the current infrastructure. Still, Figure 1 shows only a simplistic view of this structure. 3GPP, the specification body of GSM and WCDMA networks, is under constant pressure to make fluent inter-working and simplicity in the network management and build-up a priority. Nevertheless, the number of different interfaces and network



elements will stay high even after unification of certain parts of the network infrastructure.

## **2.2 GSM with GPRS and EDGE**

After the phase one of the GSM standard was rolled out, a clear need to evolve circuit switched mobile networks to increase data rates and make also packet switched traffic possible was imminent. This need rose from the fact that the packet switched services in fixed networks were gaining a wide audience and acceptance. Most of these new services, covered in more detail in Chapter 2.5, do not have requisite of being connection-oriented, but can be handled with connectionless protocols such as Internet Protocol (IP). The first answer to these needs was the wireless packet radio service called GPRS. [San03]

After the introduction of GPRS, it became clearly evident that even the maximum data transfer rates of GSM modulation based GPRS were not enough to fulfil all the requirements some of the services required. More innovative and modern modulation techniques had been developed for other wireless networks. The modulation technique called Gaussian Minimum Shift Keying (GMSK) is used in phase one GSM. 8-PSK (Phase Shift Keying) modulation technique was the one chosen to improve existing GMSK. This new approach obtained the name EDGE. Later this combination of new modulation and GPRS was named Enhanced GPRS (EGPRS). From here on the term EGPRS is used to define the combination of GPRS and EDGE. [Mis07]

GPRS and EGPRS offer different kinds of data rates depending on the radio conditions and network quality. These different data rate combinations are created to make compromises between error correction and user data. In GPRS these are called Coding Schemes (CS) and there are four different CSs defined. Since in EGPRS the used modulation can also differ, the coding schemes are called Modulation and Coding Schemes (MCS) and there are nine different MCSs defined. These different (M)CSs are created to make GPRS and EGPRS a suitable data transfer method in bad quality areas and on the other hand offer the maximum data transfer capability in good quality areas. Of course the faster data transfer rates in the Um-interface put a bigger strain on the rest of the network infrastructure. In Table 1 GPRS, and EGPRS (M)CSs are presented



along with modulation and bit rates. The requirements for Abis-interface sub TSs are presented in the last column. [San03], [Mis07]

**Table 1: GPRS and EGPRS Coding Schemes [Mis07]**

Coding Scheme	Modulation	Bit Rate (kbps)	Sub TSs required on Abis
CS-1	GMSK	9.2	1
CS-2	GMSK	13.55	1
CS-3	GMSK	15.55	2
CS-4	GMSK	21.55	2
MCS-1	GMSK	8.8	1
MCS-2	GMSK	11.2	2
MCS-3	GMSK	14.8	2
MCS-4	GMSK	17.6	2
MCS-5	8PSK	22.4	2
MCS-6	8PSK	29.6	3
MCS-7	8PSK	44.8	4
MCS-8	8PSK	54.4	5
MCS-9	8PSK	59.2	5

The concept called Timeslot (TS) bundling was first introduced in High Speed Circuit Switched Data (HSCSD). TS bundling means that in order to provide faster data rates for the user more than one TS - up to all eight TSs - can be assigned for a single user to use. With circuit switched traffic combined with TS bundling the resource requirements that would fulfil all the QoS requirements set to different services were too much of a strain for the existing network and the benefits that they would bring did not suffice the extra financial efforts needed. With EGPRS this kind of virtually circuit switched or “always-on”-feeling can be provided, but the resource requirements are a lot less, because users can share the same TSs over time or more precisely utilise TS, when the MS needs to send or receive some data [ETS01], [San03]

**Table 2: Theoretical maximum data rates [MIS07]**

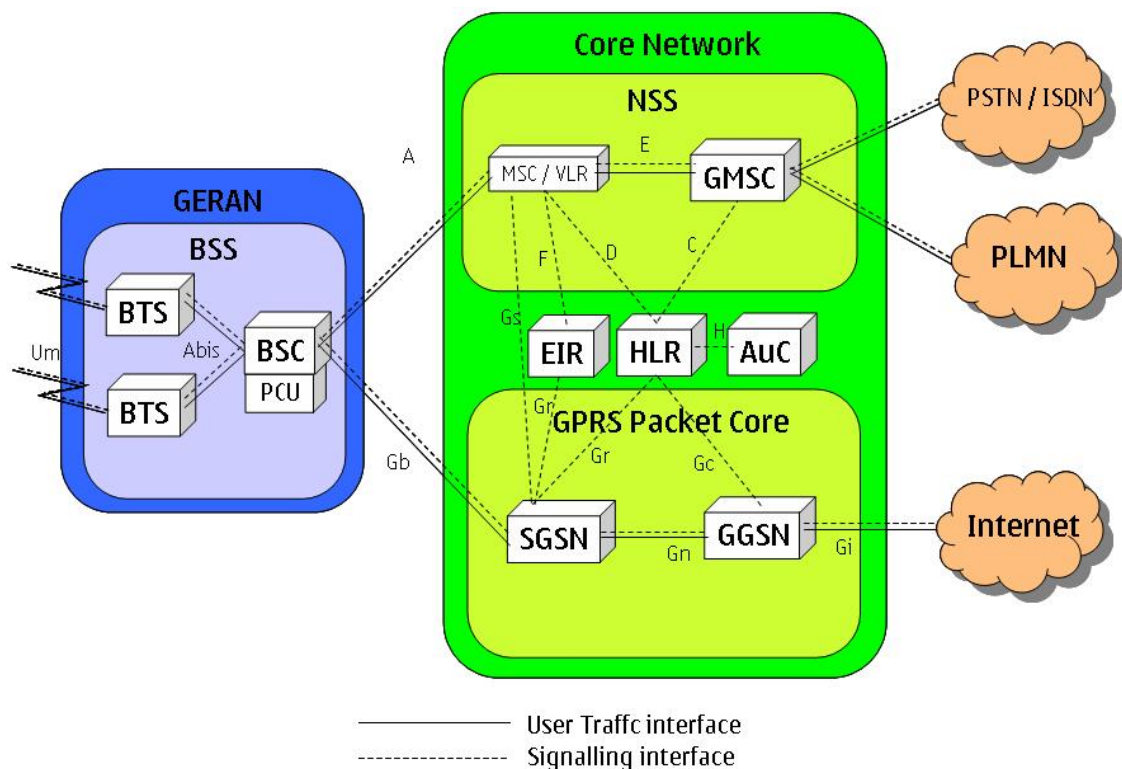
	GSM	GPRS	EDGE
1 timeslot	9.6kbps	21.4kbps	59.2kbps
4 timeslots	-	85.6kbps	236.8 kbps
8 timeslots	-	171.2kbps	473.6kbps

From Table 2 it is clearly visible that the increased data rates that the new evolutions provide put also a great strain to the existing infrastructure of the GSM network. This means in practice a great deal of changes to existing network elements and also the introduction of a few additional network elements.



## 2.2.1 Changes to Existing GSM Network

As EGPRS needs to be build on top of existing GSM network infrastructure, some limitations to practical implementation exists. Firstly, because EGPRS cannot and is not meant to replace the GSM network structure, changes need to be planned so that original GSM network remains to function as before. The adding of new network elements cannot be done over night. As a result there is a requirement to build the EGPRS capabilities incrementally to existing network without compromising current traffic in the network.



**Figure 2: EGPRS enhanced GSM network architecture [Mou92]**

In Figure 2 the new network elements needed are visible. But as said before, the existing network elements also require some changes to be able to handle EGPRS requirements. ME needs to be EGPRS capable, but ME without EGPRS has to be able to function as before. EGPRS enabled ME are split into three different categories depending on the EGPRS capabilities. C class ME is attached to EGPRS or GSM service. If both services are available, as is the case in a typical network, the ME can only receive calls from selected service. B class ME is attached both to EGPRS and GSM service simultaneously, but ME is only able to operate one set of services at one time. A class ME is attached to both services simultaneously and can use services



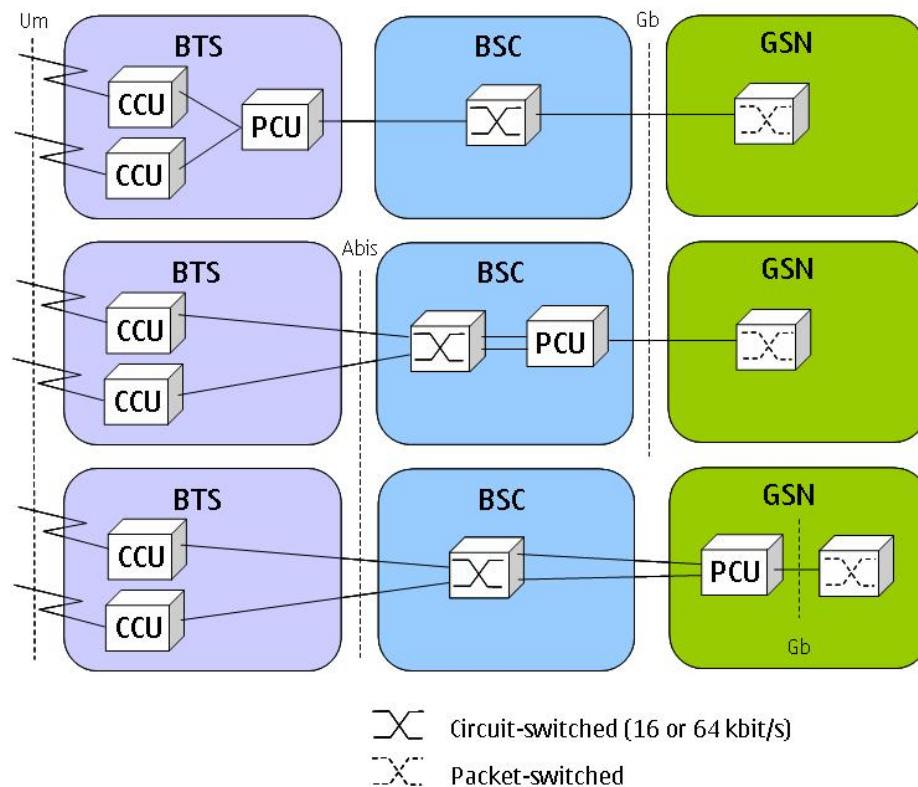
provided at the same time. Currently MEs are mostly class B, but some class A MEs already exist on the market. [San03], [Nok07a]

The BTS also needs some modification to support the new EGPRS traffic. Abis-interface requires some changes because the throughput per TCH increases. The Abis-interface implementation is highly vendor specific. Thorough details about Nokia solution are described in Chapter 2.2.2. Also some changes are needed to the MSC to be able to communicate with the SGSN.

The Channel Coding Unit (CCU) is a part of the BTS and its task is to receive the packets coming from the Packet Control Unit (PCU) and to code them into radio bursts to be sent to the ME. The coding adds redundant information and also check sums into the data and mixes the order of the bits by using interleaving to make bursts more error resistant. In the other direction, the CCU decodes the radio bursts received from the ME into radio packets and sends them to the PCU. The CCU also gathers data on the received power levels, noise levels and time shift of the signal in proportion to the timing of the BTS. [3GP02]

The PCU receives the packets from the network subsystem (NSS) and controls their delivery to the mobile stations. PCU also allocates the radio capacity for the ME for transferring data packets to the network. PCU splits the packets going to the ME into radio packets and combines the received radio packets into data packets. PCU communicates with BTSs through Abis-interface. PCU needs additional timeslots to be allocated in a territory upgrade, that is, when more TSs from the BTS are reserved for EGPRS traffic. [Yib01]

The standard does not define the interface connecting the PCU and the CCU. There are three options to place the PCU as represented in Figure 3. Furthermore, according to the standard, it is possible to move some of the functionalities of the CCU in the PCU and vice versa. PCU and all the functionality is placed to BTS, BSC or SGSN depending on the option used. [3GP02]



**Figure 3: The placement choices for Packet Control Unit in BSS and NSS [3GP02]**

The interface that connects the BSS to the core network is called the Gb-interface. The Gb-interface is between the PCU and the SGSN. This interface is fully packet switched and can support either frame relay protocol or IP for data transfer. [3GP02]

The introduction of GPRS brought two totally new network elements to the GSM system. These are the Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN). These two network elements combined build the core of GPRS network called GPRS packet core. [San03]

The SGSN controls GPRS in a particular geographical coverage area. The SGSN is responsible for maintaining the location information of the mobile stations belonging to the BSCs connected to it. One or more BSCs can be connected to same SGSN. The SGSN provides a point of attachment for the GPRS mobiles. After the mobile station has attached to the system, a logical link is established between the mobile station and the SGSN, via the base station. The SGSN handles the registration and authentication of MSs and also saves the subscriber information. The SGSN takes care of buffering the traffic and of segmenting, ciphering and compressing the packets. The SGSN also collects charging information and performance information related to service quality and throughput. The SGSN is connected to other GSNs through the Gn interface if the





counterpart is in the same network or through the Gp interface if it is in another network. [3GP04b]

The GGSN serves as the gateway between the GPRS network and other packet networks like Internet or company Intranet. The GGSN functions as the interface between the GPRS network and the external data network. The external network sees the GGSN as a router to a sub-network. GGSN routes the user data from the external network to the SGSN that is serving the receiving MS, and the data from the MS to the external network. In order to be able to route data to right SGSNs the GGSN maintains a database about the mapping of the ME to the right SGSN. The GGSN may also collect charging information or the charging information can be collected to a centralised location along with other charging information. [3GP00], [3GP04c]

The enhancement of EGPRS does not greatly impact the SGSN or GGSN with the exception of the increased demand associated with the faster data rates that EDGE allows. The primary modifications required are at the physical layer and the data link layer. The increased data load brought by EGPRS traffic also puts strain on Abis, PCU and Gb dimensioning. This needs to be taken care of in the preplanning and rollout phase of EGPRS and also in the further optimisation. [3GP02], [Mis07]

## 2.2.2 Nokia GPRS and EDGE

Although a large amount of specifications for GPRS and EDGE exists to define certain interfaces from the network perspective still a lot a room to manoeuvre is left to the network vendors. Internal algorithms for PCU data scheduling and resource handling as well as the dynamic solutions created inside Abis to provide flexibility to resource handling vary from vendor to vendor. In this chapter the Nokia specific solutions for EGPRS data handling in different parts of the network are presented.

There are parameters in the BTS that define the dedicated, default and maximum amount of timeslots that can be used for GPRS / EDGE traffic. This timeslot allocation is dynamic and is based on the traffic load in the BTS. The dedicated timeslot defines the minimum, default timeslot defines the typical and maximum defines the absolute maximum GPRS timeslot allocation. Although the timeslot allocation for GPRS timeslots is dynamic, in order to keep the priority still in the circuit switched traffic, this reallocation of GRPS timeslot should be minimised. This reallocation procedure is



called a territory upgrade and requires great deal of signalling and resource allocation also from Abis and PCU and is therefore a lengthy procedure. [Nok07b]

In the Nokia model the network elements that receive and transmit radio signals on one radio channel at a time are called transceivers (TRX). BTS may have one or more TRX. The TRX dictates the capability of GPRS and EDGE. From Abis-interface point-of-view the static transmission path of the circuit switched traffic of the TRXs is allocated to include two consecutive TDMA timeslots. Transmission on the Abis-interface varies greatly depending on the call type in use. The increased bit rate provided by EDGE increases the demand also from the rest of the network path. Instead of allocating fixed transmission capacity according to the highest possible data rate to each traffic channel, it is much more efficient and economically practical to share common transmission resources between several traffic channels. This common resource for EGPRS traffic is called the EGPRS Dynamic Abis Pool (EDAP). The EDAP functionality allocates capacity only when the capacity it is needed. The statically allocated transmission paths in TRX can also carry PS traffic, but they may not in all cases be enough. If EDGE is enabled or pure GPRS uses coding schemes CS-3 or CS-4, the TRX is mapped to EDAP of the same Abis where the circuit switched TSs are connected. Each TRX may have its own EDAP, but typically each BTS has only one EDAP. The size and number of EDAPs in a BSC has also an impact on the Packet Control Unit (PCU) dimensioning. EDAP size can vary from one to twelve PCM timeslots. This corresponds to 4-48 sub-timeslots. Scheduling for Abis-interface is done every 10 ms in other words the user in TS can change every 10 ms. Up to 9 simultaneous active users can share the same TS. [Nok04]

The PCU is limited in the number of Abis channels it can support and the BSC has a limitation on the number of PCUs it can support. These hardware limitations put also certain limit to the amount of EGPRS traffic that can be handled by one single BSC. The number of PCUs needed has also an impact on the Gb-interface and thereafter to the SGSN dimensioning. Typically PCU and Gb-link have one to one relation, but in some cases for the reason of redundancy there may be two Gb-links for one single PCU. More thorough specification for the PCU scheduling algorithms and internal network elements structures exist, but from this thesis perspective they are more or less out of the scope and are therefore not reviewed. [Nok06a]

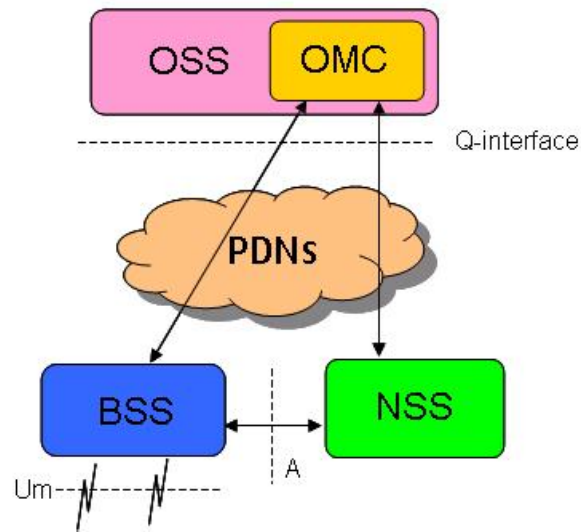


### 2.2.3 Logical Network Structures

From explicit specification perspective the network structure presented in Chapter 2.2 can be thought of being the true hierarchical network structure. There are, however, other structures that are equally hierarchical at least in a logical sense. The PS data network structure that starts from the MS through BTS, EDAP and PCU to SGSN and GGSN can be considered as a hierarchical network structure as well. A logical group from the analysis perspective can also be made from the TRXs that are connected to the same EDAP. From the radio network planning point-of-view another logical structure can be created. In the lowest level of this logical hierarchy is a cell, a group of BTSs with typically same antenna. These cells typically also contain the antenna bearing and in this case the cell bearing information as well. Cells belong under a site or simply put a geographical location. To fill the logical chain the sites can be grouped under BSC. Other logical structures can be found all over the network, but the ones presented above are the most important from radio network planning and optimisation viewpoint.

### 2.3 Operation Support System

Operation Support System (OSS) is part of NMS. Generally the OSS can be considered as a set of software tools that should help the operator or network administrator in the management of day-to-day tasks related to network administration. These include, for example, network planning, fault detection and monitoring or network performance optimisation. Where as, the NMS is responsible for providing interfaces to networks elements and storing configuration and performance data gathered from the network elements, the OSS is thereafter responsible for using the gathered data to make decision about configuration changes to the network.



**Figure 4: OSS connects to PDN and NSS and BSS**

Since the interface between the OSS and the network is well specified, all Operations Maintenance Centre (OMC) implementations should be compatible with all networks. OSS itself is not considered as a part of the logical GSM architecture. For the network management functions to work properly, the OMC must be connected to all of the appropriate network elements. This is accomplished through the standardised Q-interface as shown in Figure 4. There can be differences in the Q-interface implementation and all network vendors have their own extension to the Q-interface. There are, however, extensive standardised parts of the Q-interface that can handle most of the configuration change needs.

There are various different software in OSS responsible for different management functions of the network. Most important functions are fault management, configuration management and performance management. The most interesting parts from the capacity optimisation point-of-view are the configuration and performance management functions.

The configuration management function's responsibilities include storing the network element configuration information and keeping this information consistent. Keeping the network configuration data consistent is a tedious task, because network elements can be configured using many different tools in OSS and also using direct connections to upload new parameter sets to network elements on physical site.

The performance management function's main responsibility area is to gather and upkeep the measurements gathered from the network. Performance measurements are



needed to get a clear picture about network functionality and possible problems as well as for finding the possibilities for increasing the performance. Measurements are in the very core of the analysis and optimisation process and are analysed more thoroughly in the next chapter. The analysis and optimisation software tools are typically also part of the performance management part of the OSS. [Yan07]

## **2.4 Measurements**

Although there are many prediction models and simulation tools to evaluate different aspects of wireless networks, the best possible information can still be provided directly through measurements. This is mainly because measurements are always a result of the current state of the real network and therefore bring in the latest actual information about the quality or traffic situation that the individual measurement is responsible of providing information on. The measurements can be split into two categories. There are the active measurements, which are gathered from the real network coverage area with, for example, drive tests. Certain measurements like geographical field strengths and other location based measurement information can be gathered currently only by active measurements. The problem with active measurements is that they are rather expensive and time consuming procedures. Then there are the passive measurements that are gathered from mobile measurements by the network. The passive measurements are more cost efficient and can be performed simultaneously to the whole network if needed.

The measurement results are heavily dependant on the measurement strategy, environment and setup. The wrong setups with inappropriate hardware and software can cause unreliable measurement results and make the analysis more difficult especially in the BSS network performance analysis.

The MSS and the BSS measure different characteristics of a mobile network like signal strengths, dropped calls, handover information and limitations in resource allocation. This information is gathered in BSS usually to BSC, which then forwards the information typically to NMS. In NMS this information can be stored as long as weeks or months. The measurement or performance data can be further analysed into Performance Indicators (PI). These PIs use the measurements or raw counter data to attain a certain aspect of the network quality using particular formula defined for the PI.



Some of these PIs have been defined as more important than others due to their value in analyzing the network quality or business. These PIs are called Key Performance Indicators (KPI). The KPIs are typically the ones used in measurement-based network optimisation. Operator can specify certain thresholds for the KPIs that need to be reached in order to fulfil quality standards or financial targets in the network. Operators typically also defined their own measurement strategies and KPIs.

The best time period to gather measurements is the time when the network is the working with peak capacity. This period is called a busy hour. Typically in a communication system the busy hour is defined as a sliding one hour period during which the maximum total traffic load in the 24-hour period takes place. The busy hour can be calculated to individual BTS or summarised to, for instance, BSC level. With the networks that carry only circuit switched traffic the definition of traffic is simple. The traffic is simply the traffic throughput from each BTS in the network. But with packet data network the definition and usage of busy hour becomes a bit more complex. This is because the busy hour can be calculated to circuit and packet switched traffic individually or a combined circuit and packet switched traffic busy hour can be used. The complexity to define the busy hour increases even further as on the radio side PS traffic still uses timeslots, but on the transmission side the amount of information in bytes is more vital mostly due to the variety in data throughput because of modulation and coding scheme changes. With packet switched traffic the downlink and uplink traffic amount may differ depending on the service used. This has also some effect to the busy hour definition. It may depend from analysis that which busy hour should be used to bring the most accurate and truthful analysis result.

## **2.5 Services**

Although the voice services still account as the most important revenue source for operator, new services have been emerging with rapid pace. These new services have a large variety of needs from the mobile side but especially from network side. Although the main emphasis in this thesis and the biggest headache for the operator in the PS network is the capacity analysis, the part that can be called service analysis and optimisation will the important future study area when the capacity analysis can be automated. The end user perception, that is, the service quality improvement is the goal where the field of service optimisation should aim for. [Cas01]



ITU-T has a recommendation that the key KPIs of service quality can be divided into three categories: accessibility, retainability and integrity. In short, service access means the reliability of the service provider in providing the service that the customer has requested. Service retainability refers to the probability that a service, once obtained, will also continue to be provided under the conditions that were given, through the duration of the given time. For voice calls, retainability can be measured by simply measuring the amount of calls interrupted by something other than the user also called a dropped call. For data connections, retainability can be measured by GPRS connection drops. Service integrity refers to the quality which the user experiences after the service access has been accepted by the network. The requirements from the network differ greatly depending on the service used. Web browsing, for instance, has a low real time requirement and can tolerate great delays before the perceived QoS is clearly visible to the end user. The requirement for the continuous bandwidth is also not that high and variances in transmission rate can be handled. On the other hand a video call has a high real time expectancy and can not handle great delays. Also a fairly high and continuous bit rate is required without variances. [ITU93]



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### **3. NETWORK ANALYSIS AND OPTIMISATION**

#### **3.1 Introduction**

From Chapter 2 it is fairly obvious that the management of different parts of the network is by no means an easy task for an operator with even a fairly simple and small mobile network. Especially, when the number of different network elements and functions begins to grow, the management of numerous interfaces and attributes in the network elements becomes more and more difficult to handle and monitor. The GSM networks in developed countries have reached this point quite long time ago and as the more complex GPRS and EDGE networks are growing all the time, a need for easier management of day-to-day operations becomes even more important. Therefore operators are looking for all possible methods to ease the monitoring and analysing of the network and also to automate and optimize network management where ever possible. Automation is one of the key ways to reduce the capital and operational expenditure.

The model that quite well describes the management of business in the service provider market can be explained with the Telecommunications Management Network (TMN) model. The TMN model can be considered of consisting from four different levels of distinct management systems layered in hierarchical fashion. On the top the business management system tries to capture the business efficiency and business plan with measures like operational expenditure and return on investment. The business management system may also define certain QoS criteria for the services and functions in the network. The second level is called service management system. Service management system attempts to control and manage subscriber data and create, promote and monitor different services as well as collect and rate the services offered. The third level is called Network management system. In previous chapters, particular aspects of the NMS like the OSS was described in more detail due to the fact that planning, analysis and optimisation typically take place in the NMS. The fourth and the lowest level of TMN model is the Element management system (EMS). The EMS is a part of network elements and the focus is on the monitoring and data collection functionality. Although there are four substantially different levels in the TMN model, the focus in this hierarchical model should still be in the information flow between the levels. The TMN model tries to capture the abstraction level of different decisions and how they are





implemented in different levels of the structure. Although many of the decisions are made in the highest level of the hierarchy, still the implementation of the decisions to some extent happens in the lower levels. Even though the business targets like cost-efficiency and QoS come from the upper levels, in this chapter the aim is to concentrate on the issues related to applying these decisions in NMS level and to what kind of decisions are made and why. [Lai02]

## **3.2 Network Optimisation**

As was stated in Chapter 2.4, a mobile network can be analysed with different methods. The most accurate method is the active measurements and the most inaccurate of the methods used is simulations. The problem with active measurements is the cost and the fact that active measurements are also very time consuming. Therefore the feedback loop from measurement gathering to the implementation of the changes becomes too long. Although simulations typically provide rapid feedback loop, the result can be less than satisfying due to the fact that simulation can not estimate all the possible variables in real life. Even though simulations can be run on several different abstraction levels of the network it still may prove to be time consuming and difficult to adapt the simulations parameters to match the intricate nature of real mobile network. In start-up phase the simulations may be the only source of information, but as stated before in developed countries the modern mobile networks are quite mature so the usage of simulations is not a necessity. The third alternative to provide analysis results is the passive measurements gathered by the network from the mobile measurement results. These passive measurements provide fairly accurate analysis results and also fairly swift feedback loop to be analysed and verified. [Hal03]

### **3.2.1 Statistical Optimisation**

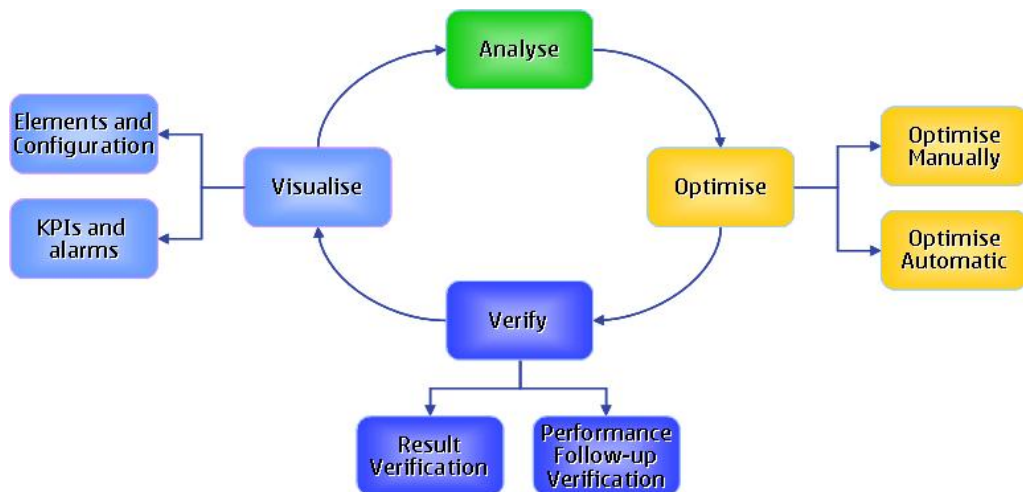
The changes that occur in short time frame in mature mobile networks typically existing in developed countries are usually relatively minor mainly because the physical infrastructure that has been built has proven to fulfil the needs of users for short periods of time. This kind of stability provides a good basis for the usage of passive measurements. The passive measurements typically require a certain period of time for instance a day or in statistical analysis even week. The network changes that usually occur during this time frame in mature network are small in nature and do not affect



greatly to the performance and quality of the network. Although there are also few instance of analysis of mobile network that require a feedback loop of minutes or hours like alarm monitoring. The task of network optimisation and especially statistical optimisation requires a feedback loop of a day or several days.

Statistical optimisation means optimisation of operational network based on network statistics. The KPIs and performance counters provide the most accurate input information for finding the optimal parameter settings. In addition to optimisation tasks the optimisation process includes steps like actual network data visualisation and analysis. Careful root cause analysis is an essential phase for selecting the right corrective actions. To make this root cause analysis most conclusive a snapshot of the network attributes is needed and the network needs to remain relatively unchanged during the period of optimisation.

Figure 5 aims to visualise the needed steps and measures to be taken into account in network optimisation process. In order to provide the required efficiency in the statistical optimisation all the steps need to be seamlessly supported.



**Figure 5: Phases in operational network optimisation process [Lai02]**

The optimisation process, although seemingly an endless loop, needs to start from somewhere. Typically the data acquisition is the place to start. That is in this case the measurement collection phase. Visualisation of data can differ greatly based on the needs that the user has from the tool. The visualisation requirement and other user requirements for capacity analysis will be handled separately in Chapter 5.2. For the analysis phase the combination of network element data and measurement data is



needed. The analysis phase should contain elements of data verification and measurement verification as well as automation where ever applicable. The analysis phase should utilise the visualisation methods and thereby provide the greatest visibility and information for the decision making. After conclusive analysis process, the actual optimisation phase may include only a running of an automated algorithm or in addition to automated steps also include certain manual steps. After the optimisation the verification of the results should be done before provisioning the network element parameter changes to the real network for true verification whether or not the changes had positive effect on the measurement results. The verification phase may be exceedingly important if the optimisation procedure is relatively automated. In the verification phase even before the actual provisioning the business requirement for investing into new hardware and QoS defined in the highest level of the TMN model should also be taken into account.

### **3.3 Capacity Analysis**

As explained in Chapter 2.2, there are many different complex parts in a sophisticated system like the GSM/EGPRS mobile network. From the mobile phone user point-of-view this complexity is made transparent, but still a poor network quality and inadequate data transfer rates are nevertheless visible to the end-user. In this chapter the emphasis is put on the PS traffic and how to configure and analyse the capacity sufficiency for the PS data users. Circuit switched and PS traffic in GSM/EGPRS networks is sharing the same transport medium from the air interface up to the BSC in the Nokia approach. This is because the PCU is located in the BSC and the data traffic is separated in PCU. This causes few challenges from network planning, capacity planning and QoS perspective. The network capacity for data traffic is defined with a few constraints. First is, as with all wireless networks, the available bandwidth in the air interface. Second is the available hardware and the third is the parameter configuration between circuit and packet switched traffic. The available bandwidth or the number of frequencies can be omitted from this analysis, because it is more related to the frequency planning and should be considered a prerequisite for the capacity analysis. The second and the third aspect are the ones very much in the scope of capacity analysis and are also highly network vendor dependant. In the following chapter we will focus on the analysis domain in Nokia EGPRS Capacity analysis.

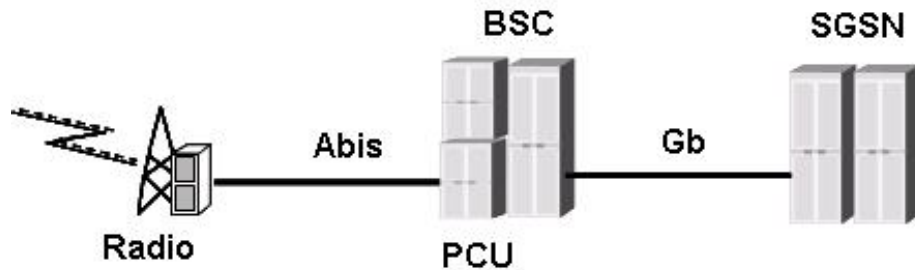


### 3.3.1 Analysis Domains

Capacity bottlenecks in the different network domains can be considered being one of the main limiting factors for PS traffic. The focus in this chapter will be in the BSS side. Although various points in the core network can act as possible bottlenecks in the future, the BSS side is still seen as the limiting factor for the capacity. From the BSS side four distinct domains can be identified as possible bottlenecks. These four distinct analysis domains are: Radio parameters related to GPRS traffic, EDAP size in Abis, PCU throughput and Gb-link size. To ensure that the throughput of data is adequate even in the BSS side the capacity in all of these domains needs to be sufficient. The biggest challenge for the operators' is to provide the required capacity in these different network domains according to the network traffic demand in correct location and at correct time. On the other hand over dimensioning of the network may lead to unused resources and lost for operators' revenue. The four domains cover all the relevant network elements concerning (E)GPRS traffic and all these domains together form an end-to-end chain in the BSS side. This end-to-end chain is very difficult to monitor without suitable tools, primarily, because some parts of the chain are part of radio network planning and some are part transmission planning. The different analysis domains also require the knowledge of what to measure and when. In order to get a comprehensive picture of the mobile network behaviour, the network has to be monitored continuously and supply the demand accordingly by identifying the network capacity bottlenecks. The continuous monitoring may in some cases mean that a single event at one time does not necessarily indicate that there are big problems in the network. In some cases a statistical validity is required meaning that the same problem needs to occur during several days to be certain that the capacity problem is actually existing. [Nok04], [Nok06a], [Nok06b], [Nok05]



The different bottlenecks are presented in Figure 6 below in an overview figure that tries to capture a simplified network hierarchy and all the capacity analysis domains in BSS.



**Figure 6: Interfaces handled in Capacity Analysis for Nokia BSS**

The capacity problems may occur as an insufficient capacity in radio timeslot, too small size of EDAP in Abis, misconfiguration or lack of capacity in PCU and as too small capacity in Gb-interface. The problems in these domains are not isolated. They are correlated and must be investigated together when PS capacity problem has occurred in the network. When an inadequacy of PS capacity is discovered from the network by any means, the capacity increase with one new TRX to the BTS is probably not enough. The capacity from Abis, PCU and Gb should also be taken into account. These interfaces and network elements are expensive pieces of hardware and operator is always trying to minimize the costs of acquisitions and cost of operations. Therefore there is no more spare capacity that could be utilised to accommodate the increased PS traffic. This is why the engineers must consider the Abis capacity, PCU capacity and Gb capacity, create new DAP elements to Abis or increase the DAP size and associate the DAP to the new EGPRS TRXs and so on. [Nok04], [Nok06a], [Nok06b]

In each of the capacity analysis domains different measurements need to be combined with the network element configurations. The troubleshooting for the capacity problems may include usage of tens of KPIs and require data collection for the verification of the problems up to weeks at a time. At the moment, the planning engineers are using different methods and tools to fix the PS capacity problem basically for each part in mobile network separately. Since the problems in each part correlate to each other, this kind of work is time-consuming and complicated, and feasible solution to remedy the problem is not easy to find by combining the results from several tools. Consequently



from this fact alone a clear need for a centralized tool that can provide the means to help the planning engineers to maintain and optimize the network can be drawn. [Nok05]

The analysis can be completed with a certain set of rules with different thresholds. These thresholds define the quality standards for the operator, which have been identified in the business and service management levels. The combination of these rules can detect various different capacity problems in the network. The outcome of the rule, based on the KPIs measured and thresholds set for each domain, should therefore be the corrective action for the capacity problems when the capacity problem has been identified. The details of the rules themselves are not in the scope of this thesis. [Nok06a]

### 3.3.2 Edge-to-edge Analysis

In order to manage all these challenges presented Chapter 3.3.1 there is a need to review the network optimisation processes, tools and practises. Usually the experts spend far too much of their time doing unnecessary data validation and data transfer and modification between various systems, or the time is needed for routine task execution.

Although the analysis process for BSS side is by itself not enough to build a comprehensive set to analyse and optimise the whole end-to-end chain from the mobile phone or user equipment up for instance to the server in the internet, it is still step to right direction. Therefore it is a bit misleading to talk about an end-to-end solution as the proposed analysis covers only areas from radio interface to the Gb-interface. This is why the analysis is named edge-to-edge.

The actual requirements for the capacity analysis tool are handled in a separately in Chapter 5, but still from the optimisation environment few external boundary conditions can be derived. Edge-to-edge analysis requires a flexible way of obtaining and storing data into the tool from various different sources to combine all the different domains into one coherent chain. This is not only related to the network element configuration data, but also for the measurement data as well. The other external factor that needs to be taken into account is the management of changes proposed by the optimisation that is the configuration changes to the network elements. There are few prevalent ways of handling configuration changes for the network elements and also different tools inside Nokia OSS for handling the provisioning of the changes. Therefore the capacity



analysis tool should be able to produce as an outcome a list of configuration changes usually called a plan to allow easy and simple provisioning of data.

### 3.3.3 End-to-end Optimisation

Although the edge-to-edge analysis presented in the previous chapter provides a step to the right direction in the automation and unification of the capacity analysis and optimisation process, still the suggested solution is far from a complete end-to-end solution. From the BSS and core network side there are certain QoS guarantees that can be made, because the data transfer channels are reserved only for data traffic from EGPRS network. The protocol used from Gb-interface onwards in the core network is increasingly changing from frame relay to usage of IP. The QoS guarantee in IP is more difficult to make, but can be estimated as dedicated traffic channels are used. But when you move from the core network to the Internet for example the QoS assurance is much more difficult to achieve. The IP is by its nature a best effort protocol and therefore a QoS level can not be guaranteed. There are certain initiatives ongoing to build QoS for the IP as well, but the QoS assurance for the whole end-to-end chain over Internet is still a dream. This is why, when considering an end-to-end solution for GSM/EGPRS capacity optimisation, the scope of different analysis domains should be narrowed to cover MS, BSS and core network only. [San02], [Wyd02], [Met99]

The fact seems to be that operators do not have a loyalty to any network vendor when it comes to acquiring new network infrastructure, that is, the network hardware and software. Therefore the operators typically have a wide range of network elements from different network vendors in the BSS side and also in the core network side. This causes challenges both to the network element data import and to measurement data import. The existence of a centralised solution for the sake of simple and unified information data flow is not necessarily any more justified. From this fact alone, a conclusion can be drawn that to fulfil the requirement of being able to combine configuration and measurement data from many different sources or NMSs a loosely coupled tool instead of centralised solution could be needed. Thus, it would be important to verify that the installation base would not be NMS dependant and that how making the most of the possible customer based. Loosely coupling in this case could mean for instance clear interface to external data sources. Due to the fact that although there are many highly specified interfaces in the BSS and core network, different vendors have still solved



certain problems in various ways and these different approaches also need special analysis and optimisation solutions. Even when excluding this, the support of multiple vendors presents a challenge so intricate and wide that it is not in the scope of this thesis. The border condition, however, presented in this chapter, should still be kept in mind in the architecture and solution development.





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## **4. USABILITY AND USER-CENTERED DESIGN**

### **4.1 Introduction**

In this chapter a brief overview is given to the field of usability and user-centered design to clarify certain design practises and methods used. The field of usability in general consists of many different schools and approaches and only a small part of this is presented in this chapter. Any further choices made in the detailed UI design are justified and explained in Chapter 6.

### **4.2 Usability**

Usability engineering can be seen as a software engineering method that takes principles from human-computer interaction and combines them with the principles of user-centered design and development. There are many different views that try to define the essence of usability engineering, but fall short to give a complete view partly because items related to usability in general can be organized in various ways and also leave a lot of room to manoeuvre and make different interpretations. There are still, however, certain standards that try to give guidance on the approaches and methods to be applied. These standards do not provide detailed information about the methods and techniques to be used, but try to concentrate on the general principles rather than precise specifications. [Ni193]

A common misconception is that usability is the responsibility of everyone, and since usability is partly common sense, it can also be built and ensured by everyone. There are certain aspects in the field of usability that can be tackled with only common sense and by reusing existing solution. Still, it is essential that the responsibility of building a usable product and verifying usability should be left to the user experience group or similar body.

Figure 7 tries to identify the different aspects that affect the user satisfaction. The issues that are considered to be the most important when trying to create user satisfaction are the actual user goals and the product, and the interaction tasks that takes place between the user and the product. There are, however, many environmental issues that are usually overlooked when talking about complete user satisfaction and ensuring that the product exists in a certain technical environment. This is typically automatically taken into account in the look and feel, meaning a standard way the product should look and



function in common situations. The personal environment of a user is all the time present in the usage of any tool or UI. This is of course something that can not be proactively affected, but the product can enter into this personal environment with the interaction task and the effectiveness and efficiency of them. The product and the user both exist in particular physical environment and the whole playing fields subsist in a certain social and organisational environment. When taking this broad view on usability, it can be said that the task of defining the requirements while taking into account all these different aspects is by no means easy. [Hen01], [Sik00]

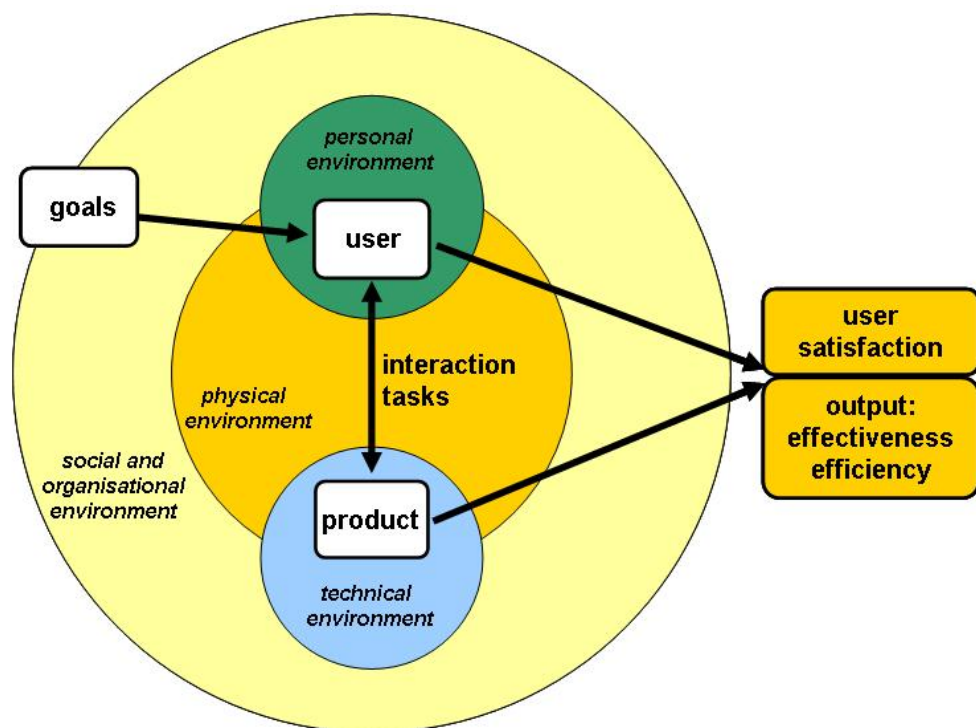


Figure 7: Usability Model

### 4.3 User-centered Design Process

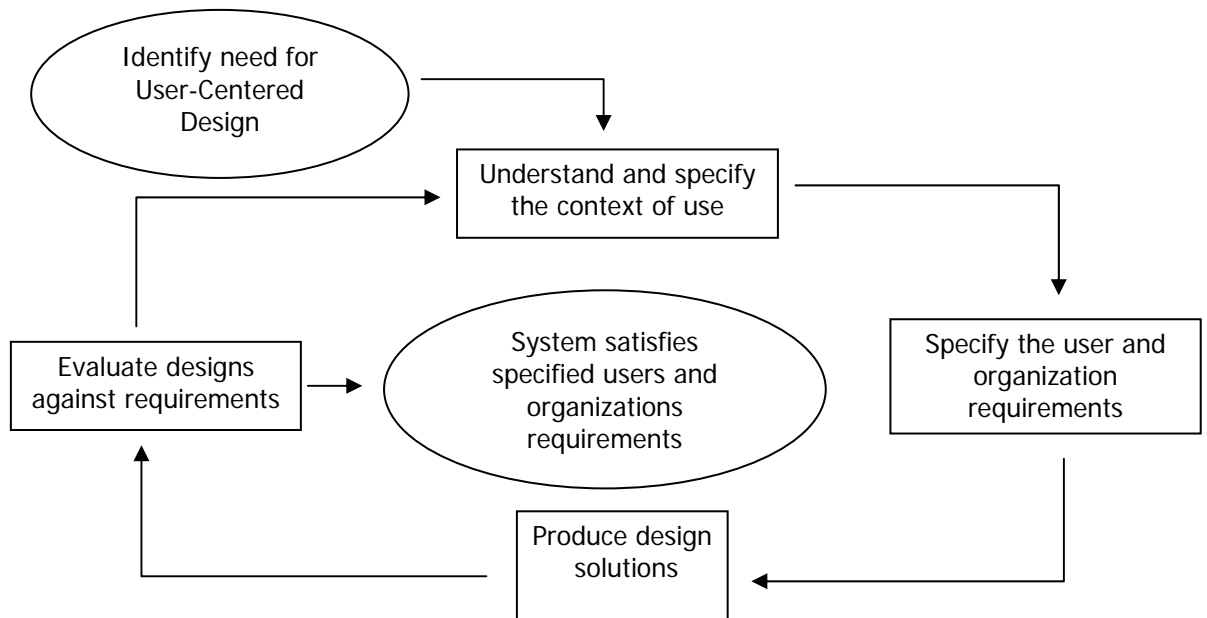
User-centered design can be defined as “an approach to interactive system development that focuses specially on making systems usable”. As a larger field, the field of Human-Computer Interaction combines various different branches of science, for example computer science, cognitive psychology, human factors, and ergonomics knowledge and techniques. Past research has shown that user-centered systems can have many benefits, such as increased productivity, superior quality of work, reductions in support and training costs, and improved user satisfaction. In some literature, instead of user-



centered design, a wider term human-centered design is used. To avoid confusion, the term called user-centered design is here on used to describe also this field. [IS099]

From the birth of interactive computer systems, usability has been a major factor when trying to analyse the overall quality of the system. The ISO standard also emphasizes the importance of usability in the system during the product life cycle, which includes conception, design, implementation, support, use, and maintenance. There are many case studies that can justify the benefits of usability over the cost of usability. Nielsen has estimated that even the very experienced users waste at least ten minutes every day because of usability problems [But96], [Nil93]

The ISO standard 13407 *Human-Centered design processes for interactive systems* is the widely used standard for user-centered design approach. The standard defines user-centered design as multi-disciplinary and iterative process that requires active involvement of users and clear understanding of user and task requirements. The ISO standard also specifies four specific user-centered design activities defined in Figure 8. As mentioned before, these activities should be taken into use in the very beginning of the development and used in an iterative manner. [Fal00], [ISO99]



**Figure 8: User-centered design activities according to ISO 13407**

From Figure 8 it is clear that UCD thrives from the iterative development loop. This iterative approach is very suitable for changing environments and it is not a necessary to get everything right with the first try.



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## 5. USER REQUIREMENTS

### 5.1 Users and Triggers

In order for a UI to be usable it must let the users use the product in an environment that is physically, socially and culturally familiar and comfortable. A usable interface must also be perceived as usable by the users who choose to use it as well as those that have to use it. The latter may be a difficult target indeed. The users must also be made comfortable and pleased how effectively the goals they intend accomplish are actually met. Before this can be accomplished, we need to first know the users: this to make sure that the development of the UIs and workflows are created for the correct users already from the beginning. [Hac98]

On the operator side Service Optimizer has two types of users. There are the users who monitor and analyse the overall performance of the network and are concerned with total capacity requirements in the network without any regard to the causes of the problems. These users can be called *Operator Analysts*. Then there are the domain specialists that need to be able to see domain specific problems and also be able to see certain causes to the problems. These users can be called *Network Planning Experts*. From tool usage perspective the *Network Planning Expert* can be considered as a sub-role of the *Operator Analyst*. Therefore in the user stories the word user is used to define a combination of *Operator Analyst* and *Network Planning Expert* [Yan07]

As a user role, *Operator Analyst* is typically not interested in the thorough analysis of individual network elements, but is interested in the overall state of the network. *Operator Analyst* does not on most cases make decisions on the actions, but only propagates the problems to lower levels. *Operator Analysts* control a wide domain where as the *Network Planning Experts* concentrate to narrower domain and on specific issues. The *Network Planning Experts* need to have high technical skills of their specific domain, because typically they are the ones proposing changes to the network.

The triggers to use Service Optimizer can be split into three different categories. One, the user has perceived some capacity problem in the existing network by for instance conducting a traditional network performance survey or receiving a customer complaint. Two, a conventional audition of the network performance has revealed possible



problems in the network. Three, a new service will be launched and user wants to make sure that network performance remains at the same level as before the launch. [Yan07]

## 5.2 User Stories

Now that the possible contexts of use have been defined and the understanding about the real user is better it is time to start defining the user requirements that form the basis of the UI design. The requirements gathered here are a result of tight cooperation with the real users, that is, the network planning experts and have been revised and modified during the requirements gathering and specification and also implementation phases of the software development. As the requirements are gathered from the actual users, the acceptance of the requirements is easier. This reduces the need to make decisions on behalf of the users and decreases also the design conflicts that can occur if the requirements are not clear and accepted from the user.

The requirements are presented as user stories. A user story is a high-level definition of a requirement; it contains just enough information so that a reasonable estimate can be given about the effort of implementation. User story can be thought to be a short description of a piece of functionality told from the user's perspective. Main driver in using user stories in UCD is that they truly focus on the user needs and as a group of user stories to user workflows. After each user story there is a short explanation about the justification or need where the requirement or story arises from. User stories start typically with phrase "As a user..." This *user* is always the defined user for the context defined in Chapter 5.1. The user can be specified even further to distinguish the user story to be applicable only to that type of user. In user stories there is usually also a section called 'conditions of satisfaction' that define when the requirement is fulfilled and satisfactory to the user. These conditions are left out from the requirements as they are irrelevant to this thesis. [Amb04], [Coh04]

User stories attempt to bring the user and developer together. Although the stories are typically written in close cooperation there is still a distinctive shortcoming with written stories. One problem that is clear from the user stories is that it is difficult to visualise the desired solution from text only. This is where the preplanning of UCD comes in to the picture, and also what the desired outcome of this thesis is, to translate the



requirements into a commonly understandable format and communicate that visual vision to all stakeholders. [McN05]

In the following are presented the most important user stories related to Service Optimizer tool. These user stories will be referenced from Chapter 6, whenever the design solution created is relevant to the user story.

**#1: As a User, I am able to load configuration data and performance data to the tool.**

As the external condition from optimisation process concluded, a requirement to the software architecture is that the software developed should act as a standalone product with only a loosely coupled connection to existing NMS and OSS. Therefore the tool needs to be able to load configuration or network element data and performance or the KPI and counter data easily.

**#2: As a Network Planning Expert, I can see the logical relations of the CM data.**

In general, topology visualisation provided in current OSS contains a network structure based on the radio network needs. Therefore some objects related to packet data network like EDAP, PCU and Gb-link are not visible in the structure. These relations are neither parent-child relations that could be simply presented, but have more complex virtual relations because the add-on nature of GPRS and EDGE.

**#3: As a User, I can see configuration and performance data.**

From requirement point-of-view this leaves a lot of interpretation and unanswered questions. Visualising data in this context is one of the most important aspects as well. From UI design perspective there is basically infinite number of different ways to visualise data. In this context the data at hand is of many forms ranging from location information and relational information to numerical values.

**#4: As a User, I can define thresholds for the KPIs used in the analysis.**

Quality requirements for different network operators vary greatly. In mature networks the quality requirements are much tighter than in developing networks. Quality requirements may also differ from service to service and this sets again requirements for



the Service Optimizer product. These requirements, as stated in Chapter 3.1, rise from operator policies and apply differently to dissimilar geographical area. As the policies for quality requirements are defined in the high level of the operator decision making, the thresholds should only be set once by the administrator.

**#5: As a User, I can set specific dates for the analysis**

Because it is hard to forecast the future, the decisions made need to be based on past knowledge. Sometimes it can be possible to predict the future events by extrapolating trend lines and that how foresee the future, but prediction is still prediction and it can be financially reasonable to be reactive rather than proactive in this situation. The analysis should be done with most current knowledge, that is the recent past, but sometimes there can be reasoning in using further down history information to make certain decisions. The analysis needs to be sometime also run over many days to build a statistically valid result.

**#6: As a User, I can define a scope for the analysis**

Typically the operator's network planning experts are responsible for a particular geographical area of the network i.e. their responsibility area. The analysis may be done to that responsibility area or even to a sub-area. In order to make the filtering of data effortless and efficient, scope handling is needed.

**#7: As a User, I can make analysis for different capacity domains for the scope**

As discussed in Chapter 3.3, there are four different domains that can be considered as bottlenecks from the network perspective. Analysis needs to be transparent to the user and the analysis of the different domains should be as similar as possible.

**#8: As a User, I can see the analysis results**

It is imperative that the tool can visualise the problematic areas in the network and that user is able to access this data effortlessly. Not only should the user see the problematic network elements, but also user should be able to see the corrective actions needed. This can be considered as the core functionality of the tool and although the workflow in general is important this is, from the usability perspective, one of the most important requirements.



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**#9: As a User, I can analyse the whole edge-to-edge chain at the same time**

To ease the visibility of the whole edge-to-edge chain presented in Chapter 3.3.2, the user should be able to easily distinguish from the tool, the network elements that have problems with the whole chain and the ones that seem to be function without problems. This user story is only a supplementary to the previous story presented, but is meant to clarify the need for a complete analysis solution.

**#10: As a Network Planning Expert, I can see KPIs to verify rule results.**

This can be thought of being part of user story defined in user story #2, but there are some actions that differ in this user story that of #3. To verify the validity of KPI values user may need to drill down deeper into the daily variations of KPI values. It is in the scope of this product to access busy hour and daily summarized KPIs. KPIs can be stored as long as weeks and any trend drawn from this is at the tool's disposal. If, however, a further drill down is needed, various other tools exist that can provide this functionality. [KPI07]

**#11: As a Network Planning Expert, I can see the Abis-interface configuration.**

The most difficult manual step in the analysis procedures and therefore also very valuable when automated, is the combination of data from different data sources. As a result of Abis analysis it may occur that the EDAP size in the whole EGPRS data flow is the bottle neck. The suggested action is to increase the EDAP size. It may occur that although the EDAP size should be increased the Abis-interface is not able to accommodate the size increase. This cannot be seen from EDAP objects, but needs combination of different network elements to build up the Abis-interface allocation.

**#12: As a Network Planning Expert, I can export the analysis results.**

When the analysis is complete the responsibility of implementing the change may differ from the quarter making the analysis. Therefore it is imperative that the analysis results can be exported from the tool with ease.

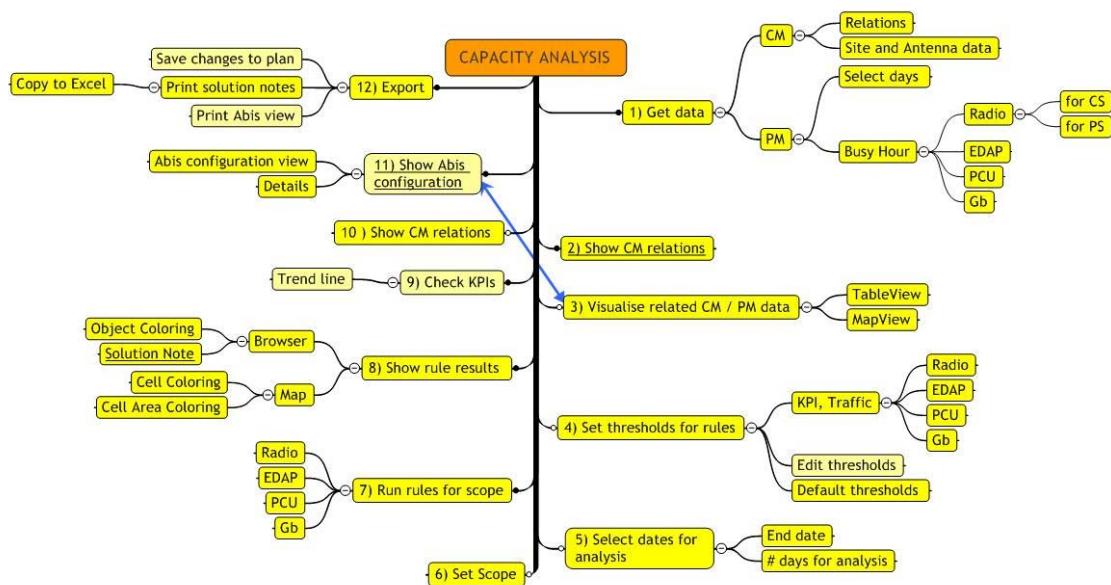
### **5.3 Workflow**

In a totally new product user stories alone can leave vast gaps to the complete use cases. Therefore it is also essential that the “big picture” is constantly kept in mind in order to





fulfil the user needs from start to end. Figure 9 presents a workflow with tasks that the user stories in high level above were trying to explain. Although the user is not forced to follow any workflows some mandatory steps still exist in the workflow. The dark yellow ones are the mandatory steps in the workflow and the lighter yellows are optional. The chain of events may differ in the actual usage, but this workflow is the foundation on top of which the UI design is based on.



**Figure 9: Capacity Analysis Workflow [Wor06]**

This workflow was created as a part of a storyboarding exercise that tried to create a complete, simple and linear process. With this workflow in mind the usability and UI could be more easily build coherent. When this thought process was done while building the workflow, the decision making responsibility was that away from the developer. This provided the developers with a framework and vision with which to concentrate on the structure of code design. [Wor06], [Pur07]

Although some parts of user interaction were already presented in the form of user stories in the beginning of this chapter, it is still essential to clarify some issues from the workflow that were left out in the user stories. The only design wise consciously made side step relates to the Abis-interface configuration. This is identified in the workflow with blue arrows. The shortcut can be made, when considering the workflow, after the visualisation of configuration and performance data before or after analysis. Before the analysis the shortcut is justified to check misconfiguration in the Abis-interface and



after the analysis, if so suggested, to verify that the EDAP size increase can be handled by the same Abis.

This workflow, presented in Figure 9, tries to capture only the user steps and UI requirements in high level. There are obviously numerous functional and non-functional requirements like performance, reliability or scalability that are not visible in the high level user story list or in the flowchart. Even though these non-functional requirements typically have direct effect to usability and user perception, they are still not handled in this thesis as they are more or less out of the scope, but could be included to the user stories conditions of satisfaction.



## 6. USER INTERFACE CREATION

### 6.1 Introduction

In this chapter the ideas and design proposal for the Service Optimizer user interface are presented in relatively detailed level. Some justification for the design solutions were already presented in Chapter 5. As the main idea in the brief user requirements overview has been to concentrate on the user goals, the emphasis on the UI design will also be in the goals and needs of the user. Other design justifications have been made to utilise existing solutions and standards when ever applicable. Many guidelines have been studied and user interface patterns used in the design to make sure that standard solutions are used for standard problems. Also the user requirements or user goals should be somehow mapped to the design solutions made. In this chapter the mapping from a design solution to the user story is made whenever applicable.

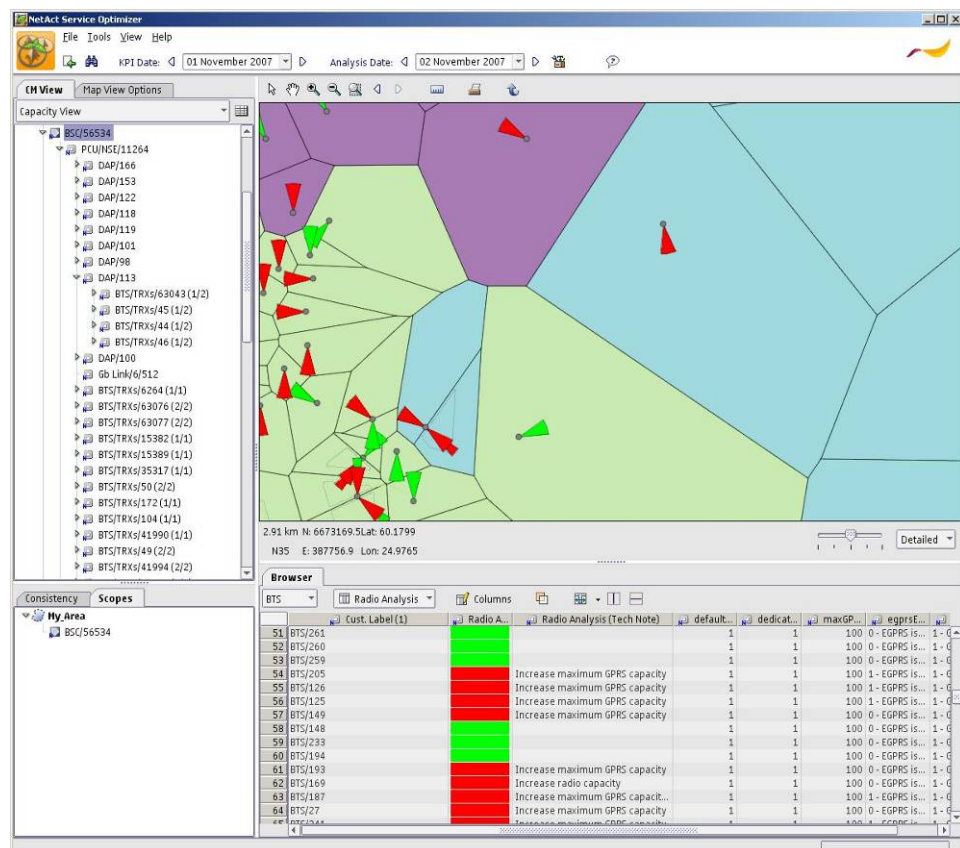


Figure 10: Service Optimizer Main User Interface

### 6.2 Visualisation

The fundamental problem in information visualisation is the task of managing and accessing a large number of information. Naturally, exploring information collections



becomes increasingly difficult as the volume and the diversity of the information grows. Therefore the emphasis in the user interface design needs to be kept on the clarity and simplicity of grouping and navigability. [Shn98]

Initially the idea was that Service Optimizer would be embedded into a product of Nokia Siemens Networks called Optimizer. This created some constraints to the User Interface design and implementation. There would be no point in creating a totally new and standalone tool into Optimizer, but the initial requirement was that the UI components that are available in Optimizer would be used as a basis and modifications made to them in order to support the user stories for capacity analysis. Still the main focus in the design has been to focus on the users' goals and use cases identified in Chapter 5.

One of the driving principles in the creation of the UI is that the needed main application functionality should be accessible from only one window. With main application functionality here means the main workflow that starts when all the necessary commissioning and preliminary setup has been completed. As a defined principle, the use of different dialog boxes is kept in minimum, because a dialog box is still a misstep from the intended workflow and user should always have a good reason to take this misstep. [Coo03]

Another design principle used in the UI design is following Shneiderman's visual design approach that tries to clarify the phases that user has in visual information seeking. These are overview, zoom and filter. The user should be able to get a good overview of the data at hand by a simple glance. There after the user should easily find the relevant and important parts of the data or the data related to the current task. Finally the user should be able to get detailed information about the data needed and also modify the data if applicable. [Shn98]

A typical solution to make the initial state of the UI to support this overview paradigm is to divide the main window into a navigation overview on the left side and detailed data view on the right side. This is done to make sure that the user does not need to move into different modes or states in order to make further action possible. The navigation overview can then provide filtering functionality, and the detailed data views provide the functionality to further filter and finally get the meticulous data needed.



### 6.3 Data Import and Export

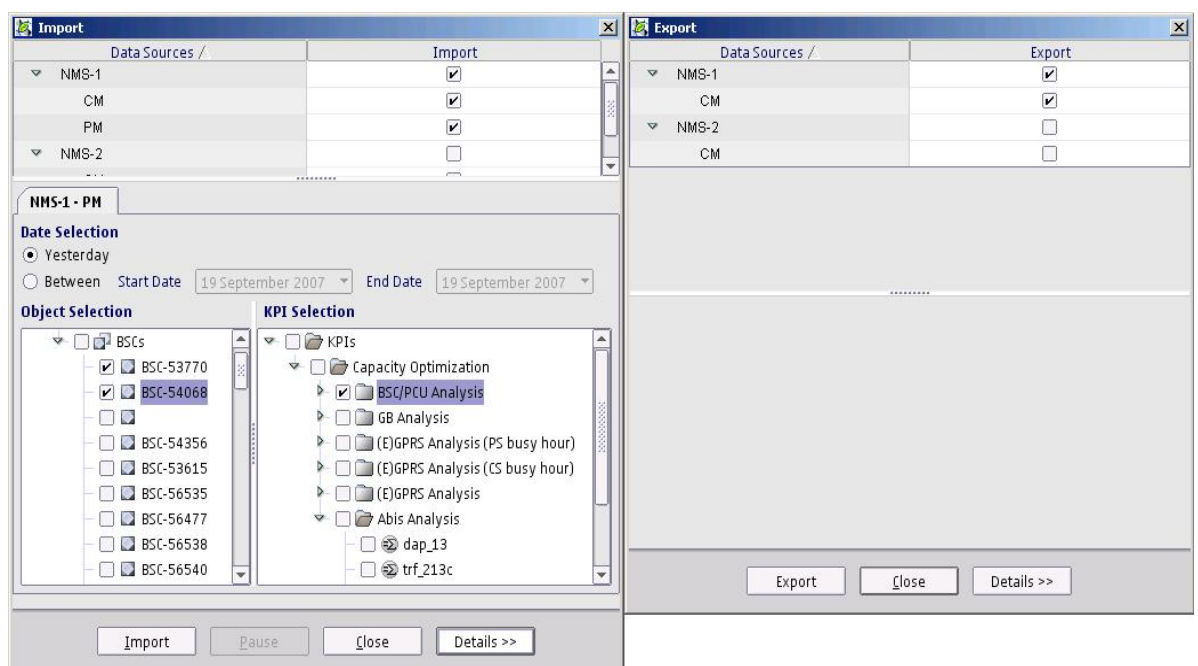
A straight continuum from loosely coupled solution presented as a border condition in Chapter 3.3.3 and concluded in the user story #1, is the possibility to flexibly define data sources for configuration and performance data import. In user story #12, a need to create functionality to export configuration changes back to the network is also presented. From the unification point-of-view these two requirements of data import and export should be designed to function in a similar fashion.

The data import and export are task that often either start or end the workflow, but not directly relate to the analysis workflow itself. Import and export can be thought of being necessary missteps from the analysis workflow that can be defined in a dialog so that the current workflow is either started in the case of import or ended in the case of export.

The dialog itself consists of two parts. The first part consists of the selection of data sources to be used in the import or export. Possible data sources can be either configuration information, meaning network elements with parameters, or measurement data, meaning KPI data. In the case of export only configuration changes are exported or provisioned back to the network and therefore only one data source alternative is available. The second part of the dialog consists of pre-filter to the data that is imported. The pre-filter mainly applies to measurement data, but can also be done for the configuration data. The filtering can be applied to the measurement time, that is, the date selection, to the network elements that the measurements are needed for and also to the measurements themselves. The default date selection is always yesterday, but data can be imported per day basis also from the past. For the object selection and KPI selection the grouping of objects of different types are done in a checkbox tree. When the data is considered to be naturally hierarchical it is worth thinking of representing the information in a tree UI component. Trees provide fairly easy means of browsing even large amounts of information. The grouping and filtering is also automatically provided with expandable and collapsible tree nodes. Trees can also present different types of objects. This minimises the need of providing different solutions for different object types. A checkbox tree component is a special UI component that provides both the tree structure and also the possibility to differentiate, which tree nodes are selected to some purpose. When grouping the KPIs the best possible grouping can be created based on



the analysis domains presented in Chapter 3.3.1. Because there are no overlapping KPIs in any of the domains the grouping can be created easily and the selection of the usage of KPIs is simple and based only on the analysis domains. Grouping of network elements is done based on the BSCs. This is justified since the measurements are always started for the whole BSC and not for individual BTSs in the BSC. In the case of export all the changes to all the network element configurations should be done at the same time and this is why the pre-filter is not applicable here. The whole UI is presented in Figure 11.



**Figure 11: Data import and export dialogs**

## 6.4 Settings for Analysis Rules

As explained in Chapter 3.3.1, the different analysis domains contain rules that are based on KPI thresholds. These KPI thresholds need to be defined by the administrative user. This need rises from the user story defined in user story #4. There are, however, a lot of other needs that can be drawn from user stories #7, #8 and #9. From some perspective these needs can be considered of being a side step from the actual workflow and that is why a distinct dialog is created to visualise and edit the thresholds. This dialog is called Preferences dialog and it includes all the preferences or parameters relevant for the analysis in different domains.



There are a lot of common items related to capacity analysis in different domains. These common parameters need to be grouped to a common place. Common parameters are basically parent parameters for all analysis domains. In the preferences dialog these common parameters are grouped under the general capacity analysis panel and all the different domains are created to a tree structure as children of the common capacity analysis settings.

The general preference includes the common date that needs to be defined for the KPIs used in the analysis of all domains. The analysis is almost always run for all the domains for the same period of time in order to see the relationships between different analysis domains. This functionality wells from the requirement presented in user story #5. There is also a requirement to be able to analyse the whole edge-to-edge chain at the same time, derived from user story #9. It would be very confusing for the user if the analysis dates would differ in different domains. Typically the analysis is run on a live network and usually measurements from previous day are used. This is why an option to use a floating previous day date selection is provided, so that the preferences do not need to be constantly changed. If the user needs to run the analysis for time past, and option to use a fixed date from the past is also provided.

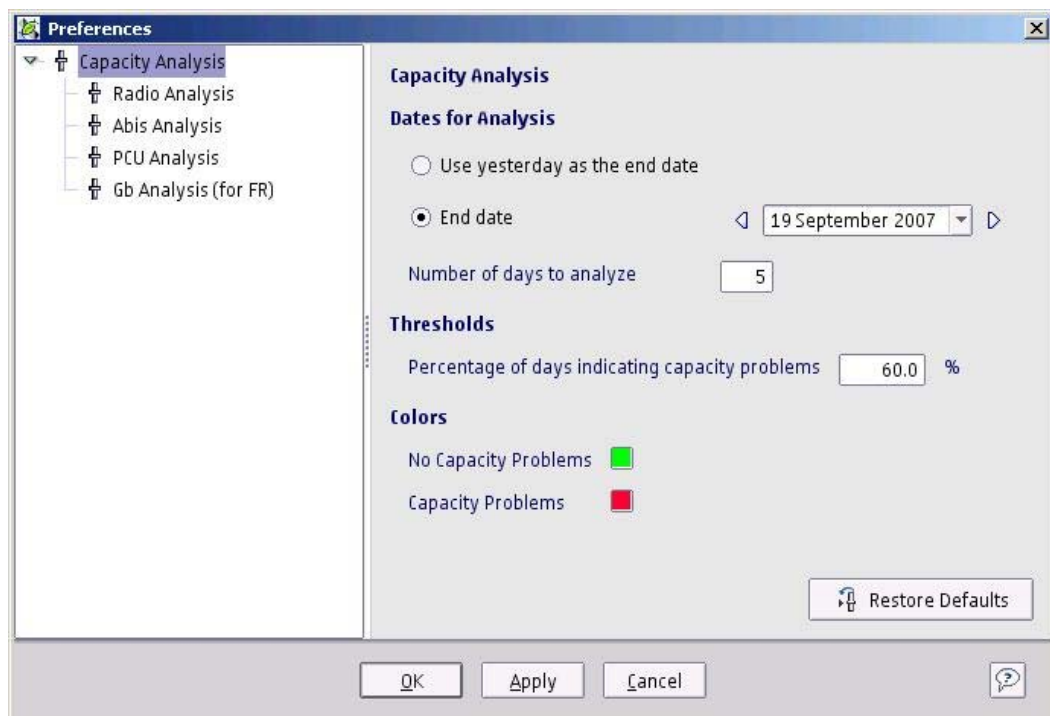
Because the analysis of capacity is by its nature statistical and cannot be completed in a short period of time meaning in hours or typically not even during one day, a possibility for the user to define the analysis duration needs to be provided. To build a thorough ground for the statistical analysis, a threshold on how many days the analysis results needs to be problematic to indicate a real recurrent capacity problem in the network is also needed. This threshold is defined in percentage of the days the analysis is made.

To visualise the analysis results in a coherent fashion, in other words if the network elements related to analysis have capacity problems or do not have, a systematic and united definition of showing the problem of the analysis in different domains should exist. Colours are a powerful visualisation channel and people can easily differentiate many different colours at the same time and also much faster than just plain text or almost similar figures. There are also a few distinct, almost non-culture related colours that define the colours of danger, caution and safety. These are red for danger, yellow for caution and green for safety. It is no surprise that these are also the colours in the traffic lights. This kind of traffic light approach is also taken as a basis for the capacity



analysis. Red means capacity problems in the network and green means no capacity problems. The yellow colour could be reserved for possible capacity problem in the network, but currently only this binary on and off course is taken. The colours red and green are naturally only defaults and the user can freely change the colours to suit the means of usage. [Der03], [Gol02]

The whole dialog for preferences with the preference tree and general capacity analysis panel is presented in Figure 12.



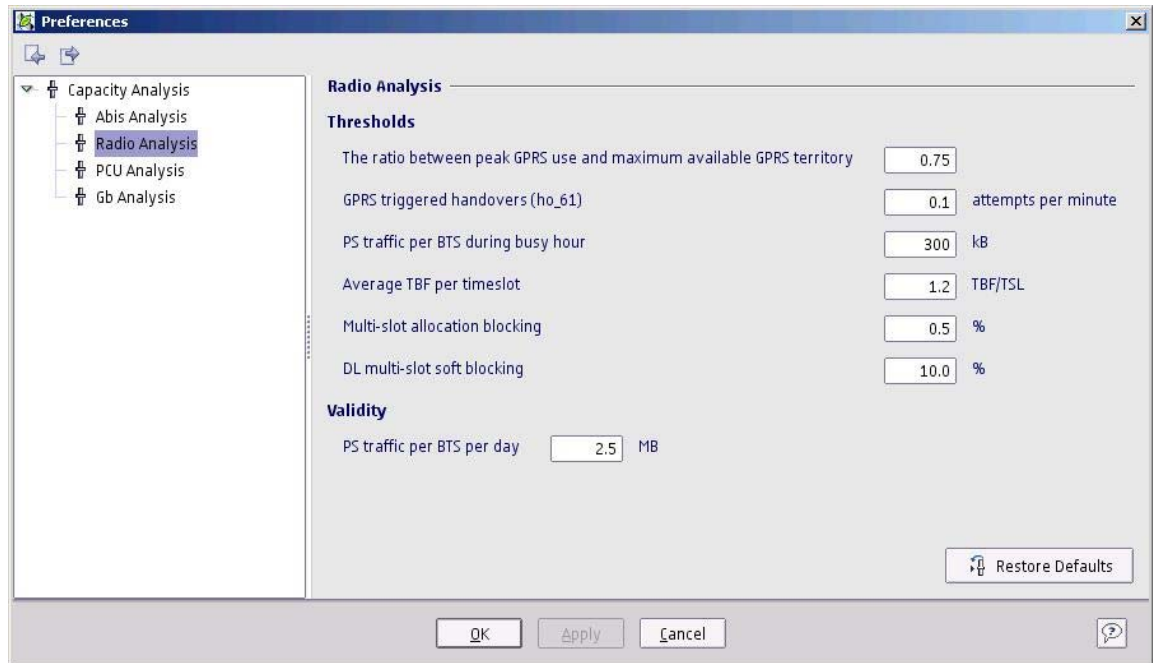
**Figure 12: Preferences dialog with Capacity Analysis Common Thresholds**

After the general parameters related to all analysis domains have been cleared out, the focus can be put to the domain specific analysis parameters, which means mostly the KPI thresholds. The KPI thresholds are defined individually for each of the analysis domains. There are no overlapping KPIs that would be used in two different domain analyses, so each analysis domain can have its thresholds in a separate panel. The panels are composed of KPI name labels and text fields where the threshold value can be inserted. If the threshold has a unit, the unit is displayed after the text field. For Radio and Abis analysis there is also a validity check for the traffic that it exceeds certain threshold. This to ensure that there is enough information, that is, traffic, to make the analysis extensive enough. Although the administrative user may change the thresholds at any convenience, there are fairly good initial values as default. These initial or default





values exist to make the start-up of the tool usage easy. The user may also restore the defaults values at any occasion, if needed. An example view of the radio analysis thresholds is displayed in Figure 13.



**Figure 13: Preferences for Radio Analysis**

## 6.5 Treeview

The benefits of using a tree structure were already mentioned in short in Chapter 6.3. The more information is needed to be fitted into a view the more important the structure and filtering functionality that a tree UI component provides becomes. A GSM/EDGE network can consist of even tens of thousands of elements therefore the grouping and filtering is very important.

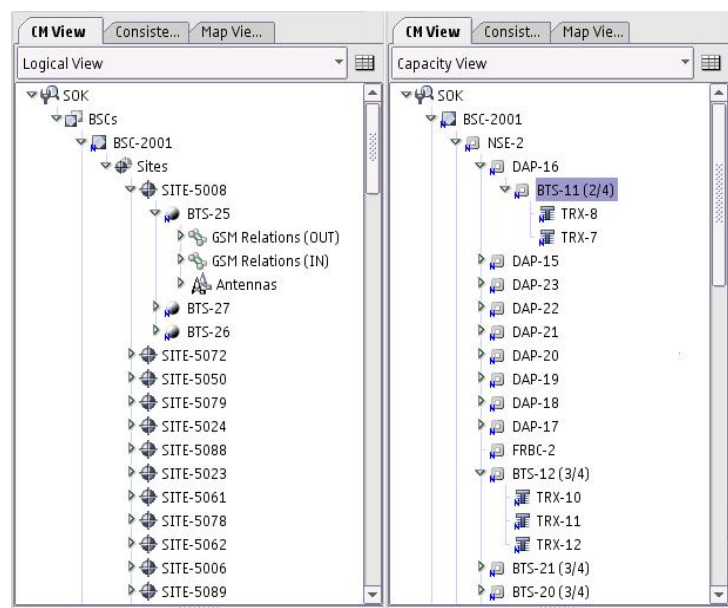
A GSM network structure can be thought of being highly hierarchical structure especially when considering the core BSS and NSS functionality and network elements related to this. Therefore from the network structure, presented in Chapter 2.2, a clear hierarchical Treeview can be created. The requirement in user story #2 raises a need to represent also the logical EGPRS network structure. This structure is also best presented in a tree structure. The third possible network structure defined in Chapter 2.2.3 can be called the planning hierarchy. This hierarchy tries to capture the logical relations for location information and network structure.



There is no need to visualise the three different perspectives of the network hierarchy at the same time so the same Treeview component can be utilised. For all the views, however, a method to allow the user to select which view is needed has to be available. For the simple reason of expandability, a combo box selection method was chosen. A combo box is also able to visualise the current selection and does not take that much room from the UI. When the number of different elements remains in few tens a combo box works very effortlessly. [Coo03]

The Treeview is the only place in the Service Optimizer UI where the whole hierarchical network information is available. Therefore the Treeview needs to support the navigability to other main UI components and also support the possible scope handing related tasks.

As seen from Figure 14, there is a root network element visible in the tree structure. This root element is the NMS. As described in Chapter 6.3, the data import functionality supports importing of multiple NMSs to the tool. The capacity workflow does not have clear borders where the analysis should end or begin, so from the network viewpoint this split in to NMSs is more or less artificial. The support of multiple NMSs is not directly linked to the usage of Service Optimizer tool itself, but is a functional requirement related to other tasks out of scope of this thesis. The visualisation of different NMSs is made relatively transparent and is only visible in the Treeview.



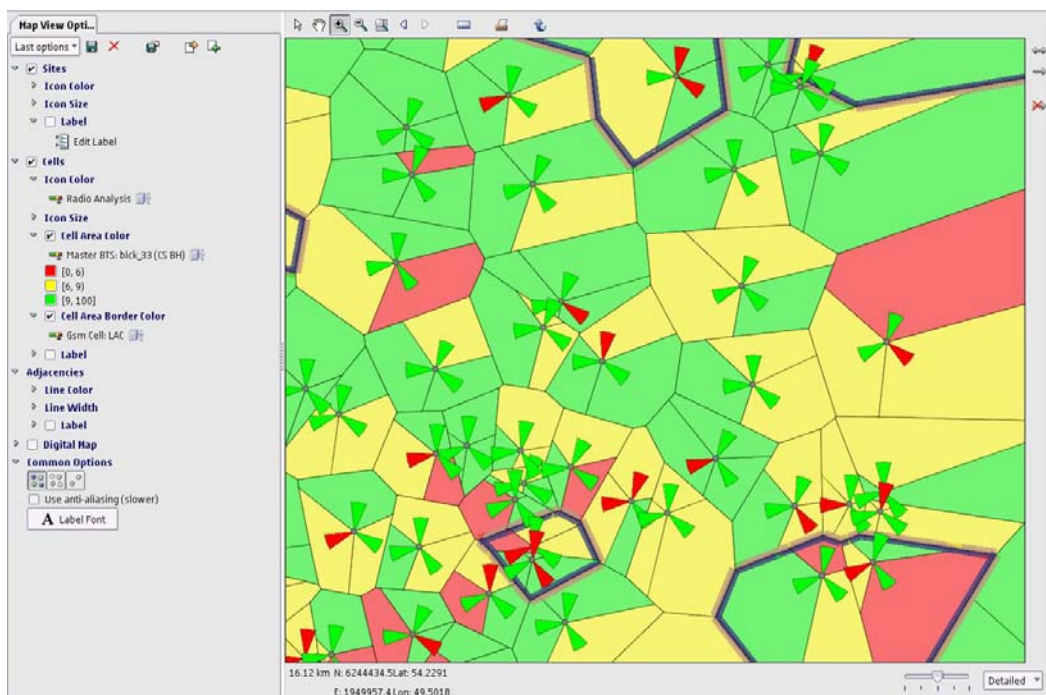
**Figure 14: Logical and Capacity View in the Treeview**



The distinction of different network element may seem difficult from the tree node labels only. The tree node labels can, however, be customised depending on the network element type to include element attributes or other labels. If the label is the only visual cue that is provided to the user, the user is forced to read the labels all the time even to make the distinction on the network element type. To build more visual cues to help the user to identify the network element types more rapidly different icons are used to differentiate the various network element types.

## 6.6 Mapview

There is an indirect requirement derived from user story #3 to visualise network configuration and performance data with location information. This requirement can be captured from the logical planning hierarchy defined in Chapter 2.2.3. The planning hierarchy has the logical network elements that are ideal when visualising location based information, that is, the sites with geographical coordinates and cells with antenna bearing. As the Treeview, presented in Chapter 6.5, can visualise the hierarchical network structure, the map takes a different view in visualising logical network relations in geographical form.



**Figure 15: Mapview with Radio Analysis and KPI visualisation**

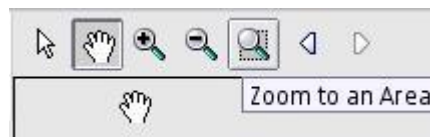


Although the map can provide a powerful tool in visualising different data, it also presents a great challenge from the usability viewpoint and adds a great deal of new requirements that can be interpolated from the requirement presented in user story #3.

An overview of the whole Mapview is presented in Figure 15. A multitude of different functionality is visible in the figure so it is worth while to concentrate on the few most important UI design solutions. These can be grouped under the following features: navigability, visualisation and customisation. These features are presented in the chapters below.

### 6.6.1 Navigability

Typical map view navigation options include zooming in and out, zoom to an area, typically a rectangle, and panning, that is, the moving visible map area from one place to another. There are many map solutions in the market and some of them provide very feasible solutions for the navigability, like *MapInfo*. These design solutions can be used as a baseline for defining the navigability. The visible navigation options are defined in a toolbar that uses toolbar buttons with an icon and tooltips to clarify the functions. [Dan99], [Coo03], [Map99]



**Figure 16: Map view navigation toolbar**

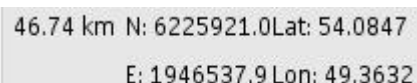
Zooming in and out are build as toggle buttons meaning that they do not perform the task, but the task is context sensitive and the functionality is only toggled on and off when pressed. When toggled on, the action can be performed by clicking the map, that is, the context. Modern computer mice also provide wheel functionality that performs in typical application the scrolling functionality. The usage of the mouse wheel is not limited to scrolling only. There is no scrolling functionality on the map, so the mouse wheel acts as a shortcut to zooming – rolling up to zoom in and rolling down to zoom out. The zoom to rectangle functions also as a toggle button and zooms in on the selected rectangle drawn on the map.



Panning is also a toggle button and the pan action can be completed by dragging the mouse while the mouse button is pressed. Usage of toggle buttons is justified when the function that they perform happens multiple times in a row. Unfortunately the case with zooming and panning is that they may or may not happen multiple times in a row, therefore as with the shortcut in zoom action a shortcut of panning action is also provided. The shortcut is applied when dragging the mouse with right button pressed. Although the functionality of right mouse button is typically reserved for popup-menus, this causes no overlapping of functionality as the action is only performed while the mouse is dragged.

The user should always discern the state in which the application is. State word here is not to be confused with modes. A key design principle is to reduce the use of different modes. Modes meaning application wide states that may affect the functionality of certain functions. These states are nothing irreversible and a simple state example is of the toggle action on the map. Although the states are not as visible as modes, still the visibility of states can be emphasised. This is why the mouse cursors, when over map view, should always react to the toggled action and performed action. This to make sure that the user always knows not only from the toggles button in the toolbar, but also from the mouse cursor in which state the map view is. Shortcut keys and actions naturally override this pattern, but the shortcuts are typically meant for the expert users that do not require that much advice about the functionality as the beginners do.

As the map is meant to visualise geographical information, that is, the site coordinate information, the user should always know not only from the site's attributes, but also from the map itself that in what area the site is. Therefore a toolbar that visualises the coordinate information of the location, where the mouse cursor is positioned, is needed. The location information is presented in Latitude, Longitude and Northing and Easting; these being the two most popular representations of coordinates.



46.74 km N: 6225921.0 Lat: 54.0847  
E: 1946537.9 Lon: 49.3632

**Figure 17: Map location toolbar**



## 6.6.2 Visualisation

The term “map” means usually a geographical representation of a certain area. The map used here, however, provides a great deal more visualisation channels than just pure geographical map. So in this sense the usage of word map is a bit misleading and the term geographical information system would be more suitable. This term, however, is not necessary in the terminology of the user, so the word map is still used.

There are few different visualisation means provided with the map. The visualisation of site and cell information as icons on the map is an important aspect of the visualisation and acts as a basis for other visualisation channels that are provided. From the requirement presented in user story #3 it is not clear if this visualisation channel is enough to fulfil the requirement. When combined with user story #10 it is clear that multiple ways of visualising different data simultaneously are needed. On top of the geographically distributed site and cell data a second channel called cell area can be build. This cell area can be considered as a physical extension to the cell icon and is visible also in Figure 15. The cell area can be confused with cell service or coverage area, but in most cases it gives only a rough estimate on the actual cell coverage area. The cell area can be used simultaneously with the cell icons in order to visualise a second layer of information. These two different channels can present information with colour differences. From static representation methods colours are the most vivid visualisation means possible, especially when certain colours stand out from the background. [Gol02]

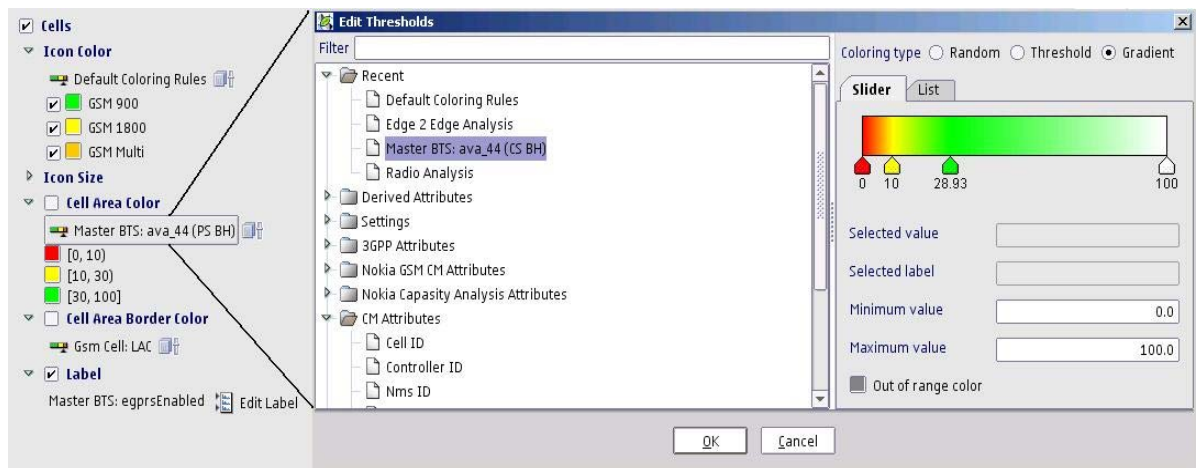
In some cases it may also be useful to visualise more than two values simultaneously. Therefore a third text based visualisation channel can be taken into use. This visualisation channel is called label. In the label, any meaningful data that cannot be visualised in colour form can be presented. When there are two different colours, namely cell icon and cell area, visible in the map already, the map area may turn into a patchwork if any more colours are added. The label is a text based visualisation method that is in this case attached to the cell object. In theory any amount of information can be represented in a label when catenating different attribute values to the label text. In a cluttered map the problem with the label is that the amount of different texts in the map can rise to the limit thus preventing the user from perceiving anymore anything valuable. The label does not restrain the user from adding a multitude of different



attributes to the label, but in most cases only few attribute values should be presented at the same time.

### 6.6.3 Customisation

As there are multiple visualisation channels available on the map, the user should be able to edit and customise the colouring types and texts of the channels available. Therefore an editable legend called Map View Options is created to fulfil this need. The Map View Options provides functionality to filter different network elements from the map and define different colouring modes or types to different network element parameter and KPIs.



**Figure 18: Map View Options and Threshold editing**

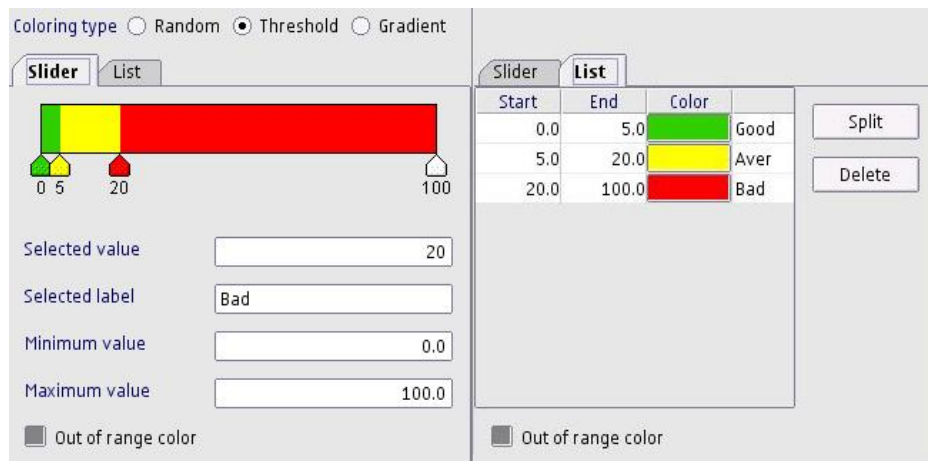
The whole Map View Options is created as an expandable tree. A tree provides, as stated in Chapter 6.5, automatically grouping and filtering functionality, so that the user can expand the tree nodes that are needed and collapse the tree nodes that are not of interest. The Map View Options Tree is not a typical tree, but all the tree nodes act as individual panels that can have their own UI components and sub-trees where needed. These panels are called *expandable panes* or panels. Each of the expandable panes contains a label row that can be parallel to the tree node label.

Map View Options acts as a dynamic legend for the map. Each tree node corresponds to a certain object like site or cell on the map and contains a filtering option to show and hide objects. This filtering functionality is provided with checkboxes in the expandable panes. The expandable pane may contain additional checkboxes that further filter the sub categories for instance different bands of the GSM cells as visualised in Figure 18.



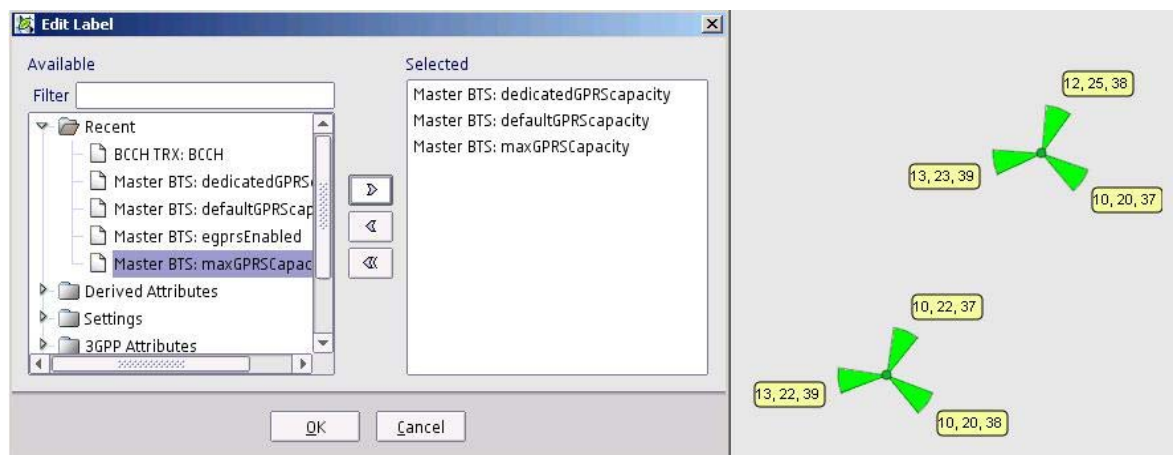
The colouring customisation is provided with a threshold editing dialog, which is presented also in Figure 18. From the threshold editing dialog the user is able to select any attribute available for the selected element. The attribute content is grouped to generic groupings of attributes used across the tool. These groups are: CM (configuration management) attributes, PM (performance management) attributes and derived attributes. The CM group defines the configuration attributes related to configuration data. The PM group defines the attributes related to performance data, that is, the measurement and busy hour definitions. The derived group defines different derived attributes deduced from different related network element and also the combinations of CM and PM attributes like the rules defined in Chapter 3.3. From the threshold editing dialog, the user is able to set diverse colouring types. Random colouring type uses predefined set of colours that are easily distinguishable from each other and can be used to visualise, for instance, the differences in attribute values. No editing is provided as the colour map is predefined. Threshold type provides editing possibility to differentiate the possible values as colours in discrete values. The user can define each threshold limit and colour with a colour slider or as a list and also add new thresholds with the split functionality. The colour slider provides an excellent way to easily edit threshold values quickly just by dragging the threshold slider. The dragging works fluently when the values are fair enough apart, but when the thresholds are very close together the slider visualisation and ability to edit the values becomes cumbersome. This is why another method of editing the colours and threshold values is added. The colours and thresholds can also be edited with a list. The list makes the editing easier when there are many values fairly close together. These two approaches of editing threshold values are complementary and support different use cases.





**Figure 19: Threshold Colour Slider (left) and Colour List (right)**

Due to measurement time problems with the KPI values and due to some configuration problems in the network, the values may be out of range of the defined threshold. Therefore an out of range colour is also provided. This colour should be different than the colour defined for missing data.



**Figure 20: Editing label content and label visualisation of map**

The label text can also be customised to include any parameter values or KPI values. These labels are attached to the network elements with proximity principle. The different values in the label are separated with dots. The font, the font colour and the background colour can be also defined for the label. [Go102]

#### 6.6.4 Capacity Analysis in Map

In previous chapters, the overall functionality of the Mapview was presented. To get a clear picture on how these different navigation possibilities, visualisation channels and customisation options link to the capacity analysis workflow it is important to go



through the aspects that the map brings to the capacity analysis visualisation and also to the overall workflow. The map is one of the two visualisation channels that can show the capacity analysis results to the user. The other one is the Tableview. Its functionality and usage in the capacity analysis is presented in the next chapter. There are few similarities with map and Tableview when it comes to capacity analysis visualisation. In this chapter the focus is on the strengths that the map brings to the analysis.

The capacity analysis rules can be selected for cell elements and cell area. Any of the rules can be selected to both visualisation channels and different rules can be applied to both channels. This is done through the Map View Options. Therefore it is possible to visualise two different capacity domains at the same time on the map. The cells will be coloured with the colours defined in preferences, so with the default values the problematic cells will be coloured with red and the ones that do not have any problems will be coloured with green. This analysis functionality fulfils the requirement presented in the user story #8 to some extent. User story #9 raises also a need to visualise the edge-to-edge capacity analysis results. This edge-to-edge result means the combination of the results of all of the four different analysis domains. The edge-to-edge result in practise means that the analysis result shows problem if any of the individual domains has a problem. The edge-to-edge analysis result can also be selected to cell and cell area in the same way as a single analysis domain.

There are few instances where the data available for the analysis is not sufficient enough to make a valid analysis result. This can be caused for instance by missing or corrupted measurement data. The capacity analysis result in these situations results in miscalculation and this kind of state is visualised with grey colour. There are also occasions where the analysis can not be executed, because the configuration of the network does not require certain elements. This can happen for example in a situation with no EDGE or no GPRS. In the case of only GPRS without EDGE, the DAP element is not needed and is therefore missing. This situation needs to be differentiated in visualisation from the situation of miscalculation. In this situation the map shows the cells as transparent.

As mentioned before the map component can visualise the location information of the site and cell elements. Therefore the cell and cell area can also attach the attribute information as well as the capacity analysis results for the location information.



Through this functionality it can be beneficial to see the area affected by the capacity problems also with the location information. When this information is supplemented with for example traffic information, the user has fairly good amount of information to prioritise the capacity problems that are to be fixed.

The visualisation on map only still fulfils parts of the requirement presented in user story #9. To fulfil the requirement fully there is need to visualise all the four domains at once. Map is only capable of visualising two different domains with colours at the same time. The remaining two domains could be visualised on the map label, but as stated before the distinction means of text visualisation, especially when the amount of information is large, is nothing compared to that of colour visualisation. To meet the requirements of the whole edge-to-edge visualisation user story some additional requirements to the rest of the visualisation functionality in the tool is needed.

## **6.7 Tableview**

From requirements in user story #3 it is apparent that a third visualisation method is needed to be able to visualise large amounts of attribute information and also edit the information. An easy way to visualise large amount of text, numerical and even colour information is a table or sheet. There are many commercially valid solutions in the market to provide a baseline from visualisation and usability perspective for tables. The most well known is probably Microsoft Excel.

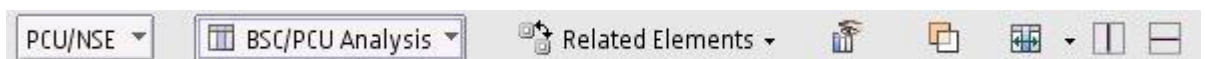
In the Treeview and the Mapview all the data is available all the time for visualisation and the filtering of the data is done in the view itself. As the Treeview and the Mapview are designed to provide the user with the access to two different aspects of the whole network data available, there is no need to build a complex Tableview to provide filtering functionality for the whole data, but the Treeview and the Mapview can act as pre-filters for the data. Therefore the Tableview can act from content perspective as a temporary visualisation channel for the data listed to be visualised there. Typically the scoping for the area of interest is done based on the logical hierarchy done in Treeview or based on the geographical area done in the Mapview. These views can provide the needed scoping functionality for Tableview. The browser can also be split into same visualisation areas as the map; these being navigability, customisation and visualisation.



Naturally these differ quite a lot from the map part and are covered in the following chapters.

### 6.7.1 Navigability

As stated in the introduction chapter, the Tableview does need to visualise all the data at once, but rather the data has to be selected or listed from some other scopes to the Tableview. Due to the fact that there is more than one visualisation channel that is able to visualise the whole network data at once, the Tableview content can not follow dynamically the selection from any other view, that is, Treeview or Mapview. The listing of objects to the Tableview therefore requires interaction from the other views. This inter-working of different elements is covered more thoroughly in Chapter 6.10. From Tableview perspective it is only important to realise a requirement that many different element types can be listed to be visualised, but different elements types do not need to be visualised simultaneously. Although the Treeview is the main channel to visualise different network element relations, from the network planning viewpoint it is also imperative that network element relations can be visualised on the attribute level as well. This need can also be realised from requirement defined in user story#9. [Nok04], [Nok06a], [Ert07]



**Figure 21: Tableview toolbar**

In Figure 21 the main navigability options of Tableview follow the navigation logic presented also in Mapview which is the usage of toolbar. The navigability options of the Tableview still differ to a great extent from that of the Mapview. Although the navigation options of the Tableview are fairly complex when compared to the Mapview, the emphasis of the toolbar design is still kept on the simplicity and informative approach prominent in the whole UI. The most important navigability options that relate to the data itself are the selection of base element and the Tableview profile. The base element selection defines the basic element to be visualised in the Tableview. The base element is the element listed to Tableview from Treeview or Mapview. The base element is defined as a combo box selection because from the base element selection the user is able to change the base element to any element that has a direct relation to the base element listed to the Tableview. The Tableview profile is dynamically related the



base element selection and different base elements have different Tableview profiles. The Tableview profile defines the column visualisation for the content in the Tableview. The profile definition is defined in Chapter 6.7.2 and the visualisation is covered in more detail in Chapter 6.7.3.

## 6.7.2 Customisation

The customisation part of the Tableview basically only covers the definition of the Tableview profiles related to each of the base elements. All the base elements have a factory default profile defined that defines the most commonly used attributes related to the base element. These default factory profiles can not be altered nor deleted. As the needs of different users vary, the users can define their own user profiles to cover all the other attribute visualisation combinations needed. The management of profiles is done in the profile editor. As defining the profiles is not directly related to any analysis functionality, the profile editor functionality is presented in a modal dialog, but user is still able to see the profile changes in the Tableview content when applying changes to the profile. The profile editor can be opened from the Tableview toolbar and is related to the base element selection. From the profile editor dialog it is possible to delete user defined profiles, create new profiles and use the existing factory profile or already defined user profiles as a basis for new profile definitions. The Tableview profile editor is presented in Figure 22. [Ert07]

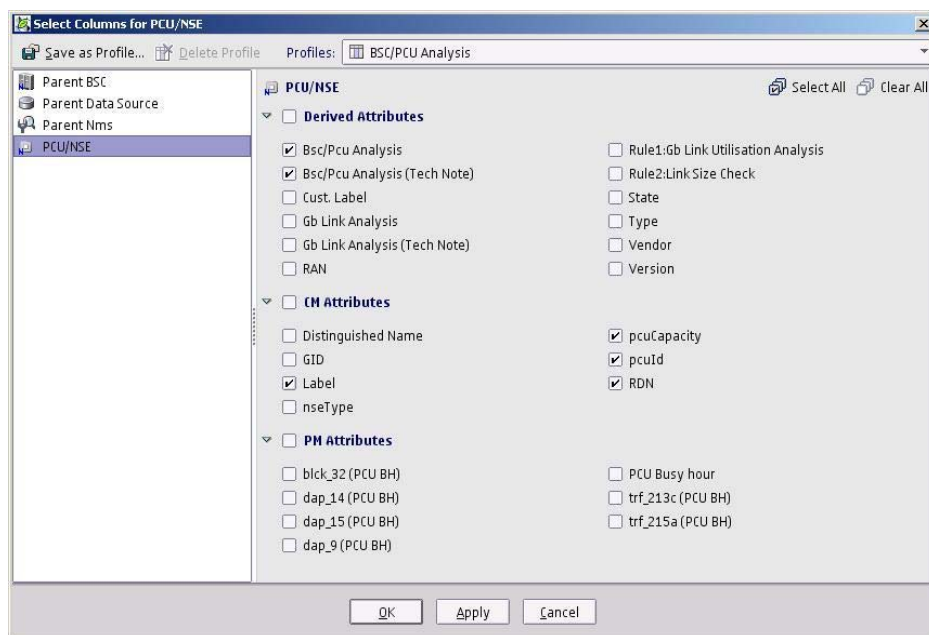


Figure 22: Tableview Profile Editor



In the left pane of the profile editor the related elements of the base element are defined as a list with the icons as well as the name of the related element. The selection from the list affects the content of the right pane of the profile editor where the attribute content of the element selected is presented. The selected element with element name and icon are also represented in the upper part of the attribute pane. The attribute content is grouped to the same generic groupings of attribute defined already in Chapter 6.6.3. The attributes selected to be visualised in the Tableview are selected from a checkbox individually defined for each attribute. The checkbox functions as typical binary selection checkbox where the check mark indicates that the attribute is selected to be visualised. The attribute group is also marked with a checkbox that acts as master selection for the attributes under the group. The group selection can select all the attributes under the group and also unselect all the attributes at once instead of selecting or unselecting individual attributes one-by-one. The groups are also built as expandable panes, so the information of individual group can be hidden if so wanted. All the attributes can also be selected or unselected from the upper toolbar of the attribute pane.

### 6.7.3 Visualisation

The management of element selections and the profiles related to the elements listed to the Tableview were presented in the previous chapters. In this chapter the content part and its visualisation and customisation is presented. As Microsoft Excel is more or less the de facto standard in the Tableview data visualisation and handling, many of the design solutions are replicated from there, but some solutions raise also from needs of the capacity analysis.

The visualisation with network element data is presented in Figure 23. As the data amount can rise fairly high also from the attribute viewpoint, but especially from the element perspective, the vertical scrolling functionality is imperative as not all the data can be shown at once. As the amount of attributes can be defined with the Tableview profiles by the user horizontal scrolling may also occur. As a design principle the horizontal scrolling should be kept in the minimum and thus few manual and also automated aids are provided to minimise necessity of horizontal scrolling. The user is able to manually modify the column width by dragging the column from the right. The user is also able to split the Tableview horizontally and vertically to cover different areas of the data at once. The horizontal split allows a distinguishing column to stay



static at the same time as the attribute columns are scrolled. The vertical split allows different elements to be visualised at the same time without sorting. The column width change and split functionality is adopted from Microsoft Excel. To reduce the need for horizontal scrolling some assistance to automatically fit the columns into the Tableview visible area are provided. These include fitting the header text into the view, fitting the data into the view disregarding the header width and header text visibility and also fitting the data to the visible area. All these are provided to minimize the usage of horizontal scrolling. [Coo03]

	Cust. Lab...	dedicated...	defaultGP...	egprsEna...	gprsEnabl...	maxGPRS...	trf_212c (C...	ava_44 (PS...
51	BTS/251	1	1	1 - EGPRS is en...	1 - GPRS is ena...	100	87.55	6.0
52	BTS/250	1	1	0 - EGPRS is dis...	1 - GPRS is ena...	100	83.22	3.0
53	BTS/25	1	1	1 - EGPRS is en...	1 - GPRS is ena...	100	110.34	7.0
54	BTS/249	1	1	0 - EGPRS is dis...	1 - GPRS is ena...	100	141.6	5.0
55	BTS/248	1	1	0 - EGPRS is dis...	1 - GPRS is ena...	100	114.76	11.0
56	BTS/247	1	1	1 - EGPRS is en...	1 - GPRS is ena...	100	146.84	9.0
57	BTS/246	1	1	1 - EGPRS is en...	1 - GPRS is ena...	100	46.38	5.0
58	BTS/245	1	1	1 - EGPRS is en...	1 - GPRS is ena...	100	84.42	6.0
59	BTS/244	1	1	1 - EGPRS is en...	1 - GPRS is ena...	100	25.17	4.0
60	BTS/243	1	1	1 - EGPRS is en...	1 - GPRS is ena...	100	72.54	9.0
61	BTS/242	1	1	1 - EGPRS is en...	1 - GPRS is ena...	100	0.08	12.0

**Figure 23: Tableview visualisation**

The data is visualised in a view very similar to that of Microsoft Excel. The columns have different attribute names as in Excel, but in addition to that the columns also contain the network element icon so as to distinguish to which network element the attribute is related to. Tooltips are provided for each attribute in order to clarify the attributes purpose, range and relation to the element. Rows, columns and individual cells can be selected from the Tableview. The column selection highlights the column and the attribute values of all network elements in the vertical line. The selection of a row highlights the row and all the attribute values of the corresponding network element in the row. The headers of the selections are also bolded to make the distinction of a column or a row selection clearer. From the top left corner box of the Tableview all the rows and columns can also be selected simultaneously. This functionality is provided because the user should be able to copy all the data or a subset of the data to any spreadsheet or text editor with the header data included or with only the raw data, that is, the attributes values. To enable multiple selections accelerator keys like shift and control with their respective functionality are also provided.

Any of the attribute columns can also be sorted to enable more efficient search functionality. This search functionality is enabled through the popup-menu of the



columns. The sorting functionality works for strings, numbers and even for colours. The sorting can be also done simultaneously for multiple columns. The sorting order is presented in the label as number. The number describes in which order the columns are sorted out. The sorting for the column number one is done first and in the case of equal values number two sorting is used to sort the attributes values according to second column and so on.

The Tableview is able to visualise different types of attribute values. The text is visualised in the left of the column and number are visualised on the right of the column. The numbers can be integer or boolean values as is the typical case with network element attributes or they can be decimal values as is the typical case with measurement data. The rule result colours can also be visualised on the Tableview cell as colour boxes in the Tableview cells.

Although the Service Optimizer in the first phase is primarily a capacity analysis tool, the user is, however, able to modify certain network element parameters. These editable configuration parameters are visualised with a white background and background is this way differentiated from the non-editable parameters that are visualised with a gray colour.

#### 6.7.4 Capacity Analysis in Tableview

Since Chapter 6.6.4 presented the capacity analysis methods for Mapview, it is also worth while of going through the functionality that the Tableview brings to the capacity analysis. Still all the functionality of Mapview and Tableview serves only one purpose to fulfil the requirements to visualise any data needed for the capacity analysis defined in more detail in user stories #3, #7, #8, #9 and #10.

As in the Mapview the user is able to visualise the rule results in colour format also in the Tableview. Where the Tableview falls short is that it is not able to visualise the geographical relations between the different analysis domains in a very understandable way. The problems with showing a multitude of attribute or parameter values simultaneously in one view is the case where the Mapview cannot fulfil the requirements set very well. Then again, the Tableview is partially built only to fulfil this need.





For the individual domain analysis, the Tableview is able to visualise simultaneously the rule results, corrective action if any problems have been identified in the analysis, configuration parameter values and measurement results. Factory profiles exist for each of the analysis domains. The factory profiles can thereafter be used as a basis to build a more conclusive profile for the analysis. When combining configuration parameters, measurement values and rule results, the user is able to get a more comprehensive picture of the situation in the network and also prioritise the corrective actions. With the help of the sorting functionality, the user is also able to sort the analysis results or corrective actions and use, for instance, the measurement values as a secondary sorter for the prioritisation. These features presented in this chapter contribute to the requirements described in user stories #7 and #8. Figure 24 presents an example view of the Radio domain analysis in the Tableview.

	Cust. Label ...	Radio ...	Radio Analysis (Tech Note)	ded...	def...	max...	egprsEnabled (5)	gprsEnabl...
51	BTS/39			1	70	100	0 - EGPRS is disabled (N)	1 - GPRS is ena...
52	BTS/38		Increase maximum GPRS capacity	1	1	100	1 - EGPRS is enabled (Y)	1 - GPRS is ena...
53	BTS/37			1	1	100	1 - EGPRS is enabled (Y)	1 - GPRS is ena...
54	BTS/36		Increase maximum GPRS capacity	1	1	100	1 - EGPRS is enabled (Y)	1 - GPRS is ena...
55	BTS/35			1	70	100	0 - EGPRS is disabled (N)	1 - GPRS is ena...
56	BTS/34		Increase maximum GPRS capacity	1	70	100	0 - EGPRS is disabled (N)	1 - GPRS is ena...
57	BTS/33		Increase maximum GPRS capacity	1	70	100	0 - EGPRS is disabled (N)	1 - GPRS is ena...
58	BTS/32			1	22	100	0 - EGPRS is disabled (N)	1 - GPRS is ena...
59	BTS/31		Increase maximum GPRS capacity	1	30	100	0 - EGPRS is disabled (N)	1 - GPRS is ena...
60	BTS/30		Increase maximum GPRS capacity	1	70	100	0 - EGPRS is disabled (N)	1 - GPRS is ena...
61	BTS/3		Increase maximum GPRS capacit...	1	1	100	0 - EGPRS is disabled (N)	1 - GPRS is ena...

**Figure 24: Capacity analysis for radio domain in the Tableview**

In the Mapview, the user can visualise the edge-to-edge rule results, but only one rule result can be presented for all the domains. If the rule result does not show any problems, the result is evident, but if the capacity analysis shows problems, the user is not able to distinguish from the Mapview that from which of the domains the problems is stemming from. Therefore the user needs to analyse all the domains individually in order to find out the real problems with the elements. Although the Mapview, to some extent, fulfils the requirement set in the user story for edge-to-edge visualisation (user story #9), still a vast usability gap exists if the user needs to rely on the map alone. As the Tableview is capable of visualising multiple attribute values simultaneously, the Tableview can also visualise multiple rule results for all the different domains at the same time. As stated in Chapter 2.2.3, an unambiguous logical edge-to-edge chain for EGPRS analysis can be derived from TRXs under BTS that connect to the same EDAP, all the way to the Gb-link. This is the reason why the base element in edge-to-edge



analysis for Tableview is defined as BTS/TRXs. The rule results are visualised in the same fashion as the individual results. With the support of default profile for the edge-to-edge analysis the browser forms an edge-to-edge “pipe” that can visualise and distinguish all the states of all the different domains in one view. The capacity analysis for the edge-to-edge chain can be performed also for GPRS only elements that use CS-1 and CS-2. In this situation the EDAP is missing from the logical edge-to-edge chain. This is visualised in the Tableview in light gray or non-existent value. An example view of the edge-to-edge analysis in Tableview is visualised in Figure 25 below.

	Cust. Label	Radio Analysis ...	Abis Analysis	Bsc/Pcu Analysis	Gb Link Analysis
233	BTS/TRXs/516 (1/1)				
234	BTS/TRXs/52 (1/1)				
235	BTS/TRXs/5356 (1/1)				
236	BTS/TRXs/5945 (2/2)				
237	BTS/TRXs/5969 (1/1)				
238	BTS/TRXs/5998 (1/1)				
239	BTS/TRXs/62132 (1/3)				
240	BTS/TRXs/63048 (1/5)				
241	BTS/TRXs/63055 (3/3)				
242	BTS/TRXs/64106 (1/1)				
243	BTS/TRXs/696 (2/2)				
244	BTS/TRXs/694 (2/2)				

**Figure 25: Tableview with Edge-to-Edge analysis results**

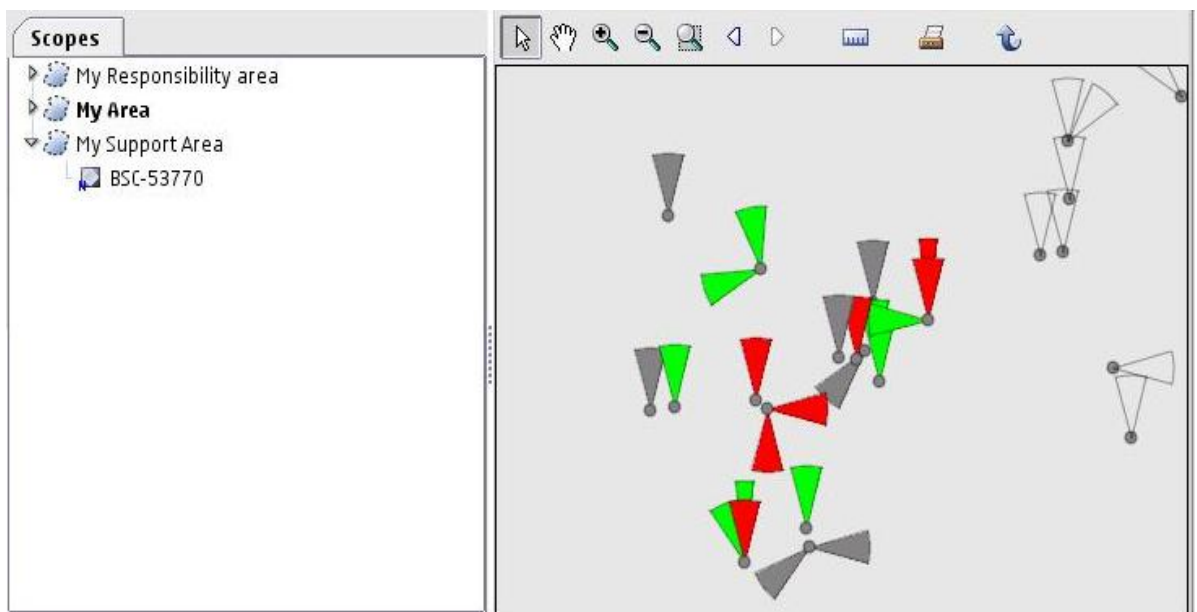
## 6.8 Scope Handling

Even though the user is able to select a temporary scope to be used for analysis from Treeview and Mapview, the transitory nature that is related to the selection of elements does not even remotely fulfil the requirement for scope definition set in user story #6. The Tableview provides a somewhat better solution to handle different scopes to be used in the analysis, but still it is evident from Chapter 6.7 that the usage of the Tableview as a substitute for fairly permanent scope handling implementation is not sufficient. As the components presented in previous chapters do not fulfil the requirement set for the scope, a need to build a component for scope handling is needed.

A steady definition of a scope can be considered to consist of a geographical area from the Mapview or a larger network element entity like BSC from Treeview. From the end-user perspective these scope definitions define the responsibility areas of the network. Therefore after the definition of the scope the different parts of the UI should adapt to the scope selection to filter the data accordingly. As the Treeview supports the grouping and filtering functionality fairly well even without a scope definition, the Treeview does



not need to accommodate and filter the data after the scope definition. It is also imperative that after the scope selection the user is able to add elements to the scope and still visualise the whole network structure. The Mapview can also filter the data via the supported zoom functions, although filtering and grouping functionality provided in the Mapview is not that suitable when comparing to Treeview in visualising the scope content without certain changes. This is why a post-filter for the Mapview is provided to visualise and clarify the scope content in better way. The post-filter consists of two different options. The first one composes of differentiating the scope content that of the off-scope content. This differentiation is created so that the scope content is visualised normally and the off-scope content is visualised in a manner that only the contour of the cell icons is displayed. The second option visualises only the scope content on the Mapview and the off-scope content is hidden completely. The cell contour visualisation example is presented in Figure 26 below.



**Figure 26: Scope with cell contour and scope content**

As the Tableview is already a temporary container for the data listed to it, no real changes are required. The scope and all of its content can be listed to the Tableview. In Figure 26 also the scope pane that visualises all the scopes created and also the content of the scopes is presented. The active scope is differentiated with a bold font. From the scope tree the user is also able to delete unneeded scopes and remove elements from existing scopes and naturally set any scope as an active scope.



## 6.9 Abis Visualisation

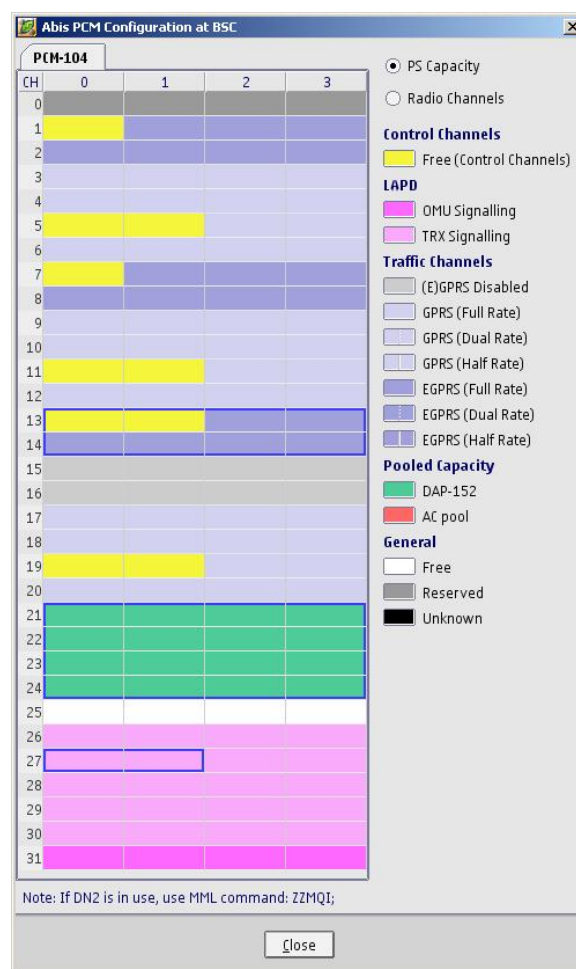
A clear side step from the capacity analysis workflow is related to the Abis-interface timeslot visualisation described in user story #11. Due to the sidestep nature of the workflow the Abis-interface visualisation is created to an independent dialog. User is not able to modify the transmission path using the Service Optimizer, so the Abis-interface dialog is built only for visualisation purposes only. The need arises basically from the ability to visualise if the user able to increase the EDAP size or not without changing other configurations in the Abis-interface.

As stated in Chapter 2.2.2, the Abis-interface consists of TDMA frames that can be further split in to four sub timeslots. E1 Abis-interface consists of 32 TDMA frames and T1 Abis-interface consists of 24 TDMA frames. Clearly a four times 32 or 24 timeslot matrix is best visualised as a table. The content of the table then comes from the usage of the timeslots on the Abis interface. As also stated before, the static timeslots used for TRXs take two consecutive Abis timeslots. To be able to visualise the unused timeslots or sub-timeslots in the Abis interface, the used TRX timeslots need to be visualised differently that of the free timeslots. The Abis interface visualisation can also be used to verify that the TRXs are mapped correctly to EDAP, if needed. Therefore it is also a requirement that the different TRX types can be differentiated from each other. The TRXs can be categorised depending on the feature that the TRXs are capable of. A TRX can be non-GPRS, GPRS only or EGPRS capable. Again different colours are used to differentiate various types of TRXs. In this case somewhat same colour with different shades is used because the differences of the object types are not as big as differences to other usage of the Abis timeslots.

In addition to TRX timeslot mapping, the EDAP timeslots are also mapped to the Abis. The EDAP size can range from 1 to 12 timeslots from the Abis. The EDAP information needs to be also differentiated with a different colour from the TRXs. In the same Abis there can be multiple EDAPs, so these needs to be also differentiated from each other. In addition to this information certain sub timeslots also carry signalling information. Moreover some of the Abis timeslots are not mapped to any purpose and are free. The only colour in the Abis interface visualisation that is self evident is the colour defined for free timeslots. Colour for free and freedom is almost in all cultures white. This colour is also used to define free timeslots of the Abis interface. [Gol02]



The EGPRS capable and GPRS capable TRXs that use CS-3 and CS-4 need to be mapped to the EDAP. This mapping is visualised as a border highlighting when the TRX timeslots are selected from the Abis interface visualisation. The corresponding signalling sub timeslots are also highlighted. Because there are many diverse differentiation means and the colours themselves can not be easily mapped to intuitively, there is also need for a legend. The legend eases the distinction of different colours and other visualisation means for differentiation. The whole dialog is presented in Figure 27 below.



**Figure 27: Abis configuration view with E1**

The exactly same dialog presented above can be used to visualise the T1 24 timeslot Abis interface. The only difference is that the timeslots from 24 to 31 are marked as reserved, that is, greyed out in the T1 Abis interface.



## 6.10 Overall Capacity Analysis

To justify the need for all of the different UI components and to sum up all the design solutions described in this chapter, it is important to describe once again from the UI viewpoint the capacity analysis workflow. The Service Optimizer tool is not restricted by modes, so the workflow described in Chapter 5.3, is just an example and some of the task can be done in any order.

From data handling alone there are basically five different actual or virtual network element types that are essential to the capacity analysis. These element types are: BTSs that are used in the radio analysis, DAP objects that are used in the EDAP analysis, BSC/PCUs that are used in the PCU analysis, Gbs that are used in the Gb-interface analysis and BTS/TRXs that are used in the edge-to-edge analysis. The visualisation and data handling capabilities of the whole tool concentrate around these five element types.

In all of the different UI components described in this chapter there has not been that much explanation about the capabilities of interaction between the views. Due to the fact that there are many different views that can handle data in a different ways, cooperation or interaction between the views is needed with the purpose of making all the views as equal and as usable as possible. In the previous chapters the focus has been on the UI component internal navigation, visualisation and customisation. To enable the external navigability and interaction with different components, a context sensitive approach is needed to enable functions to different UI component elements. These elements are mainly the Treeview tree nodes, the Mapview site and cell icons and the Tableview rows, columns and cells. Due to the fact that there are quite a few UI components that require interaction from other UI components and also because the context sensitive actions are numerous, there is a need to build functionality to enable multiple possible actions for the context at hand. The means to build context sensitive selection frame that is capable of multiple actions is usually built with a popup-menu. Typically a popup-menu hierarchy is kept as flat down as possible meaning that there is typically only one level of menu items in the simple popup-menu. If and in this case when the number of different functions rises to a level where a popup-menu becomes cluttered, a cascading or a multi-level popup-menus can be used. Although as an UI design idiom the usage of cascading popup-menu should be kept in the minimum, the



cascading menu still provides a sound grouping functionality for different menu item. The context sensitivity in the popup-menu tries to emphasis the fact that not all the functions are available for all the different elements. [Coo03]

In the Treeview there is the special capacity analysis view that is created based on the virtual elements, which form the possible bottlenecks in the EGPRS path. A mapping is created from the five network element types to virtual cell elements, which are visualised in the logical Treeview and also on the map. Because of this mapping an interaction from any context sensitive selection that includes the essential capacity analysis objects can be created to the Mapview cell objects. This enables the functionality of showing on the Mapview any objects from the Treeview, the Tableview or the Scopeview. In practise, showing means panning the Mapview automatically to the right location with the right zoom distance and the corresponding cell elements are highlighted from the Mapview. The elements from Mapview can also be located from the Treeview meaning that the Treeview nodes are expanded to the extent that is needed to display the cell of site selection. As the Tableview acts as a temporary container for the needed elements, there is also a possibility to set the objects from the Treeview, Mapview and Scopeview to be visualised in the Tableview from the context sensitive popup-menu.

The most important function of the popup-menu is the functionality related to the actual capacity analysis feature. The intended capacity analysis workflow suggestion emphasises the interaction of different UI views and customisation features, which were presented in the previous chapters. The functionality to perform the capacity analysis for the selected context is not limited to any particular UI view. The capacity analysis for any of the domains or for the edge-to-edge analysis can be performed from Scopeview, Treeview, Mapview or Tableview selection. As has been the emphasis from the beginning of the UI design, the idea has been that the analysis itself does not open any new views or dialogs that show the capacity analysis results, but the existing functionality that is presented in the previous chapters is utilised. The two UI views used to visualise the results of the analysis are the Mapview and the Tableview. When the analysis is performed the corresponding objects related to the context selection are automatically visualised in the Tableview and showed on the Mapview. Also the Mapview visualisation profile for the cell element icons is changed to visualise the



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corresponding domain analysis results. The Tableview profile is also changed to the default profile related to the domain that the analysis is performed on. When the edge-to-edge analysis is performed the user is able to distinguish the problematic analysis domain and objects from the Tableview and thereafter further drill down to the exact domain to make the final analysis and also visualise the corrective actions for the problem.

With Mapview and Tableview the user is also able to visualise and verify the day-to-day measurement values and their development and correspondence to each other. This helps in identifying and prioritising the corrective actions proposed by the analysis. In the Mapview with the help of the cell area visualisation it is also possible to visualise the geographical area affected by the problem with any of the analysis domains. This can also be used to prioritise the corrective actions. With the help of the scope functionality it is possible to filter only the special interest area to be used in the analysis. As the Mapview can even filter out the objects outside from the view, the user is able to concentrate on the essential objects that have been identified as the scope.





## 7. CONCLUSIONS

The growth in the usage of data services offered through mobile networks has increased the requirements for QoS in the network itself. As the data services offered in EGPRS networks are built on top of existing GSM network structure, the management of different network elements related to the network are fairly fragmented across the BSS. From the planning and analysis view point, the EGPRS network includes network elements from the radio and the transmission domains. In the analysis phase the split of responsibility and the lack of visibility of the whole edge-to-edge capacity analysis chain may result to poor network quality and non-optimal usage of the network elements. Centralised solution to analyse the whole capacity domain of the BSS helps in the analysis of capacity bottleneck and should reduce the capital and the operating expenditure of an operator and also increases the overall visibility of possible problems.

In this thesis the functions to visualise and analyse EGPRS networks capacity problems in a UI have been studied. The goal has all the time been to understand the user's needs and from those needs create usable solutions in a form of intuitive and easy to use UI. This has required also a thorough understanding of the overall workflow related to capacity analysis in order to create a UI that support all the needed steps in the workflow in continuous chain of different tasks.

The task of refining from user wants to user needs and eventually to actual user requirements in order to create a sufficient all-inclusive workflow to support the user goals in a usable and intuitive is a very difficult task. This requires understanding and acceptance of the real users of the software and also their context of use. When the real users have been identified, the requirements need to be created from the real needs of the users. The requirements should not be created without clear user needs. As the needs are the bases for actual user requirements, the acceptance and justification of those requirements becomes easier as the decisions are based on real user data. This kind of approach reduces design battles and opinion wars between the product management or the requirement definers and the software development or the designers. Moreover, it is essential to challenge the requirements and design solutions, but the actual user needs should never be challenged. User Stories in addition with well defined workflow help in identifying the missing features from the UI and gaps in the UI workflow. Overall, the creation of this kind of continuous workflow support in the UI has required multiple



iterations. This iterative approach is one of the cornerstones of the UCD. The used software development process has also supported the continuous loop of feedback and modifications.

The major outcome of this thesis has been the creation of a UI that would fulfil all the users' needs and goals found in the continuous requirement analysis process. The scope of defining the reasoning and background information behind this UI grew so large that the initial idea of including also the usability evaluation to the scope could not be met. Therefore it may seem that some of the justifications and decisions were left out in the air and a more through fact based reasoning could have been needed. The outcome of the usability evaluation would also give more through understanding of the actual usage and usefulness of the tool and could contribute more to the reasons related to certain design decisions. Still, it is worthwhile mentioning that during the creation of the UI a continuous effort was made to evaluate and improve the UI and collect feedback about design decisions and their justifications.

Although the functionality of the tool described in this thesis limits only to GSM/EDGE networks capacity analysis, still the overall design of the UI was kept as flexible as possible when considering the further extensions to other domains. As the analysis related to capacity analysis in GSM/EDGE networks is not only related to the BSS domain, similar functionality would also be needed for the core network part. When including also the core network to the analysis, the GSM/EDGE network part would then constitute of being a true end-to-end analysis. The GSM/EDGE network provides a good starting point as the knowledge of the networks is fairly conclusive due to the fact that the basis of the technology have been available already for more than fifteen years. Still, the GSM/EDGE networks are being complemented with new technologies like UMTS and WiMax with rapid pace. These mobile network standards provide faster data transfer capabilities and also require similar capacity analysis functionality as GSM/EDGE networks when becoming more widely used.

The loyalty of mobile operators to restrict to only one network vendor is not that high and some operators can have network infrastructure even from four different network vendors. This challenge of building extensive OSS software to support all the network vendors, also called multivendor support, is one of the hottest buzzwords in the field of



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telecommunication at the moment. To build a conclusive capacity analysis tool all the other network vendors should be also taken to be a part of the capacity analysis tool.

It has not been in the scope of thesis to describe the actual rules related to the GSM/EDGE networks analysis, but the definition of the analysis rules has been a mandatory prerequisite for the tool development. As a future study and also as background information related to the continuation of the tool development, it would equally important to create similar rules to possible extensions like the core network of GSM/EDGE, UMTS or WiMax networks.

The manual capacity analysis functionality provided in this thesis provides also a foundation to other kinds of improvements as well. Operators require more and more automation of the configuration and optimisation task related to mobile network management. The manual steps needed in the current tool could also be automated further. The reactive features related to capacity analysis could also be made more proactive with certain simulation and trend estimation methods. This functionality would also require some more research.

As seen from the many possible future development alternatives and improvement suggestions provided in this chapter, the tool described in this thesis seems to be only a good first step when thinking about a thorough and conclusive capacity analysis. Only the future will tell which steps will be taken next, but surely the need of analysing the capacity related problems in existing and future networks will only grow in the future.



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## 9. APPENDIX

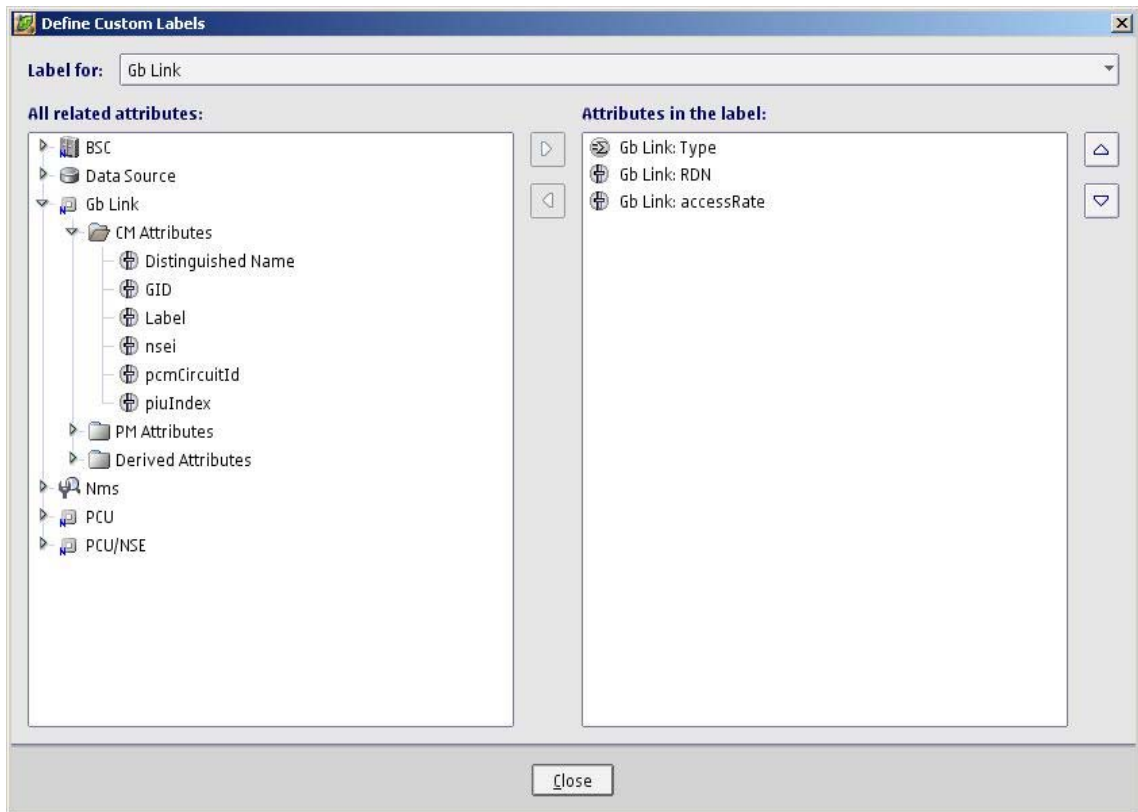


Figure 28: Custom Label Dialog

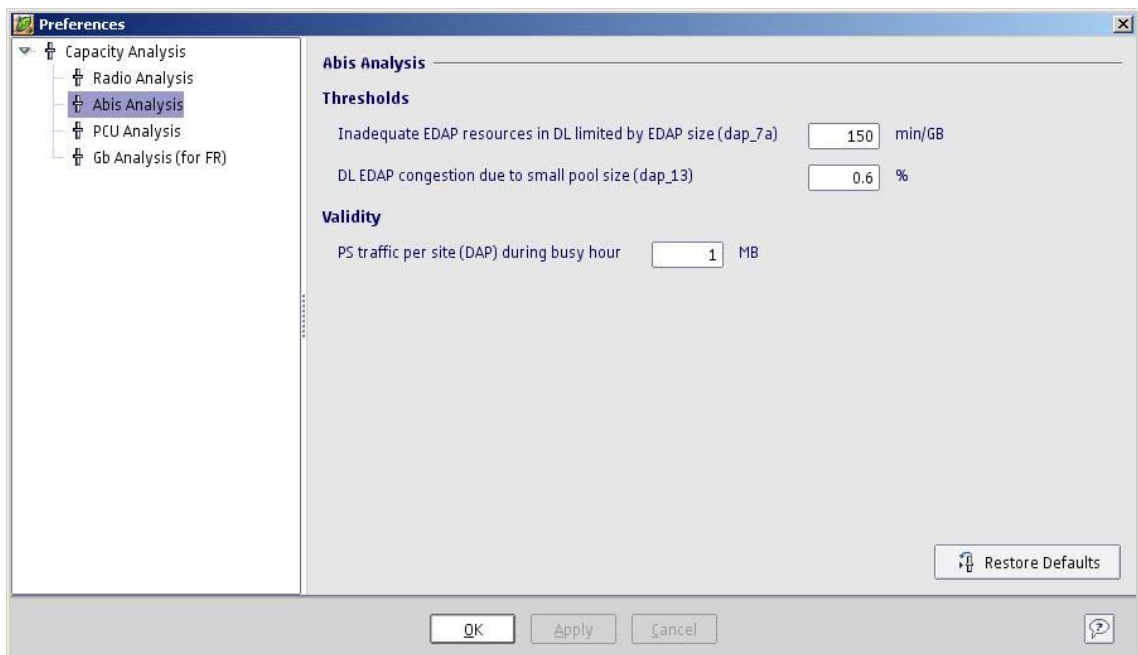
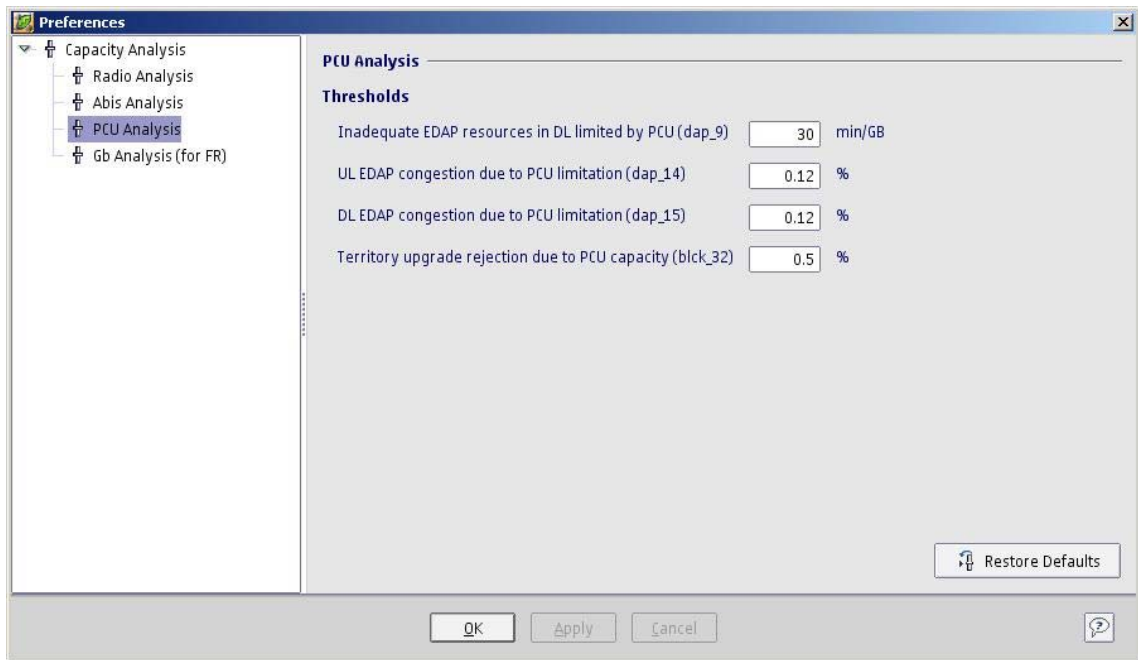
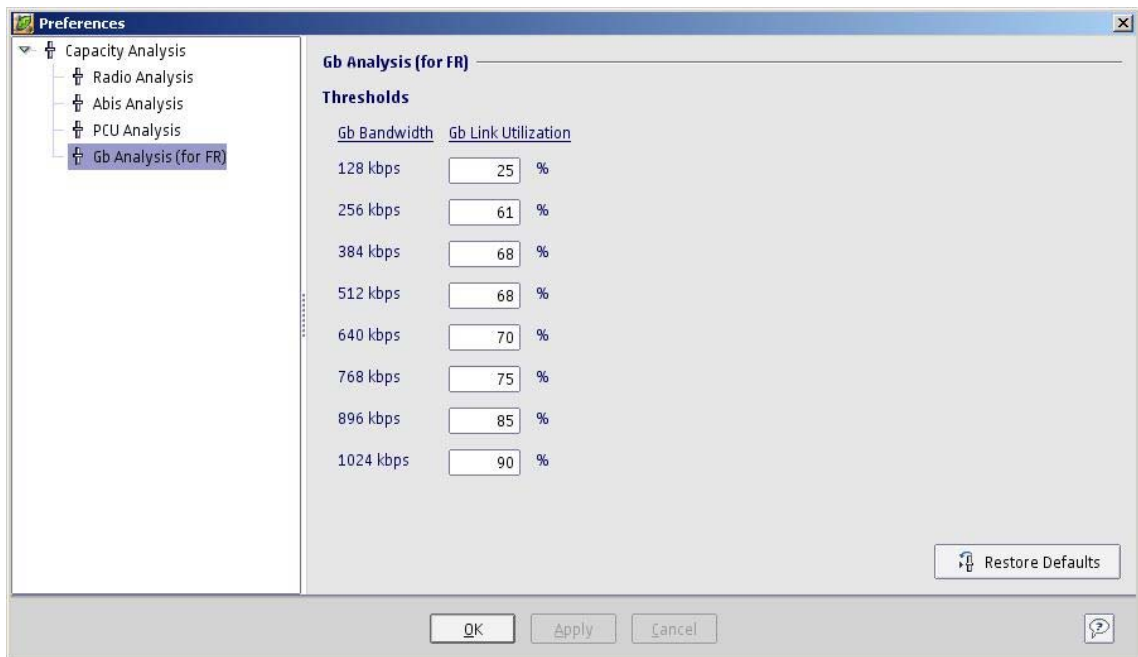


Figure 29: Preferences for Abis Analysis



**Figure 30: Preferences for PCU Analysis**



**Figure 31: Preferences for Gb Analysis**