Universidade de Aveiro Departamento de Electrónica,
2011 Telecomunicações e Informática

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Proposta 3GPP de Indicadores de Desempenho de Rede – R4 CS Core Network

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2011

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Engenharia Electrónica e de Telecomunicações (Mestrado Integrado), realizada sob a orientação científica da Professora Doutora Susana Sargento, Professora auxiliar do Departamento de Electrónica, Telecomunicações e Informática da Universidade de Aveiro.

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agradecimentos

Uma palavra de agradecimento à minha orientadora, Professora Doutora Susana Sargento, pelo apoio e válidos conselhos que me proporcionou ao longo deste trabalho.

Aos meus colegas de trabalho pela oportunidade de troca de experiências e pelos conselhos recebidos.

Um agradecimento muito especial à minha mulher, Daniela, pela força e apoio que me deu para a realização desta dissertação.

Aos meus pais e sogros, por tudo.

palavras-chave UMTS, CS, KPI, Desempenho, Monitorização, OSS, PMS, Reporting

resumo

O mercado de telecomunicações tem vindo a tornar-se cada vez mais competitivo e agressivo devido à diminuição das margens dos operadores de telecomunicações. Este facto é igualmente relevante no mercado das redes móveis em que este trabalho se foca. A maior parte dos actuais mercados de redes móveis pauta-se por uma consolidação da sua base instalada e por uma optimização dos recursos existentes. Por uma questão de estratégia comercial e técnica (não dependência de um único fornecedor) é frequente os operadores de redes móveis terem mais do que um fornecedor de equipamentos de telecomunicações para a sua rede. Devido a este facto, os problemas das redes com multi-fabricantes agudizou-se o que levou à premente necessidade de se arranjar uma linguagem comum através da qual se consiga ter uma ideia do nível global de desempenho alcançado e dos pontos críticos em que a rede pode melhorar o seu desempenho. É nesta problemática que o presente trabalho se foca.

Neste momento, o 3GPP tem definidos uma quantidade vasta de indicadores de desempenho de rede para a área Circuit Switch (CS) Core Network (CN) mas ainda não tem definidos os seus Key Performance Indicators (KPIs).

Tendo como base os indicadores de desempenho 3GPP existentes, esta Dissertação propõe um conjunto de KPIs que possibilitam a análise do desempenho da rede Core Network ao nível da sua parte CS.

Esta Dissertação apresenta as propostas de KPIs para a rede CS, as quais estão divididas em três partes. Numa primeira parte são apresentados os KPIs relativos ao MSC Server (MSS) ao nível da análise de acessibilidade, utilização e mobilidade. Na segunda secção são apresentados os KPIs relativos ao Media Gateway (MGW) ao nível da análise de acessibilidade, integridade e utilização. Finalmente na terceira e última secção apresentam-se os KPIs associados ao HLR.

keywords

UMTS, CS, KPI, Performance, Monitoring, OSS, PMS, Reporting, KPI

abstract

The telecommunications market has become increasingly competitive and aggressive due to the decreasing margins of telecom operators. This fact is also relevant in the mobile networks market in which this Thesis is focused. Most of today's mobile networks is guided by a consolidation of its installed base and by optimizing existing resources. As a matter of business strategy and technique (not dependent on one supplier) it is common for the mobile network operators to have more than one telecommunications equipment supplier. Due to this, the problems of multi-vendor networks has worsened leading to the urgent need to find a common language that everyone speaks and, through which, can get an idea of overall performance level achieved and critical points where the network can improve its performance. This paper is focused on this issue.

Currently, 3GPP has defined a wide range of network performance indicators for the Core Network (CN) Circuit Switch (CS) area but, nothing is yet set in what Key Performance Indicators (KPIs) is concerned.

The purpose of this Thesis is, based on already existent 3GPP performance indicators, recommend a set of KPIs to enable the CS CN performance analysis.

This Thesis present the CS KPI proposals which are divided in three main parts. In the first part, are presented the MSC Server (MSS) KPIs at accessibility analysis, usage and mobility levels. In the second part are presented the Media Gateway (MGW) related KPIs at accessibility analysis, integrity and usage levels. Finally we have the third and last part where the HLR related KPIs are presented.

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Acronyms

3GPP	3rd Generation Partnership Project
ARPU	Average Revenue per User
AC/AuC	Authentication Centre
BTS	Base Transceiver Station
BSC	Base Station Controller
BSS	Base Station Subsystem
CAPEX	Capital Expenditure
CM	Configuration Management
CN	Core Network
CR	Change Request
CS	Circuit Switched
CSD	Circuit Switched Data
DL	Downlink
E2E	End-to-End
EIR	Equipment Identity Register
EM	Element Manager
EPC	Evolved Packet Core
E-UTRAN	Evolved UTRAN
FM	Fault Management
FTP	File Transfer Protocol
GGSN	Gateway GPRS Support Node
GMSC	Gateway Mobile Switching Centre
GPRS	General Packet Radio Services
GTP	GPRS Tunnelling Protocol
GTP-C	GPRS Tunnelling Protocol – Control Plane
GTP-U	GPRS Tunneling Protocol – User Plane
HARQ	Hybrid Automatic Repeat reQuest
HLR	Home Location Register
HSCSD	High-Speed Circuit-Switched Data
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HSS	Home subscriber server

HSUPA	High Speed Uplink Packet Access
HTTP	Hypertext transfer protocol
ID	Identity
IETF	Internet engineering task force
IMEI	International Mobile Equipment Identity
IMS	IP multimedia subsystem
IMSI	International mobile subscriber identity
IP	Internet Protocol
ITU	International telecommunications union
KPI	Key Performance Indicator
L2	Layer 2
LTE	Long-Term Evolution
MM	Mobility management
MME	Mobility management entity
MSC	Mobile Switching Centre
MSS	MSC Server = Mobile Switching Centre Server
NE	Network Element
OBS	Operational Business Software
O&M	Operation and maintenance
OPEX	Operational Expenditure
PDN	Public data network
PDP	Packet data protocol
PDU	Protocol data unit
PM	Performance Management
PI	Performance Indicator (counter)
PM	Performance Management
PHY	Physical layer
PLMN	Public land mobile network
PM	Performance Management
PS	Packet switched
PSTN	Public switched telephone network
P-CSCF	Proxy-Call State Control Function
P-GW	PDN Gateway
QoS	Quality of Service

RAN	Radio access network
RANAP	- Radio Access Network Application Part
RNC	Radio network controller
RNS	Radio network subsystem
RNSAP	RNS application part
RRC	Radio resource control
RRM	Radio resource management
RT	Real time
RTCP	Real-time transport control protocol
RTP	Real-time protocol
RTSP	Real-time streaming protocol
SAE	System architecture evolution
SAE Gateway	System Architecture Evolution Gateway
SEQ	Sequence
SGSN	Serving GPRS support node
SGW	Serving Gateway
SIP	Session initiation protocol
SLA	Service Level Agreement
SM	Session management
SMS	Short message service
SN	Sequence number
S-CSCF	Serving-CSCF (Call State Control Function)
TTI	Transmission Time Interval
TMN	Telecommunication Management Network
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunication Systems
VLR	Visitor Location Register
XML	Extended Markup Language
WCDMA	Wideband Code Division Multiple Access
I-CSCF	Interrogating-CSCF (Call State Control Function)
I-HSPA	Internet High Speed Packet Access
1G/2G/3G	1^{st} Generation / 2^{nd} Generation / 3^{rd} Generation Networks

1. Introduction

The main purpose of public telecommunications networks started to be the establishment, maintenance and control of communications between fixed points of the network. The number of points to be linked were initially few. The number of services provided by these networks was sparse and the voice transmission was the service that clearly stood out. These networks were mainly owned by state agencies and the competition between operators was limited or simply non-existent.

Although the reality had changed from country to country, this status remained unchanged until the end of the 2^{nd} half of the XX century.

The end of the 70s and the beginning of the 80s brought the fixed network digital transmission and switching systems. This important technical breakthrough had paved the way to the revolution that took place during the next two decades. The telecommunication networks explode all of its potential starting from the 90s. Via this disruption, the previous existent status quo was abolished. The new facts were:

- The fixed networks started to no longer be only voice oriented. They started to be, more and more, data transmission services oriented.
- Due to this data service approach, a set of new services was introduced.
- The digital cellular networks were introduced with a remarkable success. Here a special remark shall be made to the Global System for Mobile Communications (GSM) networks.
- Most of the more developed countries start to open and liberalize their telecommunication networks.

As result of all these changes, the telecommunication networks that were already competitive, gain even more competitiveness and a new world of opportunities has seen the light.

With the outcome of the XXI century the fixed networks start to be more and more used for the data services and a real wide band data service access and usage start to be a reality. The number of services provided by this type of networks exploded. The mobile networks finally reached a true data mobile services. A real wide band mobile data services was achieved. Here, a special note shall be highlighted to the Evolved or Internet High Speed Packet Access (I-HSPA) introduction and to the flat rate price services. We have reached to a point where the telecommunications start to be really multiservice networks. Although varying from country to country, the liberalization process went through and reached a maturity phase. This has brought a lot of capital and more players to this day-to-day more competitive market. All these facts forced to a significant change in the traditional telecommunication business model.

At economical level, as result of this transformation process, the telecommunication market started to be extremely attractive but, at the same time, also started to need a large investment of capital and became a highly intense capital market.

Day to day, the telecommunications operators start to feel the pressure to reduce their network costs namely the Operational Expenditure (OPEX) and the Capital Expenditure (CAPEX), while trying to increase the Average Revenue per User (ARPU). The necessity to cope with all these somewhat antagonist factors raised the need to a better network control and optimization which, by its turn, lead to the development of better operation, management and supervision systems.

The changes that have just been described had result in a significant increase of the technical complexity of the network systems.

Initially, there was only one fixed network supplier with a low limited number of users with low level of competition, almost mono service with a few number of equipment suppliers. Now, we have big multiservice networks, may it be in terms of number of users, number of network equipments, used protocols or technical complexity. Huge networks were created with an immense volume of data to be transported, wide spread of different charging plans, complex technological networks difficult to be integrated and a big quantity of different network element equipment suppliers (which brings different hardware architectures, different base object and metadata models, different count update trigger points, etc.).

A point has been reached where the management of this vast sophisticated ecosystem is a major necessity. These telecommunication systems are already quite complex when analyzed separately, but it is still unclear how to cope with all these technologies and different vendor approaches. Face to its particular huge complexity, this issue is seriously felt in current mobile networks: How to manage it? How to create global network Key Performance Indicators (KPIs) applicable to the overall mobile network equipment suppliers? How to create real useful KPIs paved on so many different object, metadata models and different approaches?

This will be the subject that this Thesis will have to deal with.

1.1. Motivation

Face to the problem just presented, the 3rd Generation Partnership Project (3GPP) has defined a set of Key Performance Indicators (KPIs) that are able to be applicable to any network equipment vendor.

3GPP defined a set of KPIs for many mobile network technologies, namely:

- 3GPP TS 32.410 – KPIs for UMTS/GSM
- 3GPP TS 32.450 – KPIs for E-UTRAN
- 3GPP TS 32.455 – KPIs for Evolved Packet Core (EPC)
- 3GPP TS 32.454 – KPIs for IP Multimedia Subsystem (IMS)

However, there is yet no definition related to the Circuit Switch (CS) Core Network related part.

As a Network Management Engineer, my motivation for this work is to propose a selection of KPIs and use cases that target the CS Core Network analysis.

1.2. Objectives

This Thesis will study current 3GPP Performance Management (PM) definitions and based on such, will then propose the KPIs for CS Core Network Release 4. It will be proposed a general set of KPIs possible to be applicable to any network and equipment vendor, considering that the PM fulfils the required 3GPP specs.

The current analysis will be made for the *Circuit Switched (CS) Core Network (CN)* area (bellow highlighted in pink).

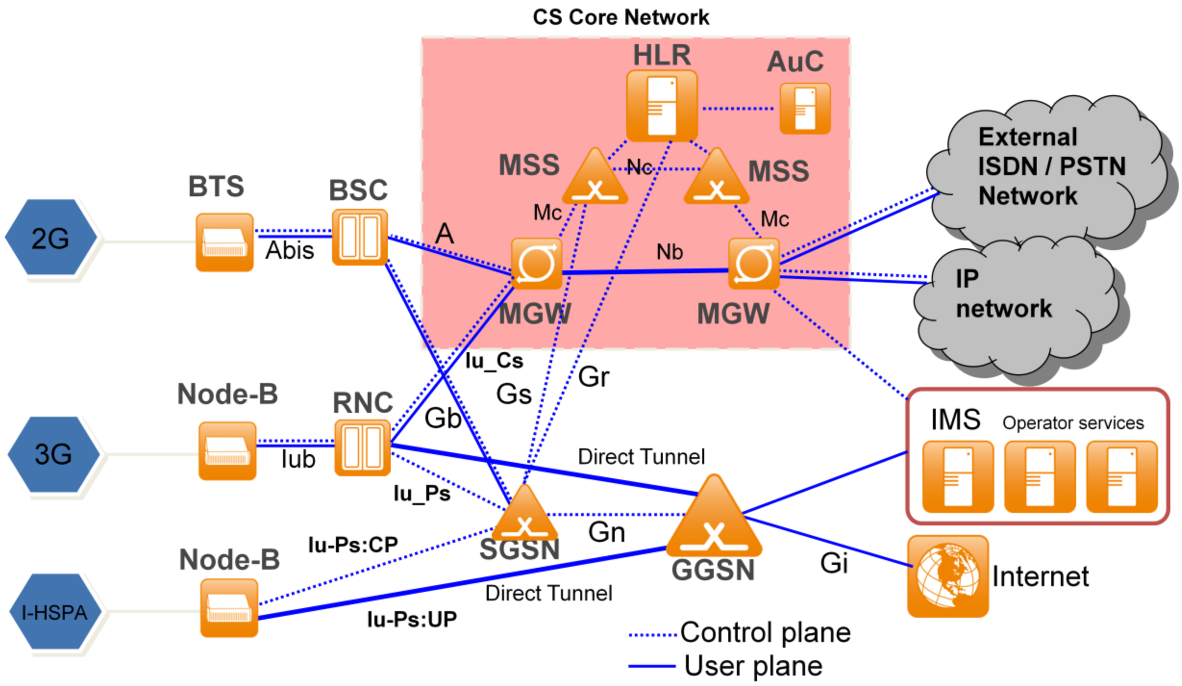


Figure 1 - Area of impact of the current Thesis

1.3. Organization of the Thesis

This Thesis has a first introductory part where the motivation, objectives, organization of the Thesis and working procedure are briefly described.

The mobile network evolution is then presented as a way to better understand the need of the currently proposed KPIs.

This Thesis then enters in the Release 4 architecture model which is the basis of this work. The signalling procedures and protocols are here explained in detail. These items are important to later better understand some of the proposed KPIs.

The Thesis next explains the already existent 3GPP CS CN performance model which will be the base for the proposed KPIs.

The KPI overall theory is subsequently presented. Finally, each KPI is presented in detail. They are divided in 3 parts: first the Mobile Switching Centre Server (MSC-S) related, next the Media Gateway (MGW) and, at the end, the ones associated with the Home Location Register (HLR) Network Elements (NEs).

At last, the final conclusion and future work ideas are presented.

1.4. Working procedure

First, the 3GPP TS 32.407 document where the 3GPP CN (Core Network) CS (Circuit Switch) Performance Management Measures were presented was deeply analyzed.

It shall be noted that, during this task, some 3GPP specification errors (wrong trigger point definitions, misleading indications, wrong unit references, etc.) were found. By using Nokia Siemens Networks 3GPP representative interface, a Change Request (CR) was issued to the 3GPP calling for a specification update.

Once this analysis was performed, the CS CN KPI proposals were made, having as source the already published and approved 3GPP PM counters and measures.

2. Background

2.1. Overview

This chapter introduces several concepts that are fundamental for the understanding of this Thesis.

This chapter is going to present the mobile networks evolution, the different technologies and types of networks involved, the network's increased complexity, the increasingly tight competition between the network operators.

In this chapter it is also going to be presented the traffic models and signalling flows that will later be used in the KPI proposals.

The CS Release 4 protocols that will be used in the proposed KPIs, are going to be presented and deeply analyzed.

It is also is going to be made a brief presentation and analysis of the important 3GPP TS 32.407 document. This is the base document that describes the 3GPP metrics that will support the subsequent KPI proposals.

Also in this chapter it is presented the state of the art of the Telecommunication Management Systems where the KPIs proposed in this Thesis will be based on.

Finally the KPI theory that will support the KPI proposals is going to be presented.

2.2. Mobile Networks evolution

This section explains how did we reach to the current CS Release 4 networks and where does Release 4 fits inside the current state of the art evolution path.

In order to better understand the current Release 4 and later architectures, it is important to make a brief step-back in order to understand how we reached to the current status. The next Table 1 summarizes this evolutionary path at technology, usage, coverage type, purpose and standardization levels.

1G	2G	2.5G	3G
TACS	GSM, TDMA, PDC, CDMA/IS-95	GPRS, EDGE, EGPRS, IS-136B, HSCSD	UMTS (3GPP), CDMA2000 (3GPP2), TD-CDMA, UWC-136
Analogue Cellular (single band)	Digital (dual-mode, dual-band)	Digital (dual-mode, dual-band)	Multi-mode, multi-band
Voice Telecom only	Voice + Slow speed data	Voice + Medium speed data	Circuit-Switched + Packet-Switched

	Full CS Technology	CS + partial PS Technology	
Outdoor coverage	Indoor / Outdoor coverage	Global roaming	Global roaming
Distinct from fixed PSTN	Complementary to fixed PSTN	Integration with PSTN	Integration with PSTN
Business focus	Business focus and consumer focus	Wide range of consumer focus	World-wide communications subscriber focus
Regional standards	Regional standards	Regional standards towards global standards	Globally harmonized standards

Table 1 – From 1G to 3G

In the late 70s, the first mobile networks were introduced. These networks used analogue technology and were only used for voice communications. These first generation (1G) mobile networks were based on regional standards and were mainly used by very specialized groups. These networks were seen as a luxury and were not spread out.

The mobile networks potential exploded with the 2G networks and, to be more precise with the GSM standard success. Most of the major GSM operators start to operate in the beginning of the 90s and reach their cruise speed during second half of the 90s has can be seen in the next Figure 2 where the Portuguese mobile market scenario is highlighted. By the end of the 90s, the mobile networks usage stopped to be a luxury and started to be major daily need.

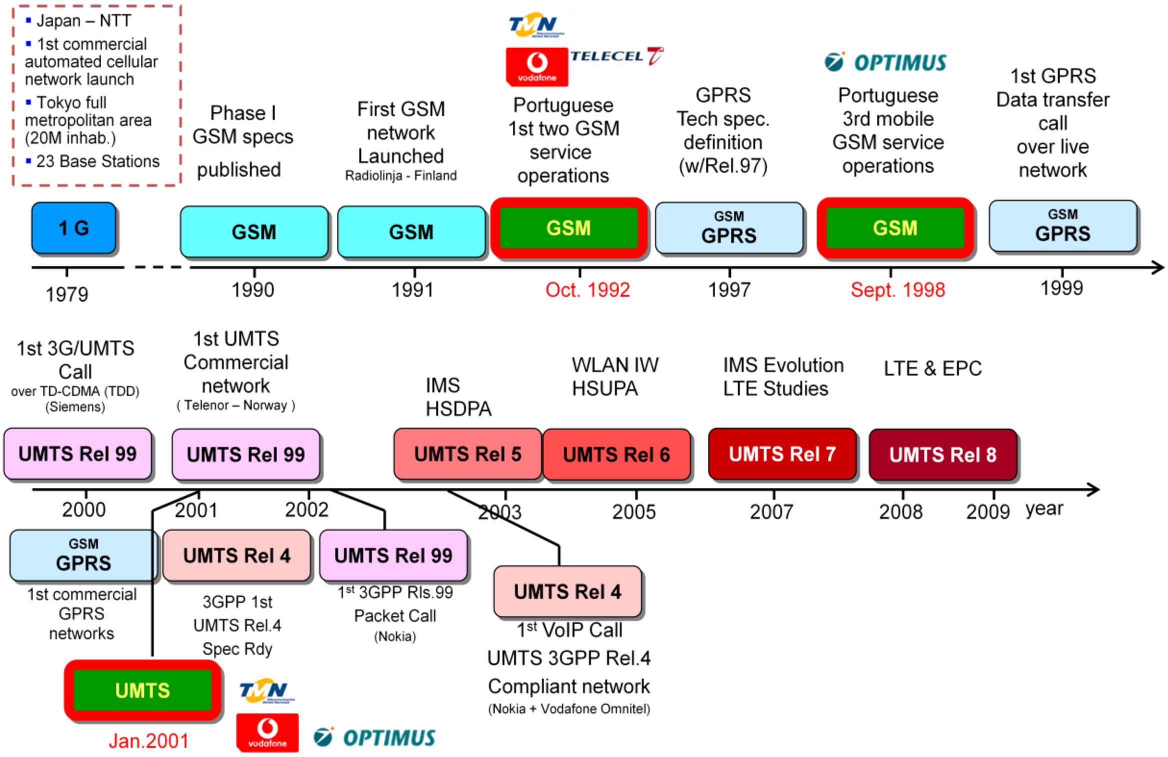


Figure 2 - Mobile networks time evolution

The second generation (2G) GSM networks start to have a quite simple network architecture especially when compared with the current complexity. The radio related part was based on the GSM technology and the core network was only circuit switched based.

This 2G GSM networks architecture is described in the next picture.

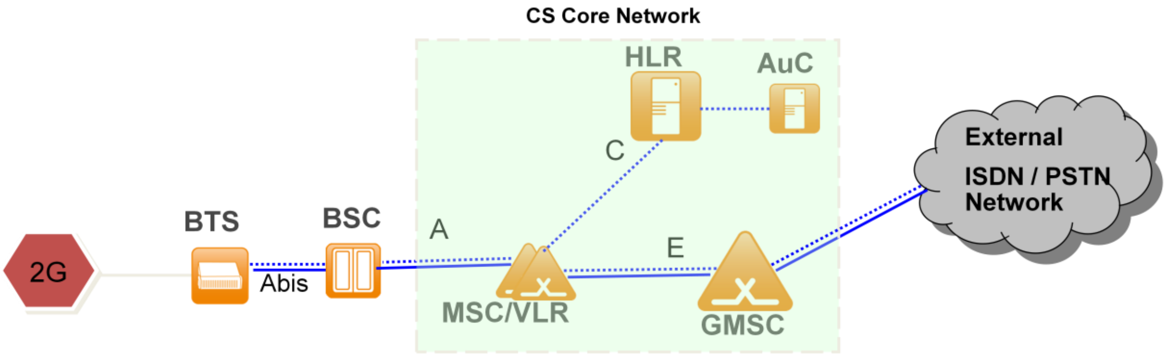


Figure 3 - 2G Networks

Next are presented the GSM Network Elements (NEs) that can be find in the picture.

The radio network related part is also known as Base Station Subsystem (BSS). It is composed of the following NEs:

- **BTS** = Base Transceiver Station
  It handles the radio interface to the mobile station. It is the radio equipment (transceivers and antennas) needed to service each cell in the network. It provides the radio cell control tasks
- **BSC** = Base Station Controller
  The Network Element controls a group of BTS/cells. It control functions and physical links between the MSC and BTS. It is a high-capacity switch that provides functions such as handover, cell configuration data, and control of radio frequency power levels in base transceiver stations.

On the other hand, the CS Core Network is composed of the following NE types:

- **MSC** = Mobile Switching Centre
  MSC performs the telephony switching functions of the system. It makes the calls control to and from other telephone and CS data systems. It performs functions like call control (identifies the type of the call, the destination and the origin of the call, sets up, supervises and clears the connection), initiation of paging (process of locating a particular mobile station in case of mobile terminated call), makes the charging data collection (collects the charging information about a call and transfers it to the Billing Centre), deals with the signalling with BSS and PSTN related part.
  The GMSC is a Gateway MSC. This is a MSC that has special purposes: make the interconnection with external networks.
- **VLR** = Visitor Location Register

It takes care of the location registrations and updates. When a mobile station comes to a new MSC/VLR serving area, it must be registered in the VLR (location update). Although not mandatory, this equipment is typically integrated or at least installed closed to the associated MSC. VLR is a database that contains information about the subscribers currently being in the service are of the MSC/VLR. The typical enclosed information is:

  - Identification numbers of the subscribers
  - Security information for the authentication of the SIM card for ciphering
  - Services that the subscriber can use

- **HLR** = Home Location Register
  HLR maintains a permanent register of the subscribers (like subscriber identity number and subscribed services) and current customer location information.
- **AC/AuC** = Authentication Centre
  It provides network security information. It assists VLR in the information ciphering (triplets provisioning). Verify user authenticity.
- **EIR** = Equipment Identity Register
  It is used for security purposes. It is used in the International Mobile Equipment Identity (IMEI) checking purpose (validity of mobile equipment check).

The traditional GSM networks had one major problem: through these type of networks, it was only possible to transmit data by using circuit switched technology and only very low data baud rates were possible to be used. The used protocols were the Circuit Switched Data (CSD) and High-Speed Circuit-Switched Data (HSCSD). This kind of data link connections were typically charged on a per-second basis, independently of the amount of data that was transmitted over the link. This specific charging limitation was a big limitation for the success of the data transmission over GSM networks.

Therefore, with the advent of the packet data networks, the year 2000 brought the introduction of the first GPRS networks (start of commercial operations).

The GPRS (General Packet Radio Service) brought some changes into the network architecture. A new item was added to the BSC: the Packet Control Unit (PCU). Its function was to separate the pure CS traffic from the packet traffic. The biggest change was, however, made into the Core Network (CN). A new network element was created in the CN: the **SGSN** (Service GPRS Support Node). This new piece of hardware was a new packet switching NE whose task was to relay the packet data to the proper outside networks (internet). Side-by-side with the SGSN, the **GGSN** (Gateway GPRS Support Node) was also created. The GGSN is a packet switching equipment with special gateway functions that is to be used at the network borders.

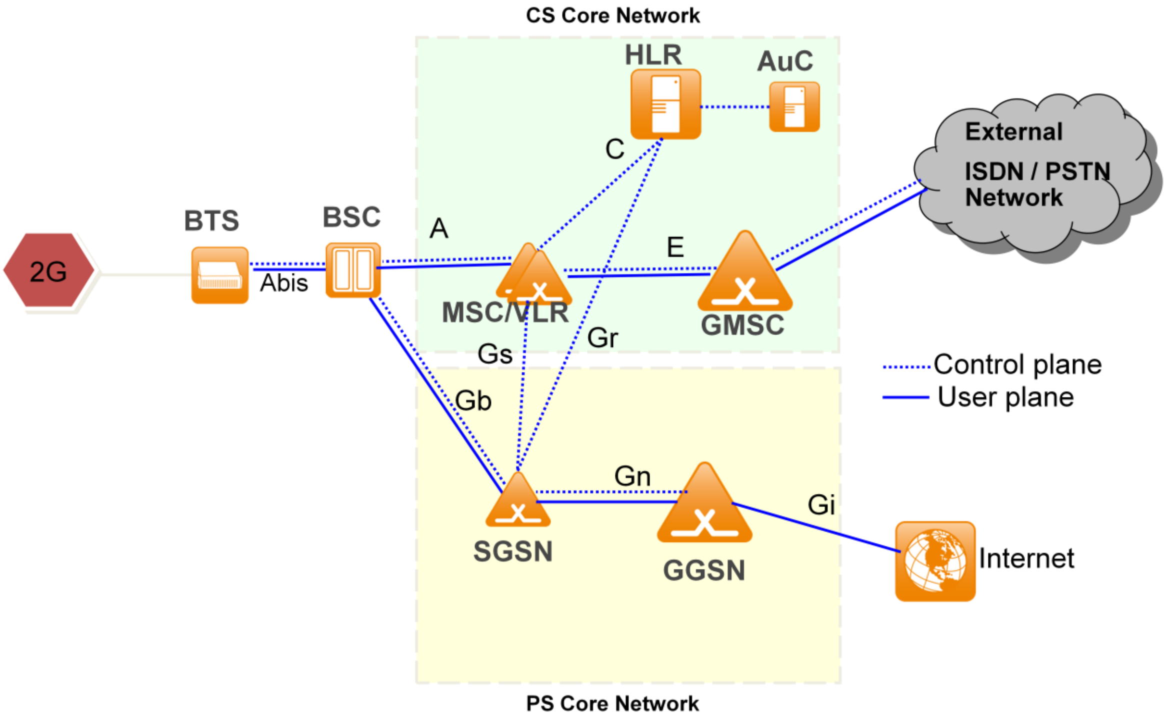


Figure 4 - 2.5G networks (GPRS)

The focus of the next big (re)volution was then transferred again to the radio network side. By mid 2001, it was the start of the commercial operations of a new radio technology based on Wideband Code Division Multiple Access (WCDMA): the UMTS (Universal Mobile Telecommunication Systems). Based on the newly created CS + PS Core Network architecture, a new radio interface was brought in. This new interface did now allow a larger number of voice users and real data transmission speeds up to 384kbps.

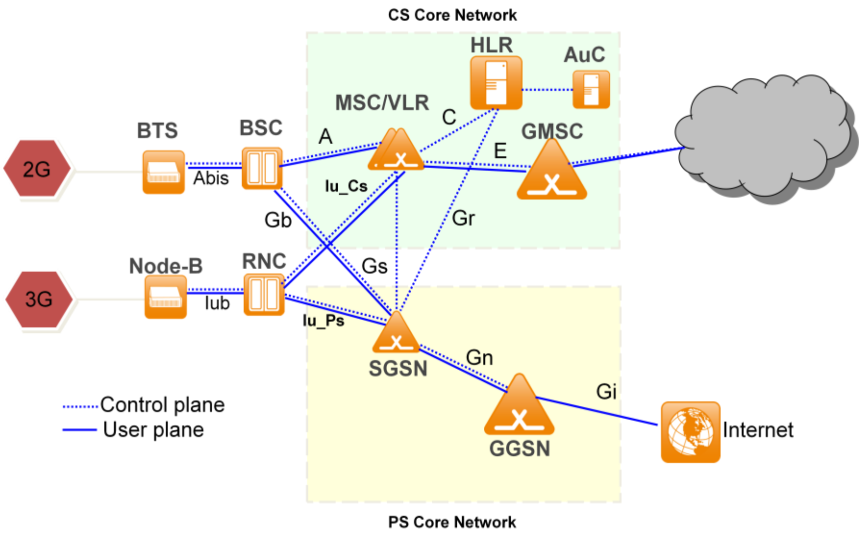


Figure 5 - 3G (Rls.99) networks (UMTS)

Once again, the next breakthrough focus was changed and this time the modification was made to the core network. By doing so, the Release 4 architecture (previously called as Release 2000) was reached.

This new Core Network architecture, that was one step further targeting all-IP (Internet Protocol) approach, brought the packet transmission technology into the CS core. A more efficient and flexible transport options were brought in. Higher switching efficiency was achieved allowing new and lower cost services like the streaming services to be introduced.

This Release 4 architecture made possible the centralization of call control functions in a few number of MSC Servers.

In this release, a separation between the control plane and the user plane was made. This split made easier the provisioning of efficient bearer services with variable associated characteristics. With this new network architecture, a more efficient transport and a better convergence with the transport packet switched domain was achieved. Another advantage of this new architecture was the usage of a single set of layer 3 signalling protocol on top of different transport layers like ATM (Asynchronous Transfer Mode) / IP, STM (Synchronous Transport Module). This fact allowed a simplification of the used protocols. This new Release 4 architecture also made possible the utilization of statistic multiplexing gain for all services including real-time services and the cost transmission was reduced. Now the calls started to be able to be "switched" at the MGW sites without being routed to the MSC Server site. This has lead to a better transmission efficiency.

As result of these breakthroughs, the previous MSC + VLR + GMSC (Gateway Mobile Switching Centre) Network Elements were replaced by new MSC-Server + GMSC-Server + CS-MGW (Circuit Switch – Media Gateway Function) NEs.

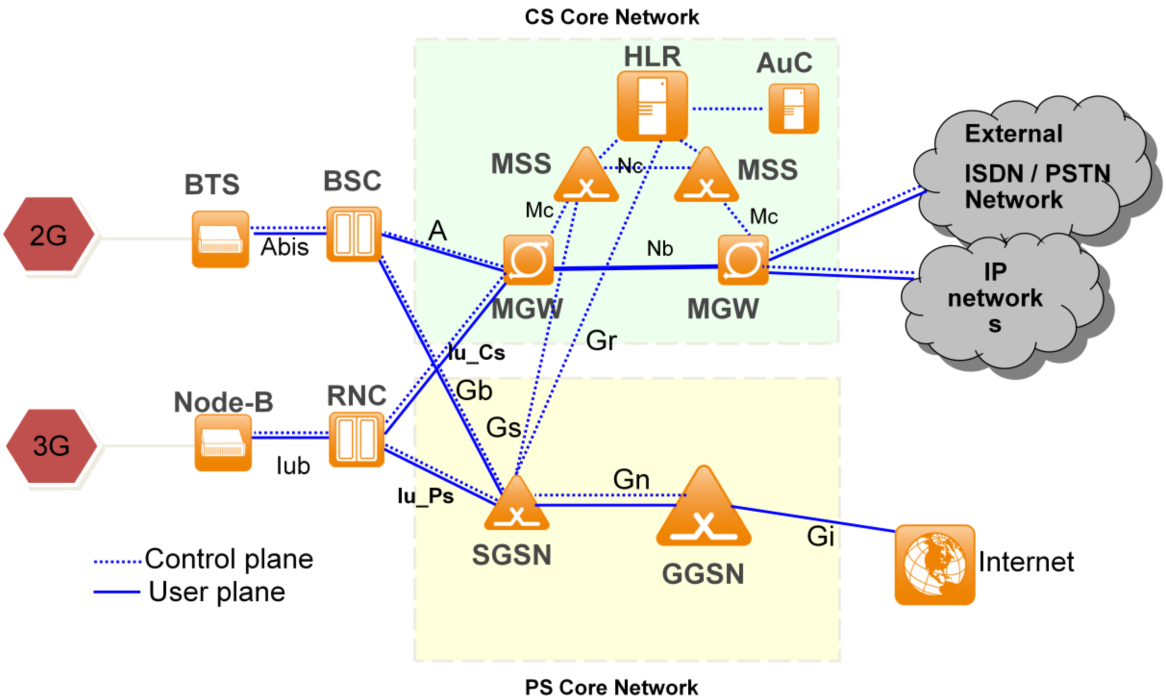


Figure 6 - Release 4 networks

The main Release 4 network NEs functions and purposes are explained in detail in the next Release 4 architecture chapter still, very briefly, the functions of each NE are:

- **MSS** = MSC Server
  NE that is responsible to make the call control and to interact with the VLR.
- **GMSC-S** = Gateway MSC Server
  NE that makes the call control tasks of the Gateway MSC.
- **MGW** = Media Gateway
  NE that is responsible for the bearer control.

The next big step in mobile networks technologies is the introduction of the Release 5 UMTS networks (please refer to previous Figure 2).

The Release 5 brought, at the Core Network related part, the IP Multimedia Subsystem (IMS) and, at the radio related side, the High Speed Downlink Packet Access (HSDPA).

IMS is a mainly a Core Network related side improvement. The objective of the IMS is to support applications involving multiple media components per session in such a way that the network is able to dissociate different flows with potentially different Quality of Service (QoS) characteristics associated to the multimedia session (e.g.: video, audio, online document sharing tools). All IMS entities are located in the Core Network. The impact on non-IMS specific network entities is kept as low as possible. IETF SIP (Session Initiated Protocol) was chosen as IMS main protocol.

The main benefits of IMS are the IP transport in the core network, the IP transport in UTRAN, the End to end IP services, the simpler service integration due to simplified protocol stacks, the easy integration and enabling of instant messaging.

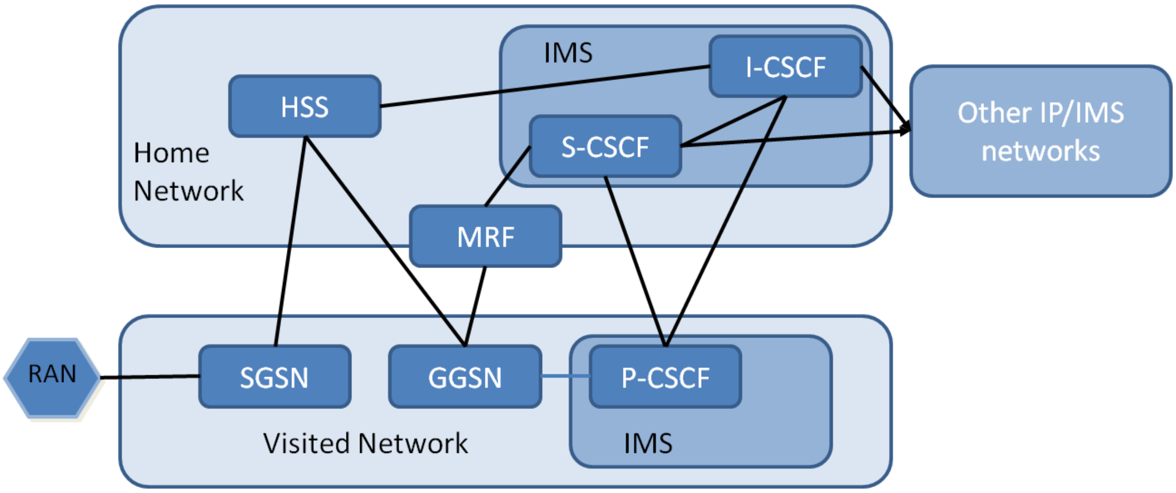


Figure 7 - IMS network

The IMS main entities are:

- **P-CSCF** = Proxy-Call State Control Function

This is the first contact point of IMS. It is located in the same network as the GGSN (visited or home network, shown as being in the visited network in the figure). Its main task is to select the I-CSCF of the Home Network of the user. It also performs some local analysis e.g. number translation, QoS policing.

- **I-CSCF** = Interrogating-CSCF
  It is the main entry point of the home network: it selects with the help of Home Subscriber Server (HSS) the appropriate S-CSCF.

- **S-CSCF** = Serving-CSCF
  This Network Element performs the actual Session Control. This function handles the SIP requests, performs the appropriate actions e.g. requests the home and visited networks to establish the bearers. It also forwards the requests to the SCSCF /external IP network of other end user as applicable. The S-CSCF might be specialized for the provisioning of a set of service or even a single service.

As previously referred, this Release 5 also brought a radio side improvements. This was achieved with the High Speed Downlink Packet Access (HSDPA) introduction.

HSDPA is a feature based on a downlink shared channel reserved for transferring only data. This feature allows data rates up to 14.4 Mbit/s. It is designed to support asymmetric services that require instantaneous high rates in the downlink and lower rates uplink. This feature also allows to decrease the level of retransmissions which in turn reduces delivery time. Examples of end-user services using HSDPA are Internet browsing and video on demand.

HSDPA is based on shared channel transmission and its key features are shared channel and multi-code transmission, higher-order modulation, short Transmission Time Interval (TTI), fast link adaptation and scheduling along with fast Hybrid Automatic Repeat reQuest (HARQ). The upgrade to HSDPA is often just a software update for most WCDMA network

The HSDPA main benefits is the support of services requiring high data rates in downlink (e.g. Internet browsing and video on demand) and the possibility to use high data rates up to 14.4Mbit/s (current typical down-link speeds are 1.8, 3.6, 7.2 and 14.4 Mbit/s).

It is not the aim of this Thesis to analyze the radio related part neither the HSDPA details so this Thesis will not enter in further details about it.

Just after the just described Release 5 came the Release 6 (refer to previous Figure 2), that brought some improvements to the IMS networks (Core Network side), WLAN integration and the High Speed Uplink Packet Access (HSUPA) that is a radio network side improvement.

HSUPA is a directly related to High-Speed Downlink Packet Access (HSDPA) and the two are complimentary to each another. HSUPA enhances the uplink speed of UMTS / WCDMA networks and is the next step after HSDPA. Both procedures resemble each other technically and, by the employment of special modulation procedures, allow a better use of the net infrastructure. The power spectrum of the UMTS network may be enhanced at relatively small expenditure. Due to these new achievements, improved intensive data services can then be offered.

HSUPA is relatively inexpensive, because it is based on software changes. No new infrastructure needs to be developed or installed by the mobile network providers. Their network equipment need only be updated with new software. With HSUPA, the uplink speeds can vary up to 5.76 Mbit/s.

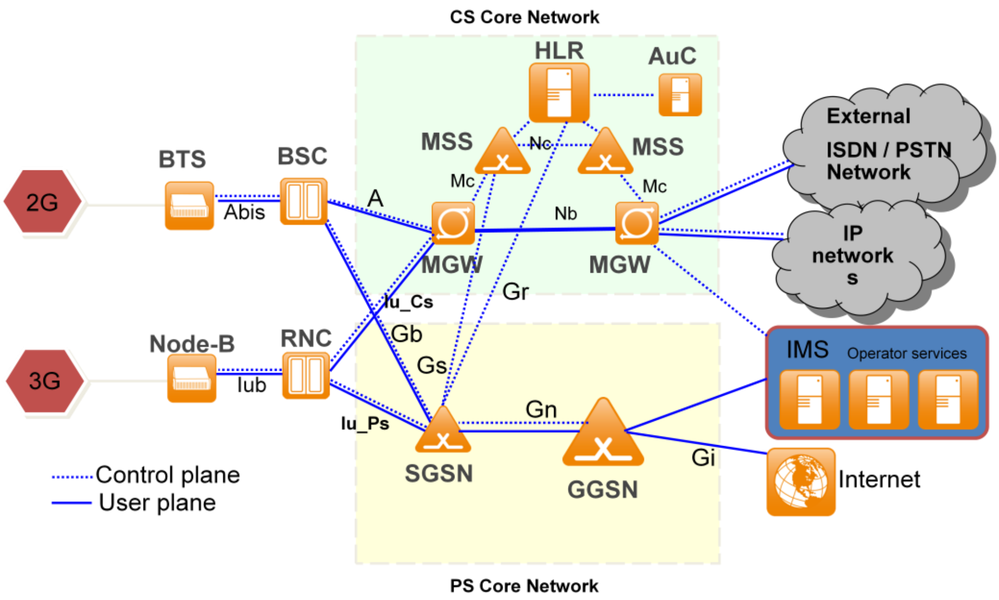


Figure 8 - Rls.5/6 network

As consequence of previous versions and, as already presented in previous Figure 2, then came the Releases 7 that brought improvements to radio and PS core network related parts.

This Release 7 brought the HSPA and the I-HSPA radio network side technological improvements.

High Speed Packet Access (HSPA) is a radio network improvement which is associated with the PS Core Network side enhancement (RNC vs GGSN direct tunnelling). HSPA is a “mixture” of two previous mobile network protocols: the HSDPA and the HSUPA. HSPA has a reduced latency and supports increased peak data rates of up to 14 Mbit/s in the downlink and 5.8 Mbit/s in the uplink. Please refer to next Figure 9.

The next big achievement, I-HSPA (Internet HSPA, also known as HSPA+ or Evolved HSPA), is a wireless broadband standard capable of supporting 84 Mbit/s in the downlink and 22 Mbit/s in the uplink (theoretical transmission speeds only possible to be reached under special network conditions). I-HSPA also introduced an optional all-IP architecture for the network where base stations are directly connected to IP based backhaul and then to the ISP's edge routers. This approach has paved the way to the to the next breakthrough, the 4G networks. I-HSPA technology has also delivered significant battery life improvements and dramatically quicker wake-from-idle time, delivering a true always-on connection.

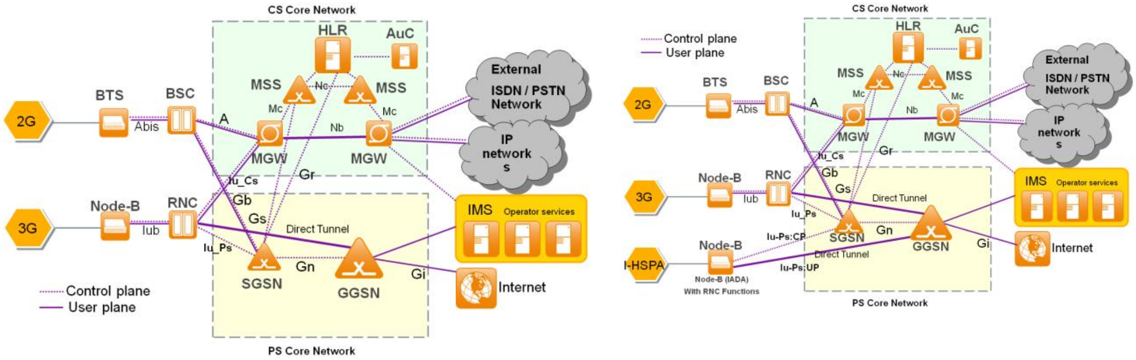


Figure 9 - Rls.7 (HSPA) + (I-HSPA) network

We then finally reach to the current last phase of the mobile networks evolution: the Release 8 that is the Long Term Evolution (LTE) and EPC 4G networks (refer to previously provided Figure 2).

LTE while a wireless data communications standard technology aims to increase the capacity and speed of wireless data networks. LTE radio interface is incompatible with 2G and 3G networks, and due to it, it must use a separate wireless spectrum. LTE speeds will be equivalent to what today's user might see at home on a fast cable modem. The LTE standard is designed to enable downlink peak rates of 300 Mbps and 75 Mbps uplink with round-trip times of less than 10ms.

From radio side, the main network element to these 4G networks is the enhanced Node-B (eNode-B). Like in I-HSPA it can be seen that the previous (BTS-BSC) and (Node-B-RNC) functions have been merged in one NE, the eNode-B.

From Core Network side we now have the Evolved Packet Core (EPC) system and known as SAE core. It includes the System Architecture Evolution Gateway (SAE Gateway) and the Mobility Management Entity (MME) Network elements.

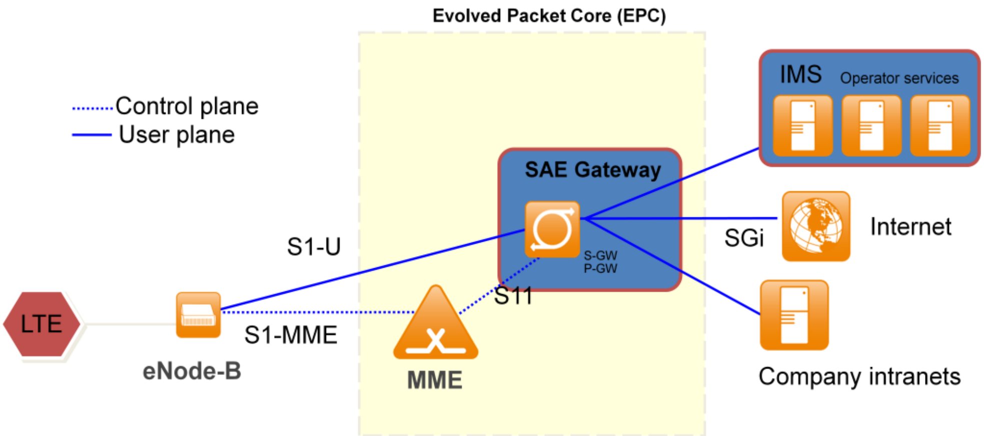


Figure 10 - 4G network

The **MME** is the key control-node for the LTE access-network. It is responsible for idle mode User Equipment (UE) tracking and paging procedure including retransmissions. It is involved in the bearer activation/deactivation process and is also responsible for choosing the SGW for a UE at the initial attach and at time of intra-LTE handover involving Core Network (CN) node relocation. It is responsible for authenticating the user by interacting with the Home Subscriber Service (HSS). The Non-Access Stratum (NAS) signalling terminates at the MME and it is also responsible for generation and allocation of temporary identities to UEs. It checks the authorization of the UE to camp on the service provider's Public Land Mobile Network (PLMN) and enforces UE roaming restrictions. The MME is the termination point in the network for ciphering/integrity protection for NAS signalling and handles the security key management. Lawful interception of signalling is also supported by the MME. The MME also provides the control plane function for mobility between LTE and 2G/3G access networks with the S3 interface terminating at the MME from the SGSN. The MME also terminates the S6a interface towards the home HSS for roaming UEs.

The Serving Gateway (**SGW**) routes and forwards user data packets, while also acting as the mobility anchor for the user plane during inter-eNodeB handovers and as the anchor for mobility between LTE and other 3GPP technologies (terminating S4 interface and relaying the traffic between 2G/3G systems and PGW). For idle state UEs, the SGW terminates the DL data path and triggers paging when DL data arrives for the UE. It manages and stores UE contexts, e.g. parameters of the IP bearer service, network internal routing information. It also performs replication of the user traffic in case of lawful interception.

The PDN Gateway (**P-GW**) provides connectivity from the UE to external packet data networks by being the point of exit and entry of traffic for the UE. A UE may have simultaneous connectivity with more than one PGW for accessing multiple PDNs. The PGW performs policy enforcement, packet filtering for each user, charging support, lawful Interception and packet screening. Another key role of the PGW is to act as the anchor for mobility between 3GPP and non-3GPP technologies such as WiMAX and 3GPP2 (CDMA 1X and EvDO).

Finally it has been reached to the current and near future status of the mobile networks.

As is shown in the next picture, we are now facing a highly complex network environment where 3 types of technologies are mixed together (2G + 3G + 4G).

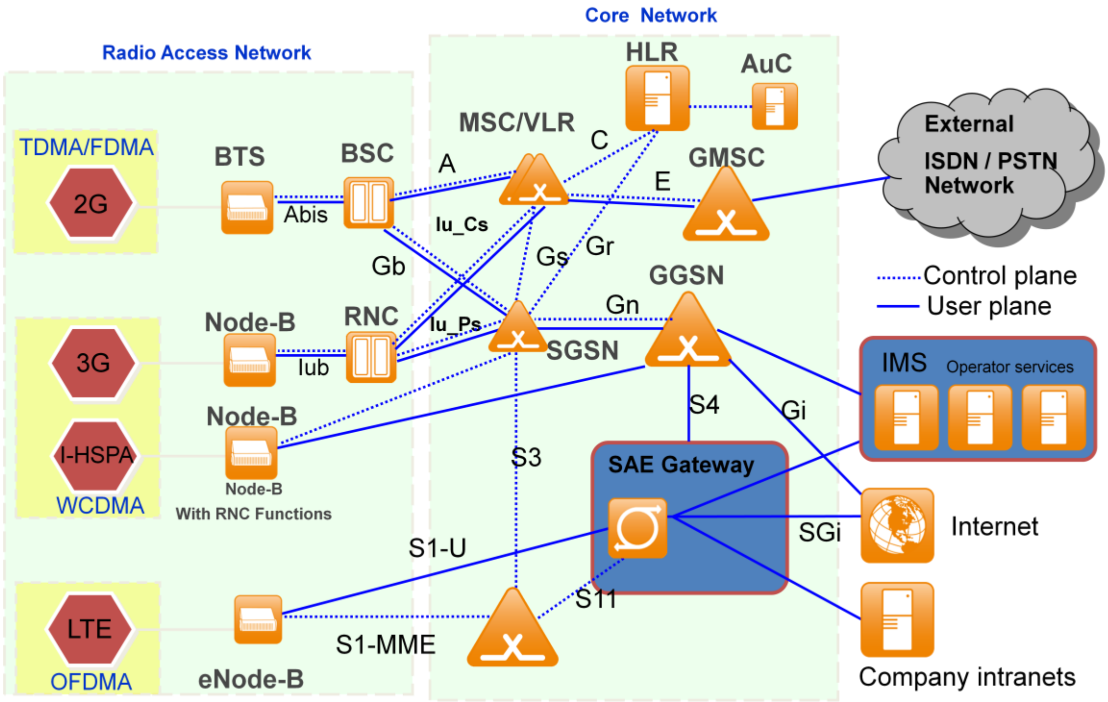


Figure 11 - Overview – LTE/SAE mixed together with 2G & 3G

From this point we reach to the current huge network complexity and to the urgent need of having commonly accepted 3GPP KPIs for all the network blocks, which is the to the aim of this Thesis.

2.3. Release 4 architecture

While the main focus of this Thesis, the Release 4 architecture will be specially detailed explained.

The Release 4 model is as next presented. The CS Core Network related part, that is the subject of this Thesis, is light green marked.

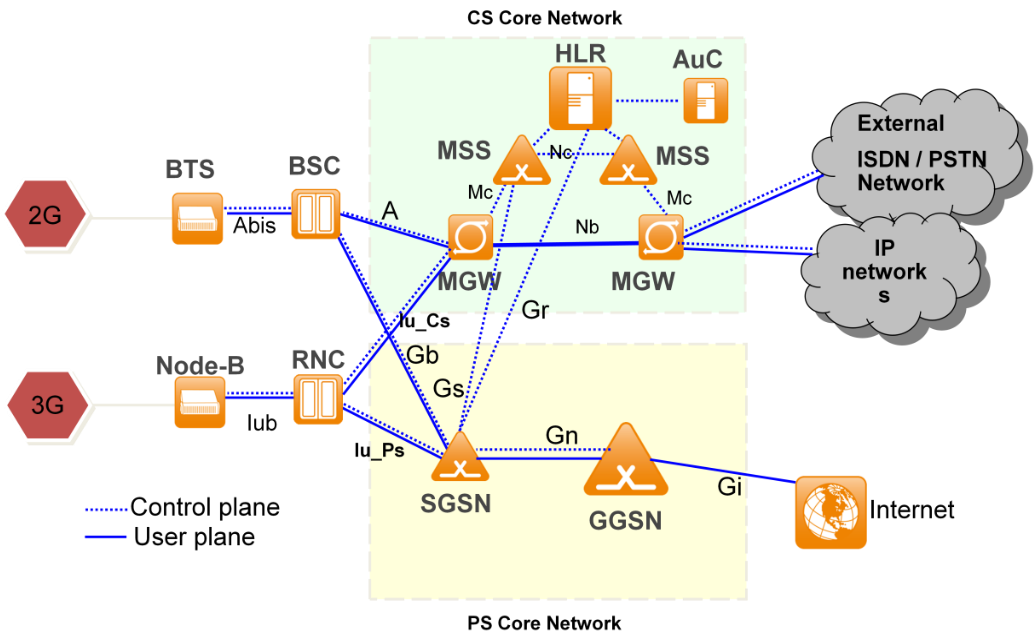


Figure 12 - Rls.4 network

Each NE functions shall be understood as next presented:

- **VLR** = Visitor Location Register
  This is a Network Element (NE) that takes care of the location registrations and updates. When a mobile station comes to a new MSS/VLR serving area, it must be registered in the VLR (location update). Although not mandatory, this equipment is typically integrated or at least installed closed to the associated MSS. VLR is a database that contains information about the subscribers currently being in the service are of the MSS/VLR. The typical enclosed information is:
    - Identification numbers of the subscribers
    - Security information for the authentication of the SIM card for ciphering
    - Services that the subscriber can use

- **HLR** = Home Location Register
  This NE maintains a permanent register of the subscribers (like subscriber identity number and subscribed services) and current customer location information.

- **AuC** = Authentication Centre
  It is the Network Element that provides network security information. Assists VLR in the information ciphering (triplets provisioning). Verify user authenticity.

- **EIR** = Equipment Identity Register
  This NE is used for security purposes. IMEI checking purpose (validity of mobile equipment check).

- **MSS** = MSC-Server

  NE responsible to make the call control and to interact with the VLR.
  - It makes the call control of mobile originated and mobile terminated calls in the CS domain.
  - VLR functionality – for all the subscribers in the MSC Server supported area it keeps, temporarily, the subscriber details (profile, location information, identities, etc.)
  - It makes the interaction with the MGW. It is the MSC-S that determines the Quality of Service parameters required for the subscriber applications. The MGW is responsible to make the bearer available. The interaction between the MSC-Server and the MGW is made though H.248 protocol.
  - It is responsible to make the CDR collection.
  - It is responsible for the network-network and UE-network (via the IU-CS interface) signalling termination.

- **GMSC-S** = Gateway MSC Server

  This NE makes the call control tasks of the Gateway MSC. Main tasks are:
  - It makes the Interrogation of the HLR
  - It terminates the network-network signalling
  - It Interacts with the MGW

- **MGW** = Media Gateway

  The MGW is responsible for bearer control. MGW responsibilities:
  - It controls the Bearer. Bearer control requirements are defined by the MSC Server and transmitted to the MGW. The MGW determine if it can make the bearer available in accordance with the QoS parameter set.
  - It makes the Bearer channel termination. The transmission technologies can be ATM and IP over Ethernet.
  - It makes the media conversion and payload processing (e.g. from voice 64kbps transmission to 12.2 kbps conversion), codec conversion, conference bridges, echo cancellation, etc.
  - It supports mobility special functions like RNC reallocation and handover procedures.

2.3.1. Basic traffic model

The next Figure 13 presents the traffic model as defined in the 3GPP TS 32.407 [1] document (Release4 networks traffic type). This is the traffic model will be used during the next CS CN KPI proposal.

This traffic model, resumes all the possible distinct types of traffic that a CS CN NE can handle. By using this model we can make traffic relationships and get a final coherent analysis. This base model is important so that all the CS CN NE vendors can have a common base of understanding in what traffic models is concerned.

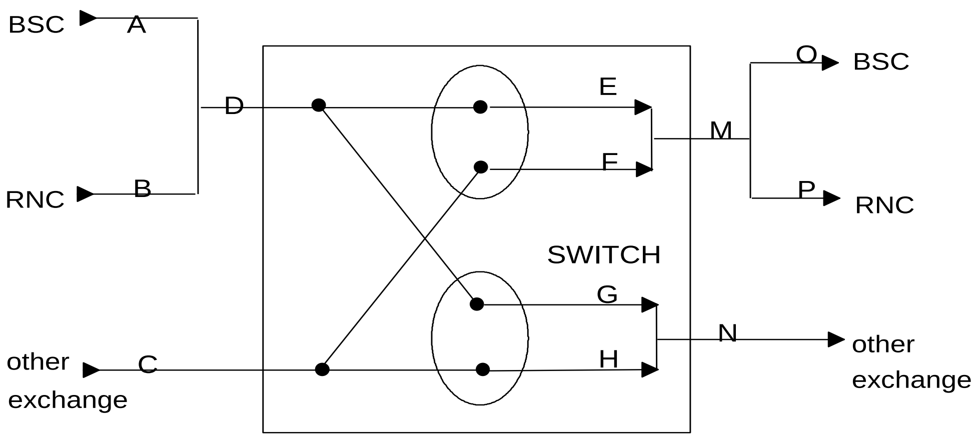


Figure 13 - Traffic model
Picture retrieved from [1]

Possible types of traffic:

A	GSM Mobile Originating call.	It considers the traffic coming from the BSC NE (GERAN traffic).
B	WCDMA Mobile Originating call.	It considers the traffic coming from the RNC NE (UMTS traffic).
C	Incoming call.	It is the traffic that is coming from other exchanges. It may come from exchanges of the same mobile network operator, from exchanges belonging other mobile network operators or from a fixed network exchange.
D	Mobile Originating call.	It counts the traffic that is originated in the mobile networks attached to the CS CN NE being observed (GSM and WCDMA/UMTS) and switched in it. D = A + B
E	Internal call.	It is the traffic that, while coming from a mobile network interface, is switched in the CS CN NE being observed and does not go to other exchange.
F	Terminating Incoming call.	It is the traffic that comes from other exchange and which destiny is a mobile network (GSM or WCDMA/UMTS) being controlled by this CS CN NE.
G	Originating Outgoing call.	It is the traffic that comes from a mobile network interface attached to this NE (GSM or WCDMA/UMTS) and is switched to other exchange. Such can be from the same mobile network operator, other mobile network operator or fixed network.
H	Transit call.	It counts the traffic associated with calls that were originated in other exchange, went through the CS CN NE being observed and were switched into a third exchange.

M	Mobile Terminating call.	It counts the traffic that terminates in a mobile network attached to this NE (GSM or WCDMA/UMTS) and is switched in the CS CN NE being observed. M = E + F
N	Outgoing call.	It counts the traffic going to other exchange. It may go to other exchanges from the same mobile operator, to other mobile operators or to a fixed network exchange.
O	GSM Mobile Terminating call.	It counts the traffic that is switched into a BSC NE attached to the CS CN NE being observed (GERAN traffic).
P	WCDMA Mobile Terminating call.	It counts the traffic that is switched into a RNC NE attached to the CS CN NE being observed (WCDMA/UMTS traffic).

Table 2 – Traffic model types

2.3.2. Signalling flow

The next presented call flows shall be used in order to better interpret the proposed KPIs. We will depict in these schemes, some trigger points and exchanged messages that will be later referred in the proposed KPIs. All schemes are in accordance with 3GPP 32.407 PM CS CN technical specification document and shall be used as future reference.

2.3.2.1. MO call

A Mobile Originating (MO) call takes place when the user tries to makes a call by using its mobile User Equipment (UE).

It is next presented a typical procedure to establish a MO call whose destination is attach to another switch. First, the UE starts to request the voice service to the switch where the mobile is attached to (MSC). Once accepted, the MSC initiates an user authentication procedure and, if successful, creates a secure communication path between the switch and the UE. The UE then establish a call setup procedure and all the necessary communication resources are seized. As soon as these tasks are successfully performed, the switch tries to allocate all the necessary resources into the call destination direction. If this procedure is successful, the B-party phone starts to ring, the switch sends an alert for the UE which, by its turn, starts to ring. Once both parties accept the call, the call is finally established.

The next signalling flow depicts a MO call procedure for a CS Release 4 call.

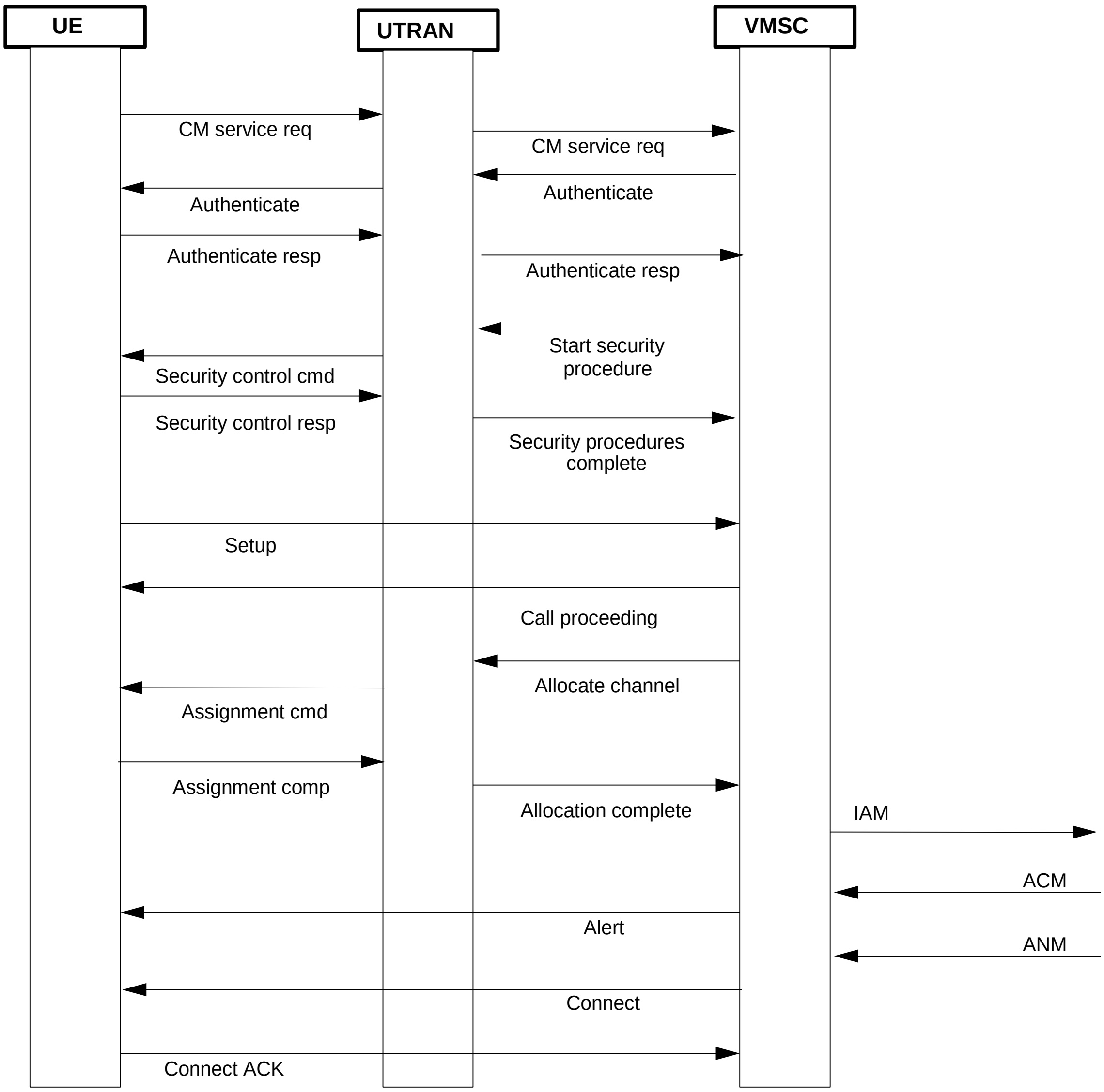


Figure 14 - Flow for a basic Mobile Originating (MO) call
Picture retrieved from [1]

2.3.2.2. MT call

A Mobile Terminating (MT) call takes place when the UE receives a call.

It is next presented a typical procedure to establish a MT call coming from an switch belonging to other network and terminating in the switch being observed.

The Gateway MSC (GMSC) receives an Initial Address Message (IAM) with the details of the call that is supposed to handle (calling and called numbers, type of service to be used, etc). The GMSC then contacts the HLR to get all the necessary details about the UE destination. Once this information is clarified, the IAM data is forward to the MSC where the UE is attached. The UE is then paged by the radio network. If successful, the UE connection is established and a sequence of security procedures is started targeting the creation of a protected communication path between the switch and the UE. The UE then receives a call setup message and confirms it. The seizure is made between the switch and the UE. The UE starts to ring and informs the originating party about it. Once both parties pick-up the call, answer messages are exchanged and the call is finally established.

The next signalling flow depicts a MT call procedure for a CS Release 4 call.

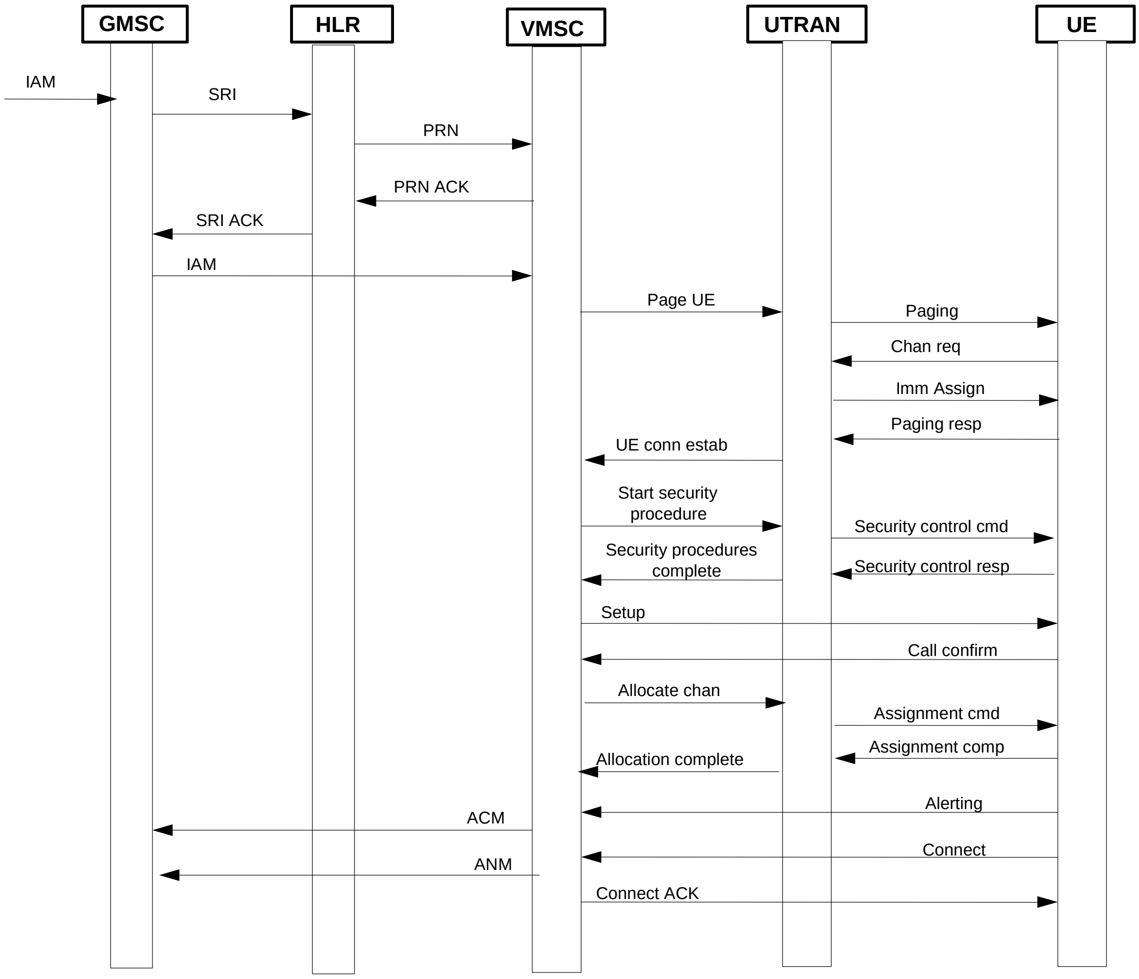


Figure 15 - Flow for a typical basic Mobile Terminated (MT) call
Picture retrieved from [1]

2.3.2.3. End to End call

The next signalling flow depicts a End to End call procedure for a CS Release 4 call.

This is a particular call, the originating UE and the terminating UE are attached to different switches. The call, by its turn is switched over via a third transit switch.

The UE that initiates the call contact the switch to which is attach and requesting a call. This switch then contacts the transit exchange and provides it the necessary information to forward the call. The transit process the received data and addresses it to the destination switch. This one, by its turn, contacts the target UE and setups the call. Once the UE confirms it, it starts to ring and alerts the upstream associated switching equipments about it. The target UE then picks-up the call, the necessary connection messages are exchanged and the communication path is opened.

Once the conversation ends, the originating UE disconnects the call and a sequence of disconnect and release alert messages are exchanged. Consequently, the previously seized resources (radio and fixed land lines) are released being as so available to other calls.

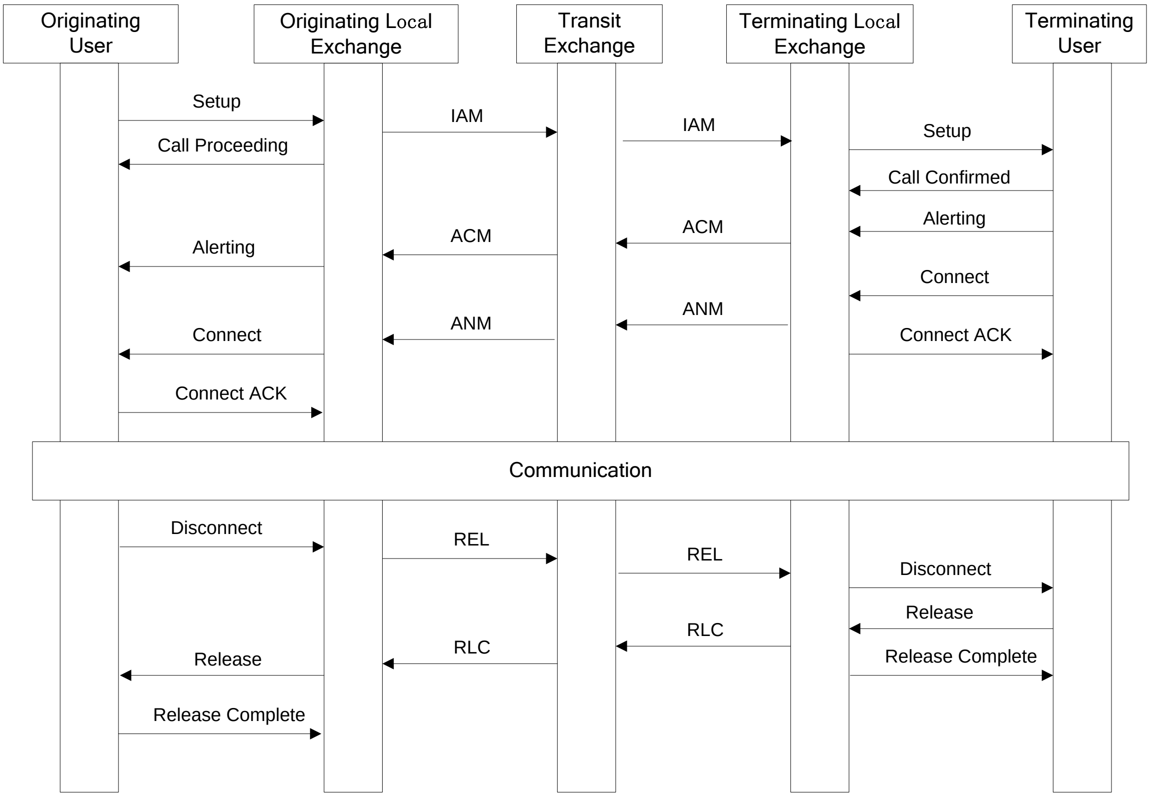


Figure 16 - Flow for a basic end to end call
Picture retrieved from [1]

2.3.3. CS Release 4 protocol analysis

Some of the KPIs proposed in this Thesis will be based on NE's protocol input. Therefore, a brief overview about the Release 4 protocol stack will be presented. This quick wrap-up is important to later understand where each protocol sits inside the big picture.

With the outcome of the Release 4 mobile networks, a clear separation between the user part and the control planes was made. This has led to two different protocol stack models where one is dedicated to the control of the communication and the other to the network transport.

Next is presented a typical Release 4 CS CN network topology (network's basic distinct elements). In the next sub-section, this picture is going to be used as the base model for this CS Release 4 network.

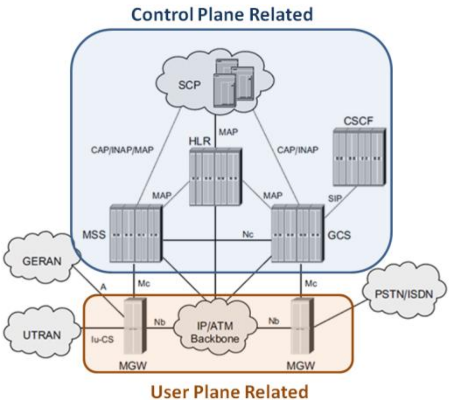


Figure 17 - Rls.4 topology
Picture adapted from [2]

2.3.3.1. Control plane protocols

This sub-section describes the protocol stack and the Network Elements interactions involved in the CS Release 4 control plane activities.

- **BSC – MSS interface - Control Plane:**

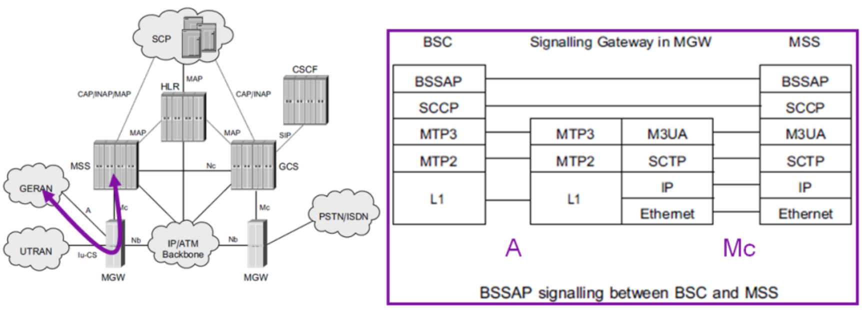


Figure 18 - BSC-MSS interface - Control Plane
Pictures adapted from [2]

The A interface is used to transmit speech, CS data, and signalling between the MSS and the GERAN.

When the A interface is connected to the MGW, the BSSAP signalling messages are routed from the MGW to the MSS using SIGTRAN[1]. The MGW acts as a Signalling Gateway.

The BSSAP (BSS Application Part) is responsible for the A interface signalling transfer functions.

[1] SIGTRAN (SIGnalling TRANsport Over IP) is a IETF (Internet Engineering Task Force) standardized way to carry SS7 signalling over an IP backbone. SIGTRAN is a Protocol for supporting transport of any SS7 MTP3-User signalling (e.g., ISUP, SCCP and TUP messages) over the IP Network. SIGTRAN consists of SCTP plus an adaptation layer (M3UA = MTP3 User Adaptation layer in current case).

BSSAP can be separated into the BSSMP (Base Station Subsystem Management Application Part) and the DTAP (Direct Transfer Application part).

Neither the BTS nor the BSC interpret the CM[2] (Connection Management) and MM[3] (Mobility Management) messages. They are simply exchanged between the MSC and UE using the DTAP[4] protocol on the A interface. RR (Radio Resource Management) messages are sent between the BSC and MSC using the BSSAP.

BSSAP includes all messages exchanged between the BSC and the MSC that the BSC actually processes. More generally, BSSAP comprises all messages that are exchanged as RR messages between MSC and BSC, and messages that are used for call-control tasks between the BSC and the MSC.

- **RNC – MSS interface - Control Plane:**

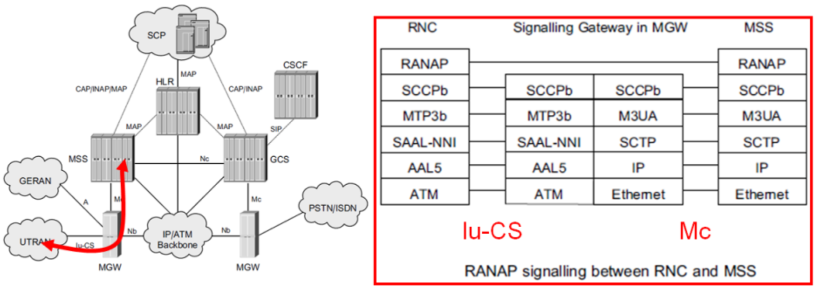


Figure 19 - RNC – MSS interface - Control Plane
Pictures adapted from [2]

Circuit switched traffic between the UTRAN and the core network is carried on the Iu-CS interface. This interface is can be ATM or IP based. In the depicted case, while ATM-based carries the control plane using the AAL5 adaptation layer (the user plane uses the AAL2 adaptation layer). The control plane consists of the RANAP (Radio Access Network Application Part) signalling protocol. This RANAP protocol is used for tasks like relocation, paging, Radio Access Bearer Management, transport of signalling between a UE and the Core Network (Non Access Stratum signalling).

In the Core Network the signalling gateway functionality in the MGW relays the control plane to the MSS using the SIGTRAN protocol.

---

[2] CM = Connection Management => Is responsible for the CC (Call Control), supplementary service management, and Short Message Service (SMS) management. CC sub layer include functions like call establishment, selection of the type of service (including alternating between services during a call), and call release.
[3] MM = Mobility Management => Supports User Terminal Mobility + security process (user ID)
[4] DTAP = Direct Transfer Application part => comprises all messages that the subsystem of the NSS and the MS exchange. DTAP transports messages between the MS and the MSC, in which the BSC has just the relaying function.

- **MSS – MGW Mc interface:**

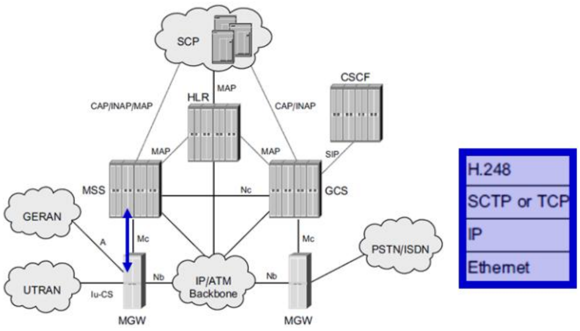


Figure 20 - MSS – MGW Mc interface
Pictures adapted from [2]

The Mc link is used for the MSS vs MGW interconnection. The MSC Server (MSS) is in charge of MGW control. This task is performed by using the H.248 protocol (also known as Megaco – Media Gateway Control protocol). This H.248 may sit over the SCTP (Stream Control Transmission Protocol) or TCP protocols which, by its turn, will work over the IP and Ethernet protocols.

By using H.248, it is possible to instruct the MGW to create, remove and modify connections, to provide tones, perform echo cancelling, give announcements, connect conferences, handle call interception, handle handover-related connection topologies, perform speech coding under the command of the MSS.

During start-up the MGW sends the necessary configuration and status information about the user plane processing resources that it provides to the MSS. The MSS uses a MGW database to store the MGW-related information.

- **MSS – MSS (MSC Server) Nc interface:**

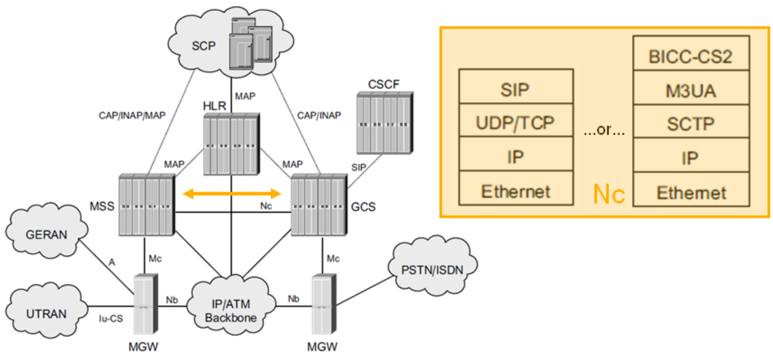


Figure 21 - MSS – MSS Nc interface
Pictures adapted from [2]

The Nc interface connects the MSS NEs. Network-to-Network based call control signalling is performed over the Nc interface between the MSS and the GMSC (GatewayMSC) Server (GCS = Gateway Control Server incorporates all the GMSC Server functionality).

The MSS supports BICC CS-2 as a call control protocol. The use of BICC CS-2 is defined in 3GPP Rel-4. BICC CS-2 is a bearer-independent call control signalling protocol, which means that it supports both ATM- and IP-based networks. BICC is based on ISUP and it provides natural interworking with ISUP as well as ISDN services.

In the MSS, SIP-T can be used as an alternative call control protocol in IP-based networks. In the MSS, SIP-T is used as a tunnelling method for ISUP messages. The use of SIP-T is not defined in 3GPP Rel-4 but the implementation is done according to IETF specifications.

- **MSS – HLR MAP interface:**

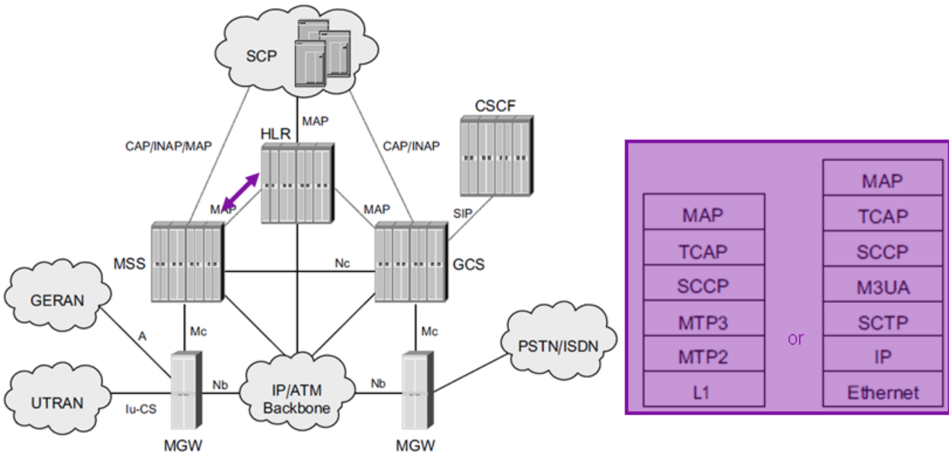


Figure 22 - MSS – HLR MAP interface
Pictures adapted from [2]

There are many "*flavours*" for this MAP connection:

MAP – C
The MAP-C interface is located between the GMSC Server and the HLR. The GMSC Server interrogates the location of the mobile subscriber from the HLR through the MAP-C interface to be able to route the call or the short message to the correct visited MSS.

MAP – D
The MAP-D interface between the visited MSS and the HLR is used for keeping the mobile subscriber location information in HLR updated.

MAP – E
The MAP-E interface between the visited MSS's carries RANAP and BSSAP messages in handovers where the serving MSS is also changed. This MAP-E is also used for delivering short messages (SMS) between the visited MSS and the SMS-GMSC Server for mobile-terminating short messages or the visited MSS and the SMS-IWMSC Server for mobile-originating short messages. Alternatively, the visited MSS can be connected directly to the SMSC if the SMSC is part of the SS7 network and SMSC can make the necessary HLR queries itself.

MAP – F

The MAP-F interface is located between the MSS and the EIR. The HLR incorporates the functionality of the EIR.

2.3.3.2. User plane protocols

The next diagram depicts the Release 4 user plane main entities and used protocols:

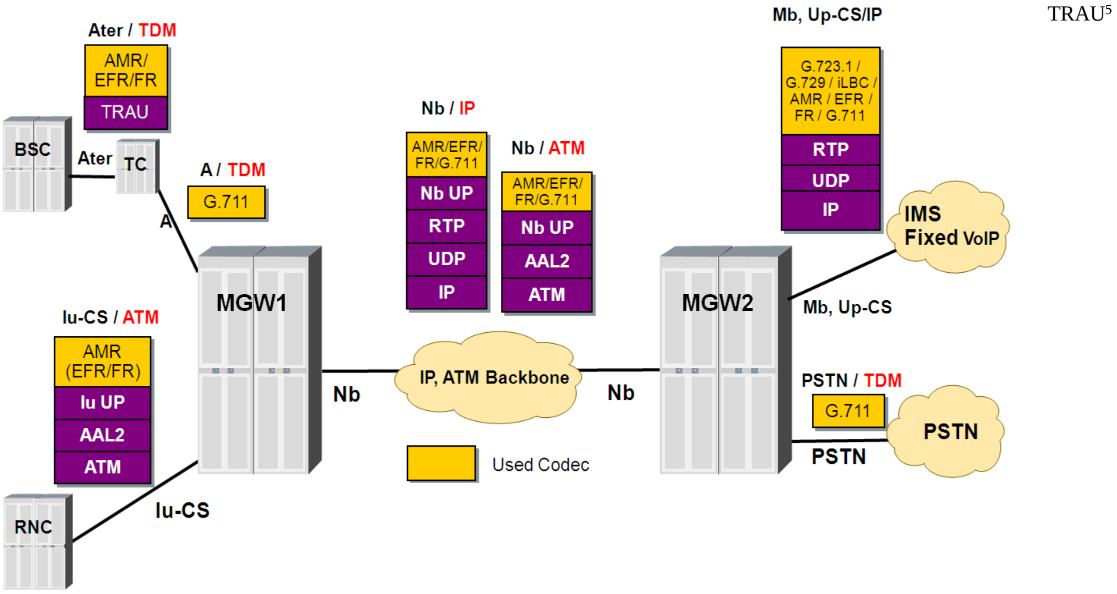


Figure 23 - Rls.4 User Plane protocol

This picture does only reflect the CS core user voice/data transmission (user plane).

As can be realized, the Media Gateways (MGW) have a central role in the overall picture. These NEs interconnect with the mobile access networks which may be UTRAN (UMTS related) or GERAN (GSM related), make the necessary media adaptation and conversion (typically from TDM based in case of GERAN or from ATM based in case of UTRAN into IP or ATM), make the required connection and switching functions and finally, in case of a mobile to fixed network call, just before delivering the data to, convert the user data again to the commonly used TDM PSTN traditional protocols. In case of mobile to fixed network VoIP connection, the frontier MGW makes the adaptation/conversion to IP based call.
On the top of these transmission technologies flows the ultimate objective of this kind of networks: the CS voice payload. Such use Codecs[6] that may differ throughout the transmission.

The typical used codecs are:

[5] TRAU = Transcoder and Rate Adaptation Unit
Performs transcoding functions (compression of speech data from 64 kbit/s to 13/12.2/5.6 kbit/s in case FR/EFR/HR speech coding) for speech channels and rate adaptation for data channels.
background noise conditions.
[6] Encoding/decoding a digital data stream or signal targeting a better efficient transmission.

- **AMR** = Adapative MultiRate Rate
  Can be AMR_12.20 (12.20 kbit/s) up to AMR_4.75 (4.75 kbit/s)
- **EFR** = Enhanced Full Rate
  12.2 kbit/s. Provides wire like quality in any noise free and background noise conditions.
- **FR** = Full Rate
  1st digital speech coding used in GSM => 13 kbit/s
- **G.711** = PCM
  Pulse code modulation (64 kbit/s bit rate). Can use u-law (North America) or A-law (rest of the world).

The previous picture only presents a resumed version of the used protocol stack. It is focused on the CS Core Network perspective.

Just to give a better idea about the overall protocol complexity involved inside the mobile network operator, please refer to the next presented diagram.

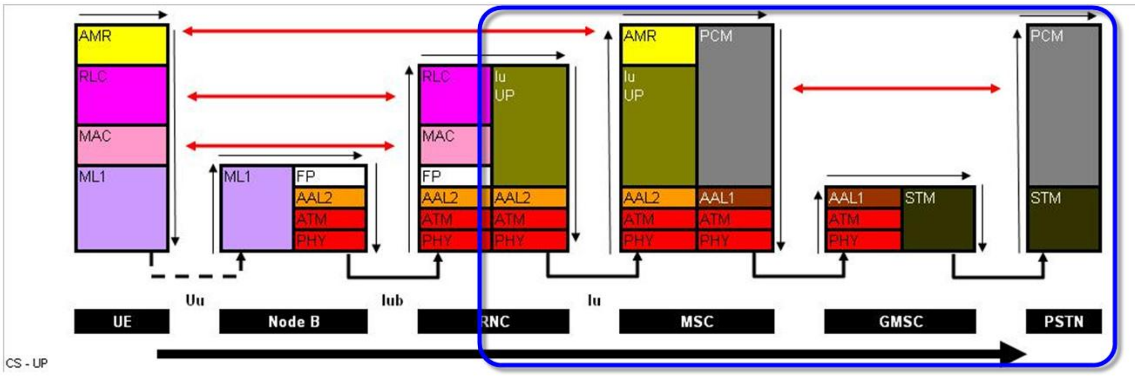


Figure 24 - Rls.4 User Plane protocol - Big picture

This shows the overall protocol stacks involved in a mobile to PSTN call (ATM based). It now includes the UTRAN, CS CN and fixed network related parts. The blue highlighted square includes the protocols depicted in the previously presented picture.

2.4. 3GPP CS CN performance measure model

The KPIs that are going to be proposed throughout this Thesis are based on the currently defined 3GPP Technical Specification (TS) Performance Management (PM) Performance measures Core Network (CN) Circuit Switched (CS) domain UMTS and combined UMTS/GSM (Release 10) document which document reference is *3GPP TS 32.407* [1].

Since this document is the basis for this Thesis, it will next be briefly described.

This document identifies the 3GPP CS CN measures and counters.

These measures are divided in 3 main group sets:

- MSC Server (MSC-S = MSS)
- CS Media Gateway (MGW)

- Home Location Register (HLR)

The MSC-S related part is divided in the following 3 main groups:

- Call Control Management
- Mobility Management
- Signalling

The MGW related part is divided in the next 5 main groups:

- Signalling
- Bearer control
- Bearer transport
- Equipment resource
- User plane services

Finally the HLR related part is the shortest one and has only 1 main group:

- Equipment resource

The document defines up to 265 counters. In fact it can be as low as 234 and as maximum as 265 counters depending on the "*(n-1) out of n*[7]" approach [3].

Measurements related to the MSC Server	Min Nbr Cnts	Max Nbr Cnts
MSS Call control management	**91**	**102**
MO/MT call related performance Nbr. of acknowledged, attempted, successful, answered and failed calls inspection.	21	29
MSC-S (BICC) call related performance Attempted, successful and answered of incoming and outgoing calls analysis.	6	6
Trunk group (TDM) call related performance Seized, answered and successful outgoing and incoming calls inspection; overflow and unavailable times per trunk group analysis.	8	8
Call establishment quality of service UE call established time analysis.	1	2
Traffic related performance Successful, answered, seized per trunk group of mobile originating and terminating traffic, total incoming, outgoing, transit call traffic analysis.	40	40
Paging related performance Attempt and successful paging requests per Lac analysis.	2	4
Out of band Call codec negotiation related performance Attempted, successful and failed out of band codec negotiation and modification number analysis.	5	5
Measurements based on Observed Destination Attempted, successful, answered calls, number, call traffic of observed destination for calling and called party analysis.	8	8
MSS Mobility management	**20**	**28**
Location update Attempted and successful intra-VLR, inter-VLR location updates; IMSI attach analysis, period location update analysis.	8	16

7 3GPP TS 32.404 => **"*(n-1)* out of *n*" approach**
The "*(n-1)* out of *n* approach" allows a vendor to choose any (n-1) out of the n defined counters for implementation but some choices can offer more detailed information than others. The missing n^{th} value can be calculated in post processing.

Hand over inter MSC-S Attempted and successful subsequent handover to MSCc and back to MSCa; incoming and outgoing HOs inter MSC-S from UMTS to UMTS, UMTS to GSM.	12	12
MSS Signalling	**15**	**15**
M3UA link related measurements M3UA link exchanged messages inspection, congestion and availability analysis.	8	8
MTP3 signalling link related measurements MTP3 signalling link availability inspection, exchanged MSUs and octets examination..	7	7
MSS Equipment resource	**22**	**22**
CPU Load Mean CPU Usage analysis.	2	2
Number of subscribers in VLR Registered and attach; total, national and international roaming subscribers in the VLR analysis.	6	6
Octets in MAC layer in MSC-S physical port Octets sent and received on MAC layer in MSC-S physical port analysis.	4	4
Trunk resource related measurements Available trunks and circuits analysis.	2	2
H.248 message related measurements on Mc interface H.248 exchanged messages analysis over the Mc interface.	4	4
BICC message on Nc interface related measurements BICC messages exchanged analysis over the Nc interface.	4	4
Measurements related to the CS MGW		
MGW Measurements related to signalling	**17**	**17**
M3UA link of MGW related performance Exchanged messages inspection, availability and congestion analysis of the M3UA link.	8	8
MTP3/MTP3B signalling link of MGW related performance Exchanged MSU messages, availability and congestion analysis of the MTP3/MTP3B link.	7	7
Route set related performance Unavailability route set destination analysis.	2	2
MGW Measurements related to bearer control	**14**	**14**
Measurements related to the ATM AAL2 connection setup AAL2 connection setup analysis.	2	2
Measurements related to IP RTP connection IP RTP connection setup analysis.	4	4
Measurements related to the User Plane (UP) Init Nb and Iu interface UP initialization analysis.	8	8
MGW Bearer transport	**19**	**19**
Measurements related to Nb interface Nb interface RTP exchanged messages inspection, lost and message delay analysis.	7	7
ALL2 related measurements on Iu CS interface AAL2 packet analysis on the IuCS interface.	4	4
RTP related measurements on Iu CS interface Iu CS interface RTP message inspection, lost and message delay analysis.	7	7
Iu CS interface PVC link analysis.	1	1
MGW Equipment resource	**12**	**12**
CPU Load CPU usage analysis.	2	2
Octets in MAC layer in MGW port MGW MAC layer traffic analysis	4	4
H.248 message related measurements on Mc interface Mc interface H.248 message analysis.	4	4
Transcode Transcoder usage analysis.	2	2
MGW User Plane services	**14**	**14**

Continuity Check (CC) CC service usage analysis	2	2
DTMF Sending and Detection (DTMF) DTMF service usage analysis	2	2
Global Text Telephony (GTT) GTT service usage analysis	2	2
Media Frame Handler (MFH) MFH service usage analysis	2	2
Multiparty Call (MPC) MPC service usage analysis.	2	2
Speech Coder (SC) SC service usage analysis.	2	2
Tone Sender or Line Test (TS) TS service usage analysis.	2	2
Measurements related to the HLR		
HLR Equipment resource	**10**	**22**
CPU Load CPU usage analysis.	2	2
Subscribers related measurements HLR subscriber detailed information.	1	13
MTP3 signalling link related measurements Exchanged MSU messages, availability and congestion analysis of the MTP3 link.	7	7
Total:	*234*	*265*

Table 3 – 3GPP CS CN counters

In terms of method collection, the counters are classified as CC (Cumulative Counter), GAUGE (dynamic variable – used when data being measured can vary up or down during the measurement period), DER (Discrete Event Registration – used when data associated with a particular event is captured at every n^{th} event) or SI (Status Inspection – when the counter reflects a snapshot condition status).

As previously referred in the working procedure description, in order to know the PM details that are already defined and settled in 3GPP for the CS CN area, the 3GPP TS 32.407 [1] had to be deeply analyzed.

During this analysis, some errors were found in this 3GPP specification document. I have made a tight document revision and proposed some corrections to 3GPP. By using Nokia Siemens Networks 3GPP representative support, a CR (Change Request) was issued next to 3GPP (Tdoc number S5-111699 => presented in 3GPP meeting held in – P.R. China – 9-13 May 2011). Such CR was accepted and a revised 3GPP spec was published (S5-111963 [rel-9] + S5-111964 [rel-10] updated reference version]: http://www.3gpp.org/ftp/Specs/html-info/32407-CRs.htm)

This is already a successful first outcome of this Thesis.

2.5. Telecommunication Management Systems

2.5.1. Overview

This chapter is going to start to make an overview about the Telecommunication Network Management System evolution. It will then present the various network management architecture types from the currently used traditional ones up to the new state-of-the-art autonomic computing and self-management architectures. Next are presented the common standard network management models (ISO OSI NMN and ITU-T TMN models). It is finally offered the performance management architecture and interfaces. This chapter ends with a PMS market trend analysis which is the market where the KPIs proposed in this Thesis will fit.

2.5.2. Telecommunication Network Management Systems evolution

As referred in [4], the use of computer based Operations Support Systems (OSS) to provide the network management operations support started in the sixties in the Bell System [5]. In the sixties, the cost of the software, hardware and networking was high and, consequently, the set of applications where some profitability could be get was limited. In the initial phase, the OSS operations were mainly made to support paper-based operations centre [4].

The fast reduction of the infrastructure that supports the operations support systems and the high performance of operations and support technology had made, meanwhile, the OSS a decisive element of the network operations business platform. Such has, in the meantime, evolved to a scenario where the OSSs are integrated in a way where they are able to support end-to-end process with minimal user intervention.

One important breakthrough to reach to the current OSS evolution status occurred during the 80’s and proceeded during the 90’s. Such had to do with the initial usage and later the mass usage of the personal computers together with the beginning of the of mobile computing technologies. These achievements made possible the user to access OSS from the field and together with business process automation improvements resulted in significant reductions in the “back office” operations [4].

2.5.2.1. Network Management

Network management deals with the activities, methods, procedures, and tools that concern to the operation, administration, maintenance, and provisioning of network systems [6]. Operations is concerned with the keeping the network and its provided services running with minimum user impacts, administration is concerned with network control which includes assets handling (existences inventory and their usage), maintenance deals with network and NE upgrades (may it be preventive or corrective) and repair tasks, provisioning is in charge of network resource configuration to support a given service requirement.

Three main phases were identified in the Network Management Systems time evolution path [7]:

The first phase that lasted from 1988 up to 1998 was characterized by a focus on the network with special care given to the device alarm management. This is the period of internet protocol adoption.

The second identified phase began by 1998 and went up to 2004 (period during which the internet was publicly adopted). During this period, the highlight was given to the service analysis while some stress was also made to the policy ideas.

Finally we have the last identified phase (from 2005 up to 2009 – internet seen as public infrastructure and advent of Web 2.0). This phase is characterized to be focused on the service analysis and the application of autonomic ideas to achieve resilience.

Another complementary time path evolution analysis can be found in [4]. Here the Network Management operations are referred to have started during the 70s targeting the support the installed switches and started to be focused on the trunk and line configuration requests. Functional integration started to happen in the 80's as the systems matured and grew cross-organizational capabilities. This maturation process did not fully fit in the network technology development status. The network equipment suppliers had created Element Manager Systems (EMS) tone support. With the advent of digital cross-connect technology, followed by the SONET/SDH and later the ATM technologies, the Element Managers System capabilities were improved in order to support homogeneous network of the specific technology, which as result in vendor-supplied Network Management Systems (NMS). This has lead us to the current status where the EMS/NMS are likely components of any equipment offer. The current EMS/NMS systems fulfil the needs of billing, data collection, configuration management, fault management and performance management. Due to the higher sophistication services that are being implemented in the network, more usual OSS functions are being shifted to the network. Some examples are the network elements policy direct implementations that responds to performance and fault changes as well as the network elements switch on self configuration. Such kind of issues are leading to a change in the responsibility of the OSS from a direct management to a more supervisory one more involved in the analysis and optimization functions [8].

2.5.2.2. Performance Management

In [4] it is referred that Performance Management started in the 70's as a collection mechanism to achieve the Busy Hour information targeting the network engineering activities support (network traffic balancing and call admission control activities targeting the call carrying capacity optimization). The overload conditions were increasingly handled by the Network equipments due to its increasingly "intelligence", automation and sophistication but the root cause analysis was still left for the performance manager equipments, through the pursuit of patterns capable of supporting the origin of the problem as well as the definition of the corrective actions. The network managers environment is, however, becoming increasingly more complex due to the introduction of IP based core with a great variety of supported services and applications [4]. Following what has been learned from the telephony domain, it is expected to be necessary some network management control at the application level while the increasingly policy management duties over the network elements suggest more dynamic control over resource allocations.

In [4] the OSS systems are still in the first phases for the desired “all over IP” OSS platform support. With the advent of IP based core networks and the IMS architectures ramp up, the services will be gradually distributed and the network infrastructure will be increasingly shared. This will lead to a service management control with a Service vs Network Element division. This is not the first time that a distributed switching functionality is made but with the IMS this will be made at a level never experienced shall it be in terms of size or complexity. Big efforts will be necessary to be made in terms of network distributed policy management in terms of combination and validation of consistent policies. Also efforts will have to be made on policy impact analysis over multi-layer, multi-service network with multiple providers. Due to the increasingly competitiveness of this market, the customer experience will be one of the drives for the future network management activities.

2.5.3. Network management architecture types

This Thesis is going to present the Network Management architectures evolution. It will start by presenting the traditional approach which is split in old Centralized approach, Distributed approach (weakly and strongly distributed models) and cooperative approaches. Finally, it will be presented the current state-of-the-art on Autonomic Computing and Self-Management approach.

The typical components of a Network Management System are the managers (which deal with the coordination of the management functions), the agents (which are in charge of performing simple tasks like gathering and saving management information from the Network Elements), Network Elements (field equipments subject to the control task), Network Management Stations (equipments where the management applications are installed and running), management protocols (handle the network management station vs agent communications), Structure of Management Information (define the managed data rules) and Management Information Bases (hierarchical management information database used for dealing with communication network entities) [9]. The next presented architectures shall be read having these concepts in mind.

2.5.3.1. Traditional approach

The traditional management approaches are subdivided in four main branches: the centralized approach, the weakly distributed hierarchical, the strongly distributed hierarchical models and the cooperative approach.

2.5.3.1.1. Centralized approach

Centralized approach is characterized by a communication network having a centralized management system which typically contains one manager which potentially controls a large number of network elements via local management agents. The disadvantages associated with this model are [10]: single point of failure due to a single centralized manager usage; the agent are only used in the management data collection being the analysis logic concentrated at the manager central point (there is no agent cooperation); the scalability of this model is limited due to the centralized management usage.

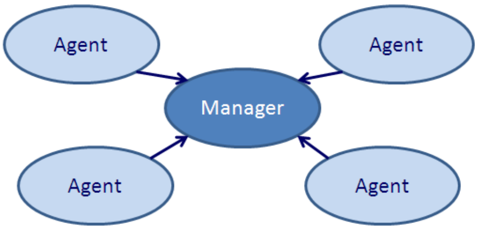


Figure 25 - Centralized approach architecture

2.5.3.1.2. Distributed approach - Weakly distributed model

In a distributed model, the managing processing load is distributed over the agent managers that sit on same hierarchy level. The few existing agent manager communications are done through the central manager entity. The OSI System Manager uses this weakly distributed model approach [11] where CMIP protocol, Common Management Information Protocol that provides an implementation for the services defined by the CMIS, is used for the communications between the network management application and the management agents. It should be noted that the OSI system management is also used as the foundation for the TMN (Telecommunication Management Network – recommendation ITU-T M.3000 [12]) and this framework is one of the widely adopted by the telecommunication management networks. The distributed object computing (software modules designed to work together, but reside either in multiple computers connected via a network or in different processes inside the same computer) shall be also considered as part of this weakly distributed model (Common Object Request Broker Architecture (CORBA) maybe referenced as a good example of such distributed object computing usage [13] [14]). This model approach also has its own drawbacks [15] which are: like the previous centralized approach, the only agent task is to collect the management data being that the logic part is located in the Agent Manager; the fact of this model is still Agent Manager statically configured and hierarchical based makes that it still has a single point of failure; this approach still have a lack of lustiness as can be easily depicted in can a Agent Manager vs Manager connection is lost (so this solution is not appropriate for huge dynamic environments).

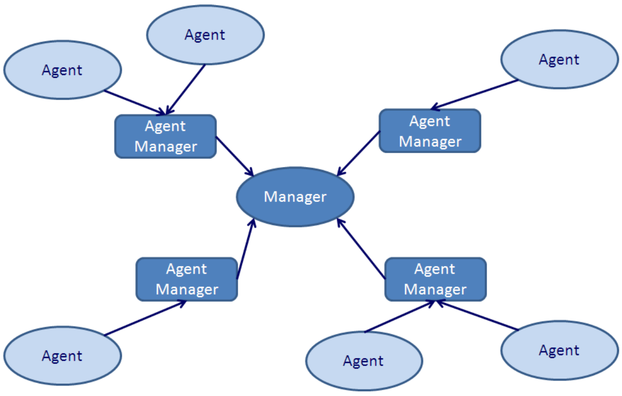


Figure 26 - Weakly distributed approach architecture

2.5.3.1.3. Distributed approach - Strongly distributed model

This approach introduces the relationship between the Agent Managers as a way to overcome weakness associated with the weakly distributed model. Like the previous presented approaches, the agent works just as data collector. The main difference between a weakly and a strongly distributed approach is that in the strongly one, each Agent Manager distributes the decision throughout all the network Agent Managers being that the Manager main task is the coordination of all the delegation tasks even though, in most of the cases, the communication distribution is already performed by the Agent Managers. Despite some of previously described problems had been solved by this approach, some other still exist, namely [16] [17]: single point of failure still exist; mobile agents need specialized platforms or containers in order to delegate tasks throughout the network; the migration task involved with this approach leads to some overhead; some mobile agents use proprietary platforms or containers which may lead to a non-flexible implementation; Agent Managers are subject to the central Manager entity and don't take their own intelligent decisions.

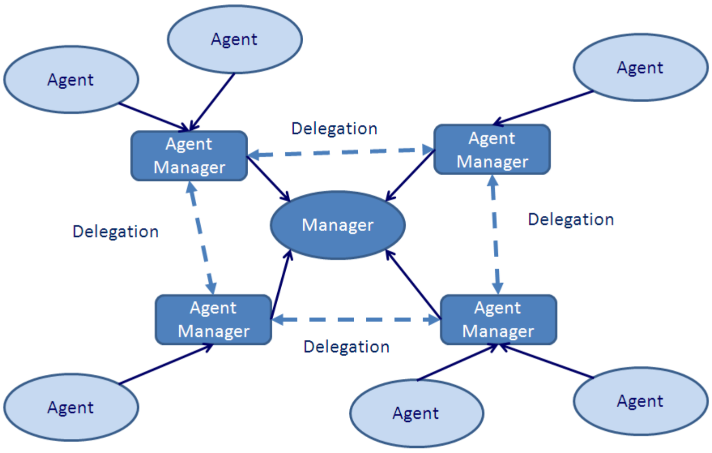


Figure 27 - Strongly distributed approach architecture

2.5.3.1.4. Cooperative approach

This is a management system based on a cooperative approach [18]. While a cooperative model, the entities, which act in both managers and agents and jointly work in a combined manner, can have many roles. The big issue that make this model distinct from the previous ones is that the collaboration and communication are flexible and not limited to a fixed managed point. In this model the agents do have more self-sufficiency while having more autonomy and intelligence, while the mobility has been stressed allowing more and better collaborative and distributed tasks. This agent-based management approach, we decentralized control and processing improving by this way the overall management effectiveness. Despite all improvements achieved, some weakness are still able to be found: this is a more complex solution due to its higher degree of intelligence (payoff); while dealing with large systems scenarios some problems related with lack of security and performance are able to be found; there is a high cost per device to collect, store and act in the management environments; the Agent Manager delegation needs a manual intervention from the network administrator; each agent is just still responsible for collecting management data while the brainpower of the decisions is still left for the Agent Managers.

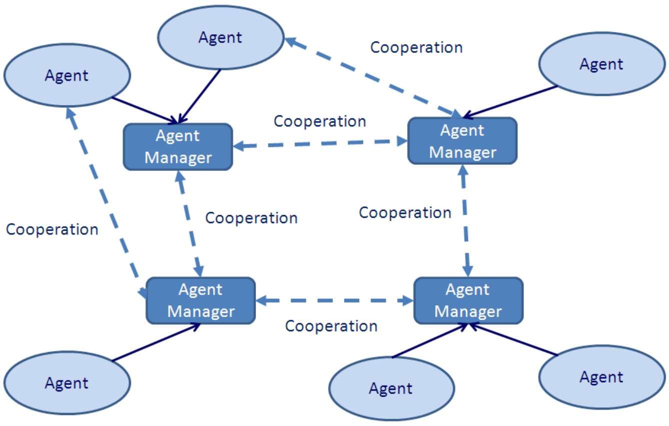


Figure 28 - Cooperative approach architecture

In resume, the centralized groups have a scalability problem, the weakly distributed hierarchical still has single point of failure, strongly distributed approach has a better performance but still has single point of failure, the cooperative approach solves the single point of failure problem but is complex and hard to implement.

As an overall big picture, we can say that each of these traditional management approaches have their own drawbacks and new approaches are now being looked for. These new solutions are the autonomic and self-management environments.

2.5.3.2. Autonomic Computing and Self-Management

The communication networks had evolved to a increasingly complexity of services and scenarios. To face these increasingly challenging demands, the network management effectiveness must be improved. The future networks will be whippy and scalable, they will have a surrounding ecosystem that will be made them easily to be configured and updated. To manage such volatile and challenging environment the Autonomic Computing and Self-Management networks are being thought as the best approaches to face this demanding problems.

Autonomic Computing is derived from the autonomic nerve system that controls the body main functions without the overall involvement of all the other parts. IBM proposed the Autonomic Computing by 2001 [19]. The idea behind was to develop computational systems capable of self-management (low-level decisions) to overcome its growing complexity challenges. The objective of the autonomic networks is to make the management process the more automatic as possible by using autonomic processes. In this self-managed autonomic process, the human manager does not control the system directly but, determines the overall policies and rules that are the input for the process. The process has four functional areas: Self-Configuration, Self-Healing, Self-Optimization, Self-Protection = CHOP [20] [21] [22] [23]. Self-Configuration deals with automatic component configuration and frees the administrator the task of setting properties depending on the specific environmental conditions. Self-Healing makes the automatic discovery and correction of the faults. Self-Optimization makes the automatic monitoring and control of the resources, ensuring the optimal performance faced to the provided input parameters. Self-Protection makes a proactive analysis of the possible arbitrary attack threats and manage with the respective protection. Autonomic Computing shall have three main features: Self-Aware, Self-Configuring and Self-Optimization, Self-Healing [24] [25]. Self-Aware: each network component shall have a detailed knowledge of its surrounding elements in order to be able to react in accordance to its environmental know-how. Self-Configuring and Self-Optimization: an Autonomic Computing shall have the ability of Self-Configuring and Self-Optimization and must be able to perform configurations in accordance with changing environment. Self-Healing: an Autonomic Computing shall be able to recover from partial malfunctions.

Self-Management is seen as an alternative to the traditional bulky volume, diverse and dynamic network elements management [26] [27]. Autonomic Computing maybe resumed to a control loop [19] [21] [28] which commands managed elements. The control loop can be described as group of components in charge of monitoring the manages entities, collecting pertinent information and supporting the higher level decisions. This procedure acts like a closed loop, it is incessantly collected, examined and compared against the expected data. The system control loops will influence each other as a whole. Some small changes in some parts of the network will influence other control loops. The brain power of the autonomic network is inside the autonomic control loop and associated mechanisms, algorithms and procedures. One example of such control loop is next depicted:

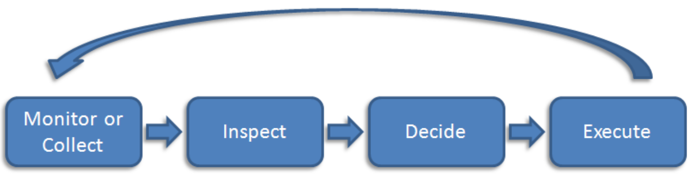


Figure 29 - Autonomic Computing and Self-Management

There are some proposed architectures and projects underway to support this state-of-the-art approach. Each use their own techniques, technologies and strategies targeting the support of the autonomic and self-management networks. Some will just next be briefly listed: Autonomic Service Architecture (ASA) [29] framework, Autonomic Network Architecture (ANA) [30] initiative, Component ware for Autonomic Situation-aware Communications and Dynamically Adaptable Service (CASCADE) [31] project, Haggle [32] architecture project, Foundation Observation Comparison Action Learn Reason (FOCALE) [33] distributed architecture, etc.

2.5.4. Network management models

Different standardization organizations tried to develop a common network management model. The two more well known are the OSI and the ISO models. Both will be next presented.

2.5.4.1. ISO network management model

ISO (International Standard Organization) introduced the OSI NMM model (Open System Interconnection Network Management Model) [34] which defines a conceptual model for managing the entire network communication entities.

In order to support a successful implementation of this OSI NMM, three main elements are necessary [35]:

1st element: a functional component that shall be concerned with the various activities performed in support of network management.

2nd element: a communication component focused on how the information is exchanged between the managed systems.

3rd element: an information component in charge of dealing with the defined five major IT management functional areas (FCAPS = Fault, Configuration, Accounting, Performance, and Security management) which facilitate rapid and consistent progress within each category's individual areas [35].

This ISO model introduces the FCAPS components which are defined as [34]:

1. F = Fault management.
   This is an event, which has a negative significance. This functional management is designed to detect, recognize, isolate, correct and log faults that occur in the network. This function uses trend analysis to predict error with the intention that the network is always available and to keep network running effectively.

2. C = Configuration management.

It is concerned with monitoring network systems and system configuration information, therefore, the effects on network operation of various versions of hardware and software elements can be tracked and managed.

3. A = Accounting management.
   It is involved with gathering of usage statistics of the users. These statistics on the network systems can be regulated which can minimize network problems and maximize the fairness of network access across all users.

4. P = Performance management.
   This determines the efficiency of the current network. The network performance addresses the throughput, percentage utilization, error rates, and response time considerations. By collecting and analyzing performance data the network's health can be monitored. Trends analysis can indicate capacity and reliability issues, which can determine if a particular network problem is worthy of attention.

5. S = Security management.
   It is the process of controlling access to assets in the network systems. This can identify sensitive network resources and determine mappings between these resources and user sets. This process also monitors access points to sensitive network resources and logs any inappropriate access to sensitive network resources [34], [36].

The OSI NMM architecture maybe represented as next depicted [7]:

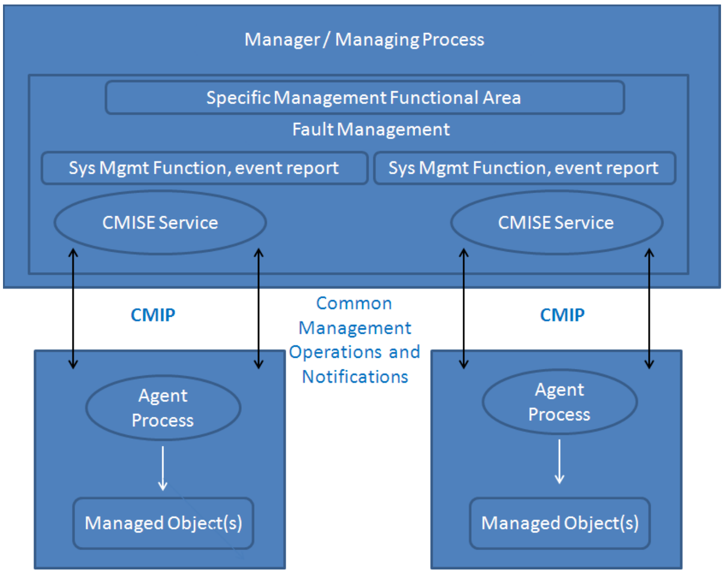


Figure 30 - OSI NMM architecture
Picture adapted from [7]

The greatest limitations seem in this model are in the areas of accounting and security [37] [38].

This architecture uses CMIP which allows a great range of actions when compared to other protocols like SNMP [7]. This OSI framework uses the client-server approach with a manager and agents. It is adaptable as it uses open standards. This architecture is scalable with mechanisms to limit the interactions between manager and agent, in order to add more network elements.

2.5.4.2. ITU-T network management model

The ITU-T (International Telecommunication Union – Telecom Standardization) has defined the Telecommunication Management Network (TMN) model [12] which has become the dominant network management model and the main reference for the telecommunication management solution providers.

TMN proposes a software framework and procedures to get a flexible and reliable communications throughout heterogeneous operations system and telecommunication networks.

This TMN protocol model is mainly based on OSI X.700-Series Recommendations. These define the bases for CMIP/CMIS services and the major management functions: Management Framework (X.700) [39], System Management Overview (X.701) [40], Common Management Information Service (CMIS) Definition (X.710) [41], Common Management Information Protocol (CMIP) Specification (X.711) [42], CMIP Protocol Implementation Conformance Statement (PICS) (X.712) [43], Management Information Model (X.720) [44], Definition of Management Information (X.721) [45], Guidelines for the Definition of Managed Objects (GDMO) (X.722) [46], Object Management Function (X.730) [47], State Management Function (X.731) [48], Attributes for Representing Relationships (X.732) [49], Alarm Reporting Function (X.733) [50], Event Report Management Function (X.734) [51], Log Control Function (X.735) [52], Security Alarm Reporting Function (X.736) [53], Summarization Function (X.738) [54], Workload Monitoring Function (X.739) [55], Security Audit Trail Function (X.740) [56], Test Management Function (X.745) [57].

TMN uses the CMIP (Common Management Information Protocol) or mediation devices (when Q3 interface is used) for communication between Operation Systems and Network Elements (NEs). CMIS (Common Management Information Service) define services that provide the communication between the network management application and the management agents.

TMN logical model defines the following five layers:

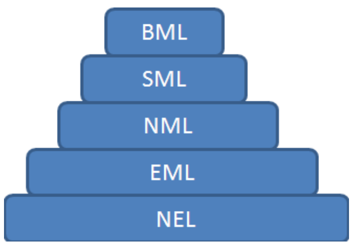


Figure 31 - TMN logical model

1. **Business Management Layer (BML)**

This is the higher level of the model. It is concerned with high-level planning, budgeting, objectives (revenues, OPEX, CAPEX), executive decisions, business level agreements, among others.

2. **Service management Layer (SML)**

Uses the information that is provided by the NML level to manage the client contracted service and to verify the SLA (Service Level Agreement) by making a QoS analysis. This layer is the central customer contact point in what provisioning, accounts, service quality and fault management is concerned.

3. **Network Management Layer (NML)**

This layer has visibility of the operator entire network based on NE details provided by the EML operating systems. This level manages the associated Network Elements. NML coordinates all network activities and support the SML requirements.

4. **Element Management Layer (EML)**

This layer is in charge of each Network Element management. It has the tools and procedures to execute in the NEL layer the upper layer decisions namely on NML layer. The Element Manager manages Network Element data, logs, actions, etc. This layer must cope with the big diversity of the NEs possible to be found at the NEL level. Typically a Element Manager is responsible to a subset of NEs that share technology similarities.

5. **Network Element Layer (NEL)**

This is the lower layer. This layer is made of the physical elements that make the telecommunication operator network. The NEL makes the interface between the proprietary manageable information and the TMN infrastructure.

The TMN architecture is defined as next presented [58]:

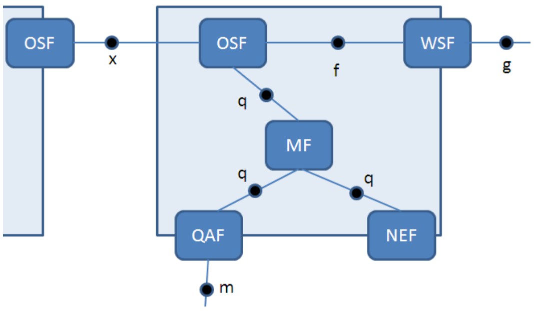


Figure 32 - TMN architecture

Picture adapted from [58]

TMN function blocks:

OSF = Operations System Functions
MF = Mediation Functions
WSF = Work State Functions
NEF = Network Element Functions
QAF = Q Adaptor Functions

There are five possible main blocks in TMN functional architecture (not all must be present). Between the blocks, the TMN model has introduced the reference point concept. There are three reference points (q, f and x) that are completely described in TMN recommendations, the other two (g and m) are only partially described in the TMN recommendations (are located outside the TMN).

⇨ The TMN typical functional blocks are:

NEF function:
Network Elements are field telecommunication equipments in charge of operating the network. They are the exchange and transmission systems that the telecommunication network consists of. The telecommunication functions (exchange of data between users) are the primary function of this NEF (Network Element Functions). These functions are the subject of the management activities. If a NE does not have a standard interface, the NE can still be managed via a Q-Adapter.

OSF function:
Operations System Function block initiates the management operations and receives notifications. The OSF may be seen as the telecommunication manager function (monitoring and controlling duties).

WSF function:
WSF stands for WorkStation Function and is a block that provides the means to interpret TMN information for the management information user. It supports the interface with the human user. It provides the network management staff a way to monitor and interact with the network management system.

QAF function:
Q Adaptor Function makes the connection between the non-standard TMN reference points and the TMN. This block is in charge of making the necessary translation between *q* and *m* reference points.

MF function:
This block makes the mediation between the local TMN interfaces and the OS information model. The Mediation Function block is charge of making the transfer of information between the QAF/NEF and the OSF function blocks. This block ensures the information, scope and functionality feet the OSF expectations. A MF can be connected to multiple QAF/NEF blocks. MF blocks can be connected in cascade.

⇨ The TMN defined interfaces are [59]:

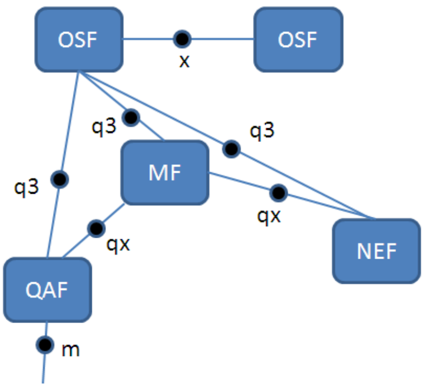


Figure 33 - TMN interfaces
Picture adapted from [59]

The TMN standard interfaces are defined as:

Q interface:
This interface lives to connect blocks that stand inside the same TMN domain.
qx exists to exchange information between the MF and the supported NEs.
q3 is the interface toward OSF block.

F interface:
This interface typically stands between the WSF.

X interface:
This interface sits between two TMN compliance OSFs in two separate domains or between a TMN complaint domain OSF and another OSF in a non TMN network.

2.5.5. Performance Management Architecture

The KPIs that are proposed in this Thesis are thought to be used in a performance management architecture that will be next presented.

This ITU-T/TMN model based performance management architecture is thought to be high performance, organized and scalable. It intends to provide the user with enough valid data that he is able to make a valid and useful network analysis under a reasonable amount of time.

The performance management system is based on the following architecture:

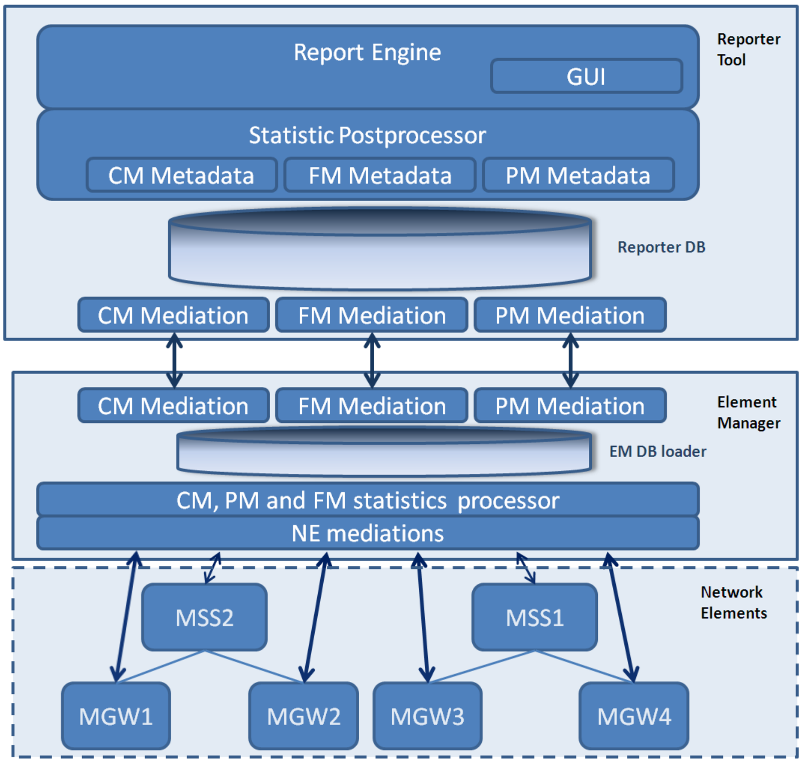


Figure 34 - PM architecture

Network Elements:
These are the telecom equipments that are intended to be monitored and from which the data is to be retrieved. Such can be equipments like a MSC Server, HLR, Media Gateway, BSC, RNC, Node-B, BTS, STP, etc. All Network Elements (NEs) monitor its own functioning via the performance mediation module. A block of this subset is responsible for the communication with the Element Manager. This block is, by its turn, divided in three parts. One part handles the performance management data (NE operation statistics), other the configuration management data (NE setup) and the last one the fault management data (handles the NE error message and alerts).

Element Manager:
A telecommunication operator can have one or more Element Managers (EM) that are in charge of the interaction with field Network Elements (NE). Each EM typically handles more than one NE. The EM uses its NE mediation block to handle the communications with the Network Elements, which consists on the extraction of the NE performance and fault information. Then, we have the EM statistics processor that converts the configuration, performance and fault NE collected data into a predefined generic metadata model. The gathered data is then uploaded to the EM raw format tables through the EM DB loader. Finally we have at the EM northbound interface the CM, FM and PM mediations that are in charge of the interaction with the Reporter Tool communication. This communication can be made on a push or pull basis (EM or Reporting Tool driven).

Reporter Tool:
This tool is in charge of presenting to the network user the pre-defined KPIs and the associated reports (a set of organized PIs and KPIs). The Reporter Tool, by using its own CM, FM and PM mediations, get in contact with the Element Manager counterpart mediations and retrieve the necessary data. Such data is then uploaded to the Reporter Database which is modulated based in accordance with the NE specific metadata. This modulation is made in terms of object class structure definition, associated performance management measures and related counters each with its own defined aggregation rules. The Reporter Database is a data warehouse prepared to combine different correlated data sources (may it be configuration, performance or fault related parameters) and is shaped to make an optimum data finding and reporting. This database has its contained data modulated against a hierarchical tree of objects defined in accordance with the technology own PM and CM parameters. This database makes possible an object or time level analysis. Once the data is properly loaded into the reporter database, the statistic postprocessor is put into action by the object and time aggregations handling. This is a crucial task in order for the user to be able to drill into the intended time and object levels. Finally the Reporter tool module is reached. This is where the “brainpower” of the Reporter Tool is located. This module is responsible for the database queries, result output processing and presentation via the GUI module. The outputs are, typically, predefined reports that can briefly be described as a logical set of PIs and KPIs with drill-in capabilities. These KPIs can be calculated on-the-fly by the report engine or be pre-calculated and stored in the Reporter Database. It shall be noted that the Reporter Tool also typically provide its own data to 3rd party applications by using its own northbound interfaces.

2.5.6. Performance Management Interfaces

As previously referred, the reporting tool collects the data from the Element Manager(s) via its Southbound interface. These connections can use equipment vendor proprietary interface protocols, 3GPP standards, OSS/J open interface standards (APIs), CORBA, etc. for reporting server vs Element Manager interconnection.

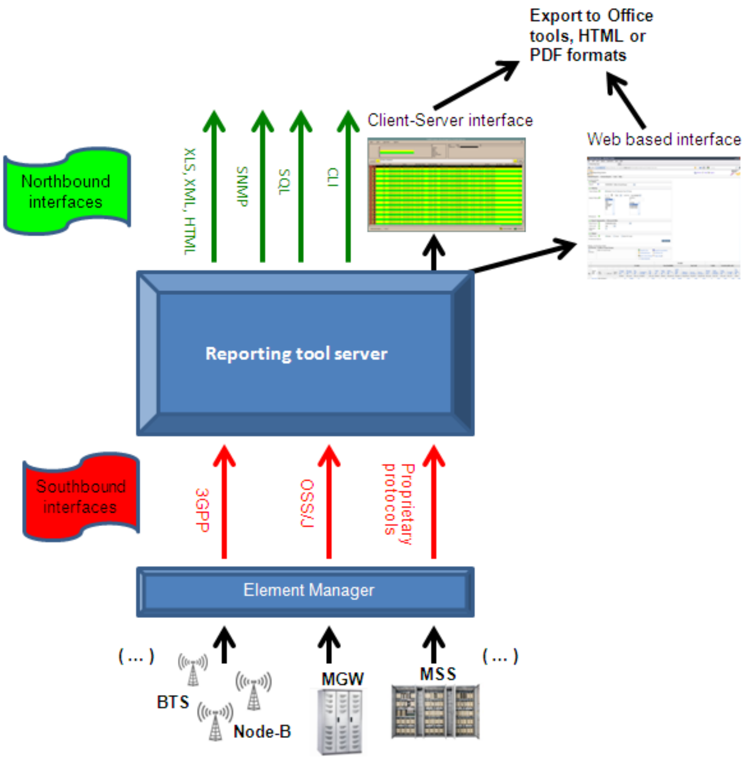


Figure 35 - Reporting tool interfaces

The reporting tool, on the other hand, maybe connected to other data systems by using its Northbound interface. This interface can be used for data access while exchanging data by using XLS, XML, HTML data formats. The direct access to their DB can be achieved by using a SQL interface. It allows office integration (Excel, HTML, PDF) and direct access via command line interface (CLI). Typically it is also used the SNMP for forwarding the alarms to other fault management system.

The user interaction with this reporting tool is made by using a client-server or web based interface access.

2.5.7. Performance Management Systems market trend analysis

Next is presented a brief resume of the current Performance Management Systems market conditions; market in which the KPIs proposed on this Thesis are supposed to be used in.

The tight telecommunication market competition and the end to the "*golden era*" (exponential growth in all major markets) had lead to the necessity of the telecommunication network operators to decrease the respective Operation Expenditures (OPEX).

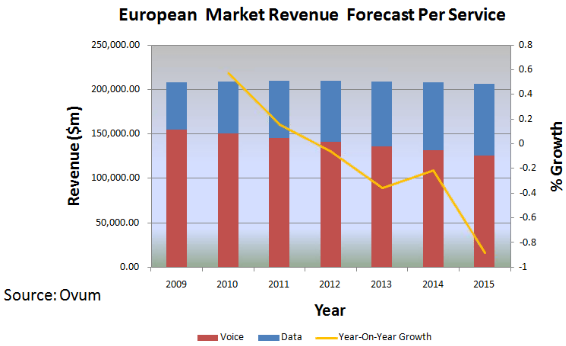


Figure 36 - Telecom market trend analysis

This has brought new challenges and market opportunities. The challenge is now to create a management system capable of handling the operator's overall network and assets. The pressure to create PMS that could handle large multivendor and multi-technology complex networks capable of dealing with a huge quantity of performance data covering all the network NEs coming from different vendors and dealing with distinct technologies, increased. New solutions based on cloud computing and SAS (Software As a Service) capable of run under GNOC[8] environments are increasingly being requested.

The market conditions, on the other way, are changing from a pure telecommunication perspective to a more telecommunication's assets overall management ecosystem (it now includes not only the pure network and resource management but also the inventory management, process automation, fulfilment and service assurance).

The seductive business opportunities and the business focus enlargement; had attracted players coming from areas outside the pure telecommunication world. IT enterprises like IBM, HP and Amdocs start to deeply enter in this PMS market which has made the competition even tighter.

The current main competitors are:

- Nokia Siemens Networks (NSN)
- IBM
- Ericsson
- Aircom
- Amdocs
- HP

As can be seen, that reflects the current tendency of the PMS market: a true join between the IT and telecommunication markets and technologies.

[8] GNOC = Global Network Operation Centres
Centralized Network Management Centres with heterogeneous environment where the operator's overall network is controlled.

2.5.8. Conclusion

It can be retrieved from the just presented sections that the performance management systems are a quite challenging and rapid growth expertise technical area that is becoming increasingly critical for the network operators due to the progressively more complexity and high load requirements of the communication networks.

From the preparation work performed it was detected some flaws in the currently defined 3GPP TS 32.407 metrics. Some corrections were proposed to 3GPP which have been successfully accepted.

The high performance and resilience requirements involved in the performance management are leading to a distributed, autonomous and intelligent new architectures.

From this chapter, it can be derived that there are many models that can be used even though the one thought as the base for the Performance Management System over which the proposed KPIs are based on is the ITU-T TMN model. The associated architecture and interfaces were described in this chapter.

2.6. KPI theory

2.6.1. Overview

In this section, the KPI theory that will be the base for the proposed CS KPIs is presented. The presented KPI theory is based on [60] .

This section starts to present the KPI creation challenge by describing how to get the KPI inputs, then it proceeds to the KPI definition main challenges, the analysis of typical intended target audience, the KPI aggregation definition problem and finally it presents the used output presentations.

It then describes the Node model that will be the base for the proposed KPIs. It starts to present the Node phases, then explains its Performance Indicators and finally explains which KPIs can be derived from the existing PIs and where the KPIs can fit inside the standard ITU KPI defined groups.

2.6.2. KPI creation challenge

The demand for a KPI may arrive from many sources. The KPIs can be suggested by standardization requirements, may come from Performance Management customer requirements (demanded by operation team ; planning team ; optimization team ; customer care team ; management team ; marketing team) of from existing feature requirements.

The first big issue when creating a new KPI is to clearly define the request. Some basic questions shall be made: are the KPI's requirements clearly defined? From where to get the KPI's inputs? To whom is the KPI being produced? Who will be the target audience?

The target audience is a major issue that should be clearly defined. The target audiences typically fit in the following main groups: Network Planning ; Network Operation ; Network Optimization ; Marketing ; Customer Care ; Management.

Depending on the target audience, a KPI definition may be differently defined. Each end group has its own needs and such may lead to dissimilar outputs.

We can typically separate two different target audiences: the Network Planning and the Operation and Maintenance teams. The Planning team typically requests the maximum (or some cases minimum) outcomes in order to get network or equipment usage limits. On the other way the Operation and Maintenance teams typically wants the real totals in order to get a snapshot overview and consequently want the sum of the counter values.

Another important issue when creating a KPI is to define what will be the intended output presentation. It is necessary to clearly define which kind of KPI output do we want to have and in which kind of report do we want the KPI to be inserted. The typical report outputs are the basic reporting which maybe depicted as tabular/matrix (for detailed examination) or diagrams views (overview approach), the topology or map views to achieve a structured view, the gauges outputs when the outcomes vary between predefined values and dashboard overview outputs that are typically used to get a wrap-up overview.

2.6.3. Node model

A Node is a measured topic derived from the requirements, use cases of the Network Element or service. A measure topic can be either physical (like a hardware card) or logical (like Clear Code or a Traffic Category condition).

The Node model provides a common powerful approach for all measured topics. This model allows generic basic KPI definitions and PI requirements.

A Node has typically 3 phases: the **Setup** which is a preparation for node function (e.g. resource reservation), the **Function** phase (this is when the Node is working normally) and, finally, the **Release** of the node function (e.g. resource release).

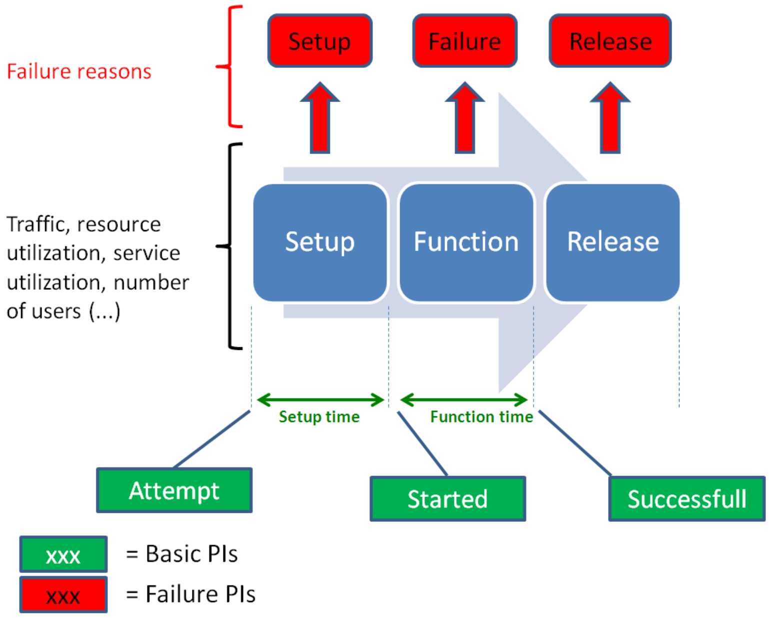


Figure 37 - Typical Node
Picture adapted from [60]

A typical Node has its basic **P**erformance **I**ndicator**s** (Network Element Counters) divided in 3 main groups: Event, Duration and Capacity Usage. The Capacity Usage, by its turn, can be divided in two subgroups that are the traffic volume and the number of connections.

A typical Node has the next presented basic **P**erformance **I**ndicator**s** (Network Element Counters) from which the Node KPIs will be derived.

PI Group	PI Name	PI Description
Event	**Attempt**	Identifies that the node has been triggered. **Trigger:** Counter is updated when a function is attempted to use.
	Started	Identifies that the node function has been started. **Trigger:** Counter is updated when a function is started.
	Successful	Identifies that the node function has been ended successfully. **Trigger:** Counter is updated when a function is successfully ended.
	Setup failure	Identifies that function has not been started. Typically there can be many reasons and therefore many failure indicators. When different reasons for failure, reason specific counters should be available. **Trigger:** Counter is updated when a function usage attempt is failed.
	Function	Identifies that function has been aborted.

		failure	Typically there can be many reasons and therefore many failure indicators. When different reasons for failure, reason specific counters should be available. **Trigger:** Counter is updated when a function usage is failed.
		Release failure	Identifies that function release has been failed. Typically there can be many reasons and therefore many failure indicators. When different reasons for failure, reason specific counters should be available. **Trigger:** Counter is updated when a function release is failed.
Duration		**Setup time**	Identifies how long the setup phase took. **Trigger:** Counter provides the delay between function usage attempt and the successful start of the function.
		Function time	Identifies how long the function phase took. **Trigger:** Counter provides the time between function start and function release.
Capacity Usage		**Number of users**	Counter provides information about amount of users using the functions.
	Traffic Volume	**Total volume**	Counter provides information about the traffic volume.
		Dropped	Counter provides information about the dropped traffic.
		Discarded	Counter provides information about the discarded traffic.
	Nbr of Connections	**Total number**	Counter provides information about number of connection to function.
		Dropped	Counter provides information about number of connections that dropped.
		Discarded	Counter provides information about number of connections discarded.

Table 4 – Node basic PIs and PI groups

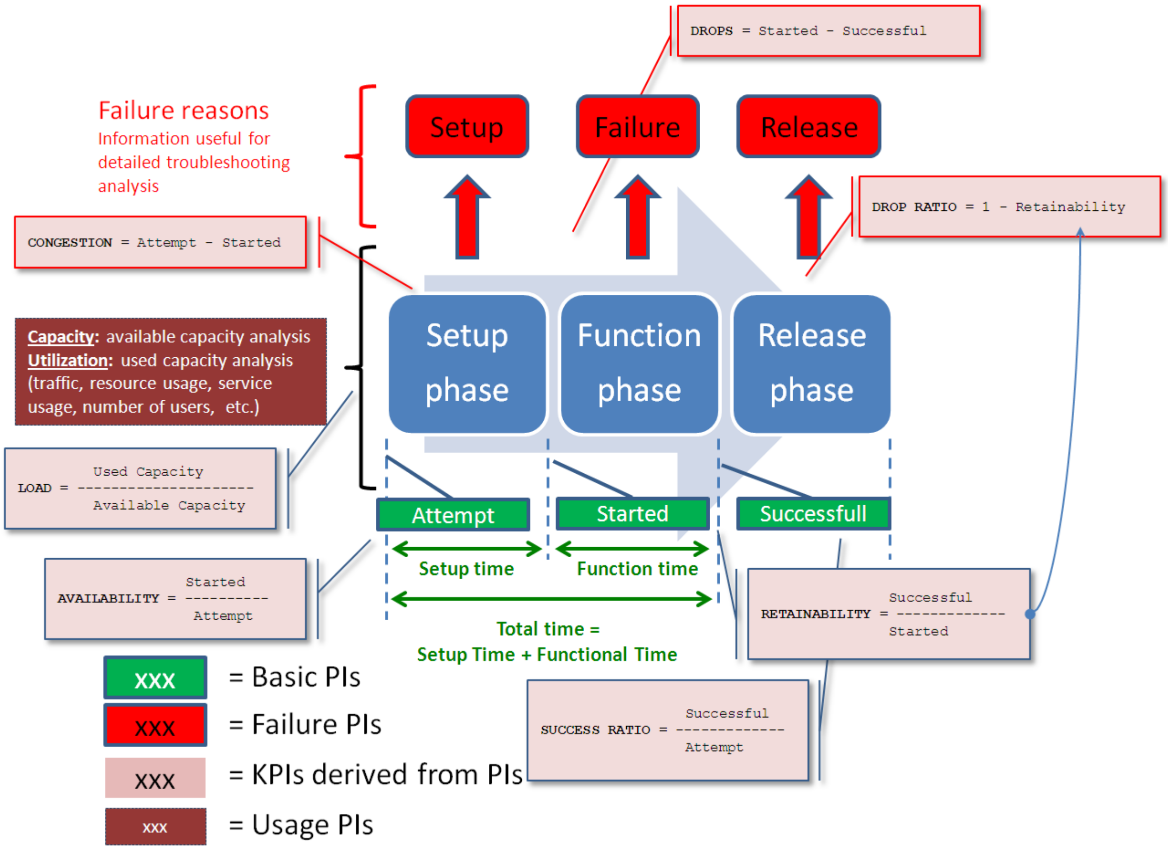


Figure 38 - Node KPIs model

Picture adapted from [60]

The presented PIs are the base for the Node model KPIs. By using these KPIs, all the Node main features and behaviour can be inspected and evaluated.

The KPIs can be divided in two main groups: one that makes the tracking of the Node events and one minor to make the Node capacity usage analysis.

KPI group	KPI name	KPI formula	KPI Description
Events	Congestion	(Attempt) – (Started)	Describes the amount of function usage attempts that were not succeeded.
	Availability	(Started) / (Attempt)	Probability to get function usage started.
	Success Ratio	(Successful) / (Attempt)	Describes the ratio of successful functions compared to function usage attempts.
	Retainability	(Successful) / (Started)	Probability to keep function.
	Drop ratio	1 – (Retainability)	Probability to lose function.
	Drops	(Started) – (Successful)	Describes the amount of not successful functions.
Capacity Usage	Load	(Used Capacity) / (Available Capacity)	Describes the ratio of capacity used.

Table 5 – Node standard KPIs

Once a KPI is defined, it shall be classified into one KPI category. ITU-T had made some recommendations (ITU-T Recommendation E.800 [61]) targeting the KPI groupings. Such have been defined as next presented:

KPI group	KPI class	Description
Serveability	Accessibility	Ability of a service to be obtained within specified tolerances and other given conditions when requested by the user.
	Retainbility	Ability of the service, once obtained, to continue to be provided under given conditions for a requested period of time.
	Integrity	The degree (service quality) to which a service is provided without excessive impairments, once obtained.
Availability (*)	Reliability	Probability that an item can perform a required function under stated conditions for a given time interval.
	Maintainability	The probability that a given active maintenance action, for an item under given conditions of use can be carried out within a stated time interval, when the maintenance is performed under stated conditions and using stated procedures.
	Utilization	Utilization of network resource such as throughput on a specific interface.
	Mobility	Visualize the end-user movements.

Table 6 – ITU KPI categories

(*) Probability to get capability to start the service usage

2.6.4. Conclusion

Many different types of KPIs may be proposed based on the provided KPI theory. We can have just simple KPIs that just provide the number of users that fulfil a certain criteria, up to more complex ones like those that are based on traffic analysis dependant on user conditions or specific event analysis.

The aim of this section was to present the challenges of the KPI creation process and provide the criteria and overall theory that is going to pave the way throughout this Thesis for the new CS Core Network KPIs proposal.

2.7. Conclusion

After reading this introductory chapter, it is now clear that there is a need for the commonly accepted 3GPP KPIs and, specifically, for the CS CN KPIs proposed in this Thesis.

It is clear that the creation of the CS CN KPIs is based on a quite complex technical environment which details have been described in this chapter.

These KPIs are thought to be used in an ITU-T/TMN performance management architecture and are based on the 3GPP TS 32.407 specifications that has been reviewed as consequence of the preparation activities for this Thesis.

The KPIs proposed in this Thesis are mainly based on the KPI theory presented on this chapter.

3. KPI definition

This chapter presents the proposed 3GPP CS CN KPIs targeting the CS Core Network analysis.

3.1. Overview

All KPIs proposed in this Thesis are in accordance with the data model defined on the 3GPP TS 32.407 Technical Specification in terms of the defined metadata, trigger points, signalling flow and others. The KPI coherent set now proposed cover all the CS CN Rls.4 NEs and interfaces.

This Thesis starts to present the base object model over which the KPIs will be created, next it is presented a brief description of the main fields that the user will be able to find in the following KPI proposals and finally it enters deeply into each NE KPI proposal. This Thesis first starts to present the MSS KPIs followed by the MGW related ones and, at last, the HLR related. For each NE, the KPIs are grouped in accordance with the previously presented ITU-T KPI categories.

The MSS KPIs are divided in three main sets: the accessibility that groups the KPIs that focus on the ability to access the network and establish a call; the utilization set which will inspect the MSS utilization profile and will collect the KPIs used for the traffic check, unit load inspection, subscriber and signalling analysis; finally, the mobility set will group the KPIs in charge of visualizing the end-user movements.

The MGW KPIs are also divided in three sets: the accessibility set will exhibit the ability of a service to be obtained within specified tolerances and other given conditions when requested by the user; the integrity set will provide the degree (service quality) to which a service is provided without excessive impairments, once obtained; finally the utilization set will include the KPIs in charge of measuring the usage of MGW NE and network resources.

The HLR KPIs include the utilization set which will be used to provide the NE usage profile.

3.2. Base object model

The Object Model describe the network object structure. It shall represent and describe, in a coherent and consistent manner, the network element roles, relationships and respective interfaces.

We can have two types of objects: the manage objects and the reference objects. The managed object is a network entity that can be monitored and managed via the OSS system. The reference object refers to virtual reporting dimensions, which are elements that are virtually created to ease network analysis. This reference objects are created and stored into the database by the Statistics Postprocessor module (please refer to the previous "*Performance Management Architecture*" section).

This Thesis is not going to enter deeply in the object model definition because such may be dependent on the specific NE vendor hardware and software implementation. Still, the next presented general OC model is expected to be found by the KPIs presented in this Thesis.

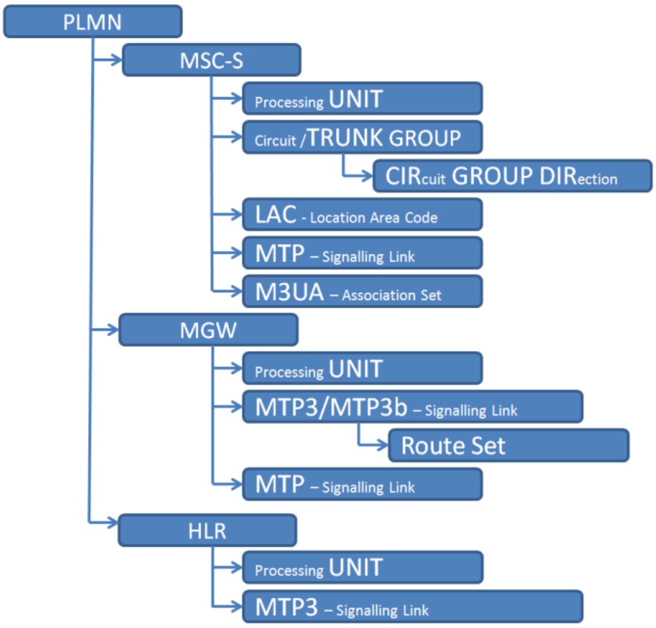


Figure 39 - CS Rel.4 base Object Class model

3.3. Description of the KPI used fields

All KPIs proposed in this Thesis will have associated a set of predefined fields that will help to describe the KPI's content and working environment.

Each KPI will be inserted in a certain KPI's category as defined in ITU-T:

- Accessibility
- Retainability
- Integrity
- Reliability
- Maintainability
- Resource/Utilization
- Mobility

The KPI's category can be inspected by checking its positioning inside the general index (index level 3).

a.) KPI name.

Here it is proposed a name for the KPI.

b.) KPI description.

The proposed KPIs will have an initial brief description about what the KPI provides and what is the KPI's aim.

c.) Unit.

All proposed KPIs have an associated unit reference. The unit may vary and can be defined as: percentage, time interval (e.g. second), Erlang, kbit/s, etc.

d.) KPI formula.

Here it is to be presented the intended KPI formula.

e.) 3GPP used counters.

The 3GPP TS 32.407 abbreviated counter names that are, sometimes, not easy to understand. The KPI's used counters shall be here described as presented in the 3GPP spec.

f.) Special Notes.

Here it may be provided some KPI special details like the intended target audience, KPI's logical formula approach (in case of more complex KPI formulas), traffic flow details, etc.

3.4. MSS - KPI proposal

This chapter presents the MSS related KPIs. These KPIs take advantage of the Performance Management measures defined in chapter 4 ("*Measurements related to the MSC Server*") of the 3GPP TS 43.407 source document.

The idea behind is that, by using the available 3GPP TS 43.407 PM data, it inspects some more significant MSS NE interfaces and protocols and, as so, it gets a detailed understanding about how the MSS Network Element is performing. This analysis will be made through the accessibility, usage and mobility MSS NE inspection.

The accessibility check is based on the call type inspection.

The usage analysis is based on traffic inspection, call failure, unit load, VLR, Trunk Group and signalling detailed check. Special care is taken with the MSS signalling inspection. The more relevant MSS protocols like M3UA, MTP3, H.248 and some specific NE interfaces like the Nc and Mc are proposed to be inspected.

Finally, we include the mobility analysis that provides the MSS NE paging, location update and handover inspection.

3.4.1. Accessibility

The next presented set of KPIs are all related with accessibility issues which means, following ITU definition, that such are KPIs that focus on the ability to access the network and establish a call.

The accessibility related KPIs will be split in two groups: the "Mobile Terminated and Originated calls analysis" and the "Mobile calls setup analysis – This MSC-S analysis".

3.4.1.1. Mobile Terminated and Originated calls analysis

The next four presented KPIs are important for the user to have an overview of the mobile terminated and originating calls that had flow through the MSC-S that is being observed:

- Mobile Terminated Answered Calls Success Ratio.
- Mobile Terminated Calls Success Ratio
- Mobile Originating Answer Calls Success Ratio.
- Mobile Originated Calls Success Ratio.

KPI name	Mobile Terminated Answered Calls Success Ratio.
Description	This KPI provides the mobile terminated answered calls success ratio.

Unit	%
KPI formula	$100 \times \frac{\sum \text{CC.AnsMobileTermiCalls}}{\sum \text{CC.AttMobileTermiCalls}}$
3GPP used counters	➢ **CC.AnsMobileTermiCalls** Non-Combined counters: GSM (CC.AnswMobileTermiCalls.G) + UMTS (CC.AnswMobileTermiCalls.U). ➢ **CC.AttsMobileTermiCalls** Non-Combined counters: GSM (CC.AttMobileTermiCalls.G) + UMTS (CC.AttMobileTermiCalls.U).
Special Notes	The answer phase is reached when the "Connection Acknowledge " message is reached.

KPI name	Mobile Terminated Calls Success Ratio.
Description	This KPI provides the mobile terminated calls success ratio.
Unit	%
KPI formula	$100 \times \frac{\sum \text{CC.SuccMobileTermiCalls}}{\sum \text{CC.AttMobileTermiCalls}}$
3GPP used counters	➢ **CC.SuccMobileTermiCalls** Non-Combined counters: GSM (CC.SuccMobileTermiCalls.G) + UMTS (CC.SuccMobileTermiCalls.U). ➢ **CC.AttMobileTermiCalls** Non-Combined counters: GSM (CC.AttMobileTermiCalls.G) + UMTS (CC.AttMobileTermiCalls.U).
Special Notes	The success condition is reached when the “Alerting” message is achieved.

KPI name	Mobile Originating Answer Calls Success Ratio.
Description	This KPI provides the mobile originating answer calls success ratio.
Unit	%
KPI formula	$100 \times \frac{\sum \text{CC.AnswMobileOrigiCalls}}{\sum \text{CC.AttmobileOrigiCalls}}$
3GPP used counters	➢ **CC.AnswMobileOrigiCalls** Non-Combined counters: GSM (CC.AnswMobileOrigiCalls.G) + UMTS (CC. AnswMobileOrigiCalls.U). ➢ **CC.AttmobileOrigiCalls** Non-Combined counters: GSM (CC.AttmobileOrigiCalls.G) + UMTS

	(CC.AttmobileOrigiCalls.U).
Special Notes	The answer phase is reached when the "Connection Acknowledge " message is reached.

KPI name	Mobile Originated Calls Success Ratio.
Description	This KPI provides the mobile originated calls success ratio.
Unit	%
KPI formula	$100 \times \frac{\sum \text{CC.SuccmobileOrigiCalls}}{\sum \text{CC.AttmobileOrigiCalls}}$
3GPP used counters	➢ **CC.SuccmobileOrigiCalls** Non-Combined counters: GSM (CC.SuccmobileOrigiCalls.G) + UMTS (CC.SuccmobileOrigiCalls.U). ➢ **CC.AttmobileOrigiCalls** Non-Combined counters: GSM (CC.AttmobileOrigiCalls.G) + UMTS (CC.AttmobileOrigiCalls.U).
Special Notes	The success condition is reached when the "Alerting" message is achieved.

3.4.1.2. Mobile calls setup analysis – This MSC-S analysis

The next KPIs are of major importance for the user to get an idea of the total mobile calls handled by the MSC-S being observed.

In order to avoid a big overhead, the next following KPIs are just provided for a GSM + UMTS total amount. Still, the GSM or UMTS detailed KPIs could be easily derived by replacing the combined counters by the 2G ("*.G*") or 3G ("*.U*") detailed ones. For example, to get the "*2G Call setup analysis - MSC-S mobile calls setup success ratio*", the next formula would have to be used:

$$100 \times \frac{\sum \text{CC.SuccMobileTermiCalls.G} + \sum \text{CC.SuccmobileOrigiCalls}.G}{\sum \text{CC.AttMobileTermiCalls.G} + \sum \text{CC.AttmobileOrigiCalls}.G}$$

And to get the "*3G Call setup analysis - MSC-S mobile calls setup success ratio*" the next KPI should be used:

$$100 \times \frac{\sum \text{CC.SuccMobileTermiCalls.U} + \sum \text{CC.SuccmobileOrigiCalls}.U}{\sum \text{CC.AttMobileTermiCalls.U} + \sum \text{CC.AttmobileOrigiCalls}.U}$$

The next following KPI shall be used for the mobile calls setup and answer analysis:

- Mobile calls setup analysis - MSC-S mobile calls setup success ratio.
- Mobile calls answered analysis - MSC-S answer success ratio.

KPI name	Mobile calls setup analysis - MSC-S mobile calls setup success ratio
Description	This KPI provides the mobile calls call setup analysis of the mobile calls handled by the MSC-S being observed.
Unit	%
KPI formula	$\frac{\sum CC.SuccmobileOrigiCalls + \sum CC.SuccMobileTermiCalls}{\sum CC.AttmobileOrigiCalls + \sum CC.AttMobileTermiCalls}$
3GPP used counters	- **CC.SuccmobileOrigiCalls** Number of successful call for MSC-S mobile originating traffic. On transmission by the MSC-S of a "ALERTING" message to the originating mobile. Non-Combined counters: GSM (CC.SuccmobileOrigiCalls.G) + UMTS (CC.SuccmobileOrigiCalls.U). - **CC.SuccMobileTermiCalls** Number of successful calls for mobile terminating traffic. On receipt by the MSC-S of an "ALERTING" message from the called mobile, for the requested mobile terminating call. Non-Combined counters: GSM (CC.SuccMobileTermiCalls.G) + UMTS (CC.SuccMobileTermiCalls.U). - **CC.AttmobileOrigiCalls** Number of mobile originating call attempts from the MSC-S's perspective. On receipt of "CM_SERV_REQ" message from the originating mobile, with service type 0001 or 0010. Non-Combined counters: GSM (CC.AttmobileOrigiCalls.G) + UMTS (CC.AttmobileOrigiCalls.U). - **CC.AttMobileTermiCalls** Number of call attempted for UMTS mobile terminating traffic from MSC-S's perspective. On transmission by the MSC-S of a "SETUP" message to the called mobile, for the requested mobile terminating call. Non-Combined counters: GSM (CC.AttMobileTermiCalls.G) + UMTS (CC.AttMobileTermiCalls.U).
Special Notes	The call setup success condition is reached when the “ALERTING” message is reached.

KPI name	Mobile calls answered analysis - MSC-S answer success ratio
Description	This KPI provide the answer ratio of the mobile calls that start or terminate on the MSS NE being observed.
Unit	%

KPI formula	$100 \times \frac{\sum CC.AnsMobileTermiCalls + \sum CC.AnswMobileOrigiCalls}{\sum CC.AttMobileTermiCalls + \sum CC.AttmobileOrigiCalls}$
3GPP used counters	➢ **CC.AnswMobileOrigiCalls** Non-Combined counters: GSM (CC.AnswMobileOrigiCalls.G) + UMTS (CC.AnswMobileOrigiCalls.U). ➢ **CC.AnsMobileTermiCalls** Non-Combined counters: GSM (CC.AnswMobileTermiCalls.G) + UMTS (CC.AnswMobileTermiCalls.U). ➢ **CC.AttMobileTermiCalls** Non-Combined counters: GSM (CC.AttMobileTermiCalls.G) + UMTS (CC.AttMobileTermiCalls.U). ➢ **CC.AttmobileOrigiCalls** Non-Combined counters: GSM (mCC.AttmobileOrigiCalls.G) + UMTS (CC.AttmobileOrigiCalls.U).
Special Notes	The answer phase is reached when the "Connection Acknowledge " message is reached. This KPI makes an overall analysis for both terminating + originating traffic.

Following the Node KPI model, the drop occurrences are counted as:

```
Drop = (Started) – (Successful)
```

The next following KPs shall be used for this Call setup drop analysis:

- ➢ Call setup drop – MSC-S mobile calls.

KPI name	MSC-S mobile calls call setup drop analysis.
Description	This KPI provides the call setup drops of the sink mobile calls handled by the MSC-S being observed.
Unit	%
KPI formula	$\left(\sum CC.AttmobileOrigiCalls + \sum CC.AttMobileTermiCalls\right)$ $-$ $\left(\sum CC.SuccmobileOrigiCalls + \sum CC.SuccMobileTermiCalls\right)$
3GPP used counters	➢ **CC.SuccmobileOrigiCalls** Number of successful call for MSC-S mobile originating traffic. On transmission by the MSC-S of a "ALERTING" message to the originating mobile. Non-Combined counters: GSM (CC.SuccmobileOrigiCalls.G) + UMTS (CC.SuccmobileOrigiCalls.U). ➢ **CC.SuccMobileTermiCalls** Number of successful calls for mobile terminating traffic. On receipt by the MSC-S of an "ALERTING" message from the called mobile, for the requested mobile terminating call. Non-Combined counters: GSM (CC.SuccMobileTermiCalls.G) + UMTS

	(CC.SuccMobileTermiCalls.U). ➢ **CC.AttmobileOrigiCalls** Number of mobile originating call attempts from the MSC-S's perspective. On receipt of "CM_SERV_REQ" message from the originating mobile, with service type 0001 or 0010. Non-Combined counters: GSM (CC.AttmobileOrigiCalls.G) + UMTS (CC.AttmobileOrigiCalls.U). ➢ **CC.AttMobileTermiCalls** Number of call attempted for UMTS mobile terminating traffic from MSC-S's perspective. On transmission by the MSC-S of a "SETUP" message to the called mobile, for the requested mobile terminating call. Non-Combined counters: GSM (CC.AttMobileTermiCalls.G) + UMTS (CC.AttMobileTermiCalls.U).
Special Notes	The call setup success condition is reached when the "ALERTING" message is reached.

3.4.2. Utilization

This is a group with major importance. By using the KPIs presented in this group, the user will be able to inspect the MSS utilization profile. This group will collect the KPIs used for the traffic check, unit load inspection, subscriber and signalling analysis.

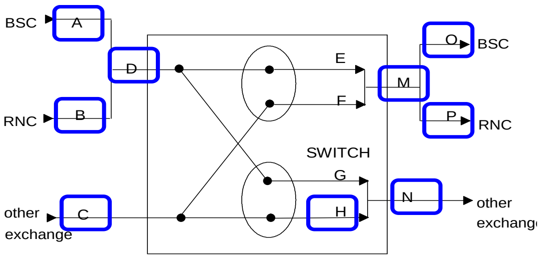
The utilization related KPIs will be divided in six main groups:

- MSS Traffic Analysis
- Call failure analysis – Subscriber reason
- Unit Load analysis
- Subscribers analysis
- Trunk Group analysis
- Signalling analysis

3.4.2.1. MSS Traffic Analysis

The 3GPP call traffic counters are obtained by summing the resource occupation time intervals over the granularity period. The outcome is retrieved as Erlang values.

The interfaces for which the 3GPP has defined such traffic counters are below highlighted in blue. The KPIs that will be following proposed will take advantage of such defined Performance Indicators.



A	GSM Mobile Originating call
B	WCDMA mobile originating call
C	Incoming call
D	Mobile originating call
E	Internal call
F	Terminating incoming call
G	Originating outgoing call
H	Transit call
M	Mobile terminating call
N	Outgoing call
O	GSM mobile terminating call
P	WCDMA mobile terminating call

Figure 40 - 3GPP - CS PM Basic Traffic model
Picture retrieved from [1]

In order to better understand the KPIs that will be following proposed, the next assumptions shall be kept in mind:

- A call is considered to be once the SUCCESSFUL (Network Element point of view) when call ALERTING message is sent (call reaches the ALERTING procedure).

- A call is considered to be ANSWERED when the call has reaches the successful CONNECTED phase.

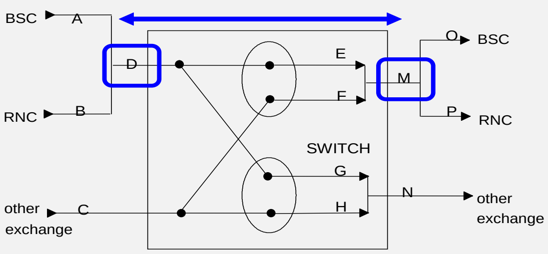
The next KPI "*Special Notes*" details shall be read with care since they are helpful to fully understand the associated KPI formulas approach. The traffic path explanation is based on the 3GPP PM traffic model. A special remark is here made to alert that these proposed KPIs are defined to only run against the MSC-S NE object class level.

The KPIs that will be following proposed were made targeting the total NE traffic analysis, which means that they are considering both the GSM + UMTS traffic and Voice + Data total traffic types. From these proposed KPIs, the specific GSM or UMTS or Voice or Data traffic types could be individually retrieved. It would just be a question of just filtering the intended proper detailed counters: "*.Voice.G*" for voice GSM specific; "*.Data.G*" for data GSM specific; "*.Voice.U*" for voice UMTS specific; "*.Data.U*" for data UMTS specific.

The following MSC-S NE traffic analysis, the following KPIs have been proposed:

- Successful mobile interface total traffic.
- Answered mobile interface total traffic.
- Successful mobile traffic.
- Answered mobile traffic.
- NE total successful traffic.
- NE total answered traffic.
- Answered call duration.

KPI name	Successful mobile interface total traffic.
Description	This KPI provides the total successful mobile related traffic (originating + terminating) handled by the MSC-S interfaces.
Unit	Erlangs

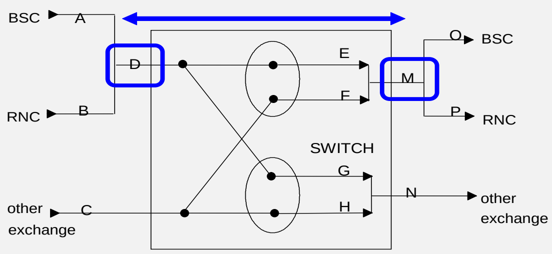
KPI formula	$\sum CC.SuccOrigiCallTraf + \sum CC.SuccTermiCallTraf =$ $(\sum CC.SuccOrigiCallTraf.Voice.G + \sum CC.SuccOrigiCallTraf.Voice.U +$ $\sum CC.SuccOrigiCallTraf.Data.G + \sum CC.SuccOrigiCallTraf.Data.U) +$ $(\sum CC.SuccTermiCallTraf.Voice.G + \sum CC.SuccTermiCallTraf.Voice.U +$ $\sum CC.SuccTermiCallTraf.Data.G + \sum CC.SuccTermiCallTraf.Data.U)$
3GPP used counters	➢ **CC.SuccOrigiCallTraf.Voice.G** Holding Traffic Successful Originating Call of Voice (GSM related). ➢ **CC.SuccOrigiCallTraf.Voice.U** Holding Traffic Successful Originating Call of Voice (UMTS related). ➢ **CC.SuccOrigiCallTraf.Data.G** Holding Traffic Successful Originating Call of Data (GSM related). ➢ **CC.SuccOrigiCallTraf.Data.U** Holding Traffic Successful Originating Call of Data (UMTS related). ➢ **CC.SuccTermiCallTraf.Voice.G** Holding Traffic Successful Terminating Call of Voice (GSM related). ➢ **CC.SuccTermiCallTraf.Voice.U** Holding Traffic Successful Terminating Call of Voice (UMTS related). ➢ **CC.SuccTermiCallTraf.Data.G** Holding Traffic Successful Terminating Call of Data (GSM related). ➢ **CC.SuccTermiCallTraf.Data.U** Holding Traffic Successful Terminating Call of Data (UMTS related). ➢ **CC.SuccOrigiCallTraf** Holding traffic successful originating call. It includes both the UMTS + GSM traffic and the Voice + Data calls. ➢ **CC.SuccTermiCallTraf** Holding traffic successful terminating call. It includes both the UMTS + GSM traffic and the Voice + Data calls.
Special Notes	This KPI considers the originating and terminating traffic in a single KPI formula (sum both). This KPI provides reliable values for the total interface usage traffic analysis. In terms of NE total usage, the output of this KPI shall be handle with care. When we have a mobile to mobile call inside the MSC-S NE under observation, there will be a double traffic count (the call is counted as SuccOrigi and again SuccTermi at the same time) although only one call was really made. This is the reason why this KPI was named as interface traffic analysis.  A GSM Mobile Originating call B WCDMA mobile originating call C Incoming call

	D	Mobile originating call
	E	Internal call
	F	Terminating incoming call
	G	Originating outgoing call
	H	Transit call
	M	Mobile terminating call
	N	Outgoing call
	O	GSM mobile terminating call
	P	WCDMA mobile terminating call

This KPI shall only run against the MSC-S NE object class.

KPI name	Answered mobile interface total traffic.
Description	This KPI provides the total answer mobile related traffic (originating + terminating) handled by the MSC-S interfaces.
Unit	Erlangs
KPI formula	$\sum CC.AnswOrigiCallTraf + \sum CC.AnswTermiCallTraf = (\sum CC.AnswOrigiCallTraf.Voice.G + \sum CC.AnswOrigiCallTraf.Voice.U + \sum CC.AnswOrigiCallTraf.Data.G + \sum CC.AnswOrigiCallTraf.Data.U) + (\sum CC.AnswTermiCallTraf.Voice.G + \sum CC.AnswTermiCallTraf.Voice.U + \sum CC.AnswTermiCallTraf.Data.G + \sum CC.AnswTermiCallTraf.Data.U)$
3GPP used counters	➢ **CC.AnswOrigiCallTraf.Voice.G** Holding answered voice traffic originating call (GSM related). ➢ **CC.AnswOrigiCallTraf.Voice.U** Holding answered voice traffic originating call (UMTS related). ➢ **CC.AnswOrigiCallTraf.Data.G** Holding answered data traffic originating call (GSM related). ➢ **CC.AnswOrigiCallTraf.Data.U** Holding answered data traffic originating call (UMTS related). ➢ **CC.AnswTermiCallTraf.Voice.G** Holding answered voice traffic terminating call (GSM related). ➢ **CC.AnswTermiCallTraf.Voice.U** Holding answered voice traffic terminating call (UMTS related). ➢ **CC.AnswTermiCallTraf.Data.G** Holding answered data traffic terminating call (GSM related). ➢ **CC.AnswTermiCallTraf.Data.U** Holding answered data traffic terminating call (UMTS related). ➢ **CC.AnswOrigiCallTraf** Holding traffic answered originating call. It includes both the UMTS + GSM traffic and the Voice + Data calls. ➢ **CC.AnswTermiCallTraf** Holding traffic answered terminating call. It includes both the UMTS + GSM traffic and the Voice + Data calls.
Special Notes	This KPI considers the originating and terminating traffic in a single KPI formula (sum both). This KPI provides reliable values for the total interface answered traffic analysis. In terms of total NE usage, the output of this KPI

shall be handle with care… When we have a mobile to mobile call inside the MSC-S NE under observation, there will be a double answered traffic count (the call is counted as AnswOrigiCallTraf and again AnswTermiCallTraff at the same time) although only one call was really made. This is the reason why this KPI was named as interface traffic analysis.



A	GSM Mobile Originating call
B	WCDMA mobile originating call
C	Incoming call
D	Mobile originating call
E	Internal call
F	Terminating incoming call
G	Originating outgoing call
H	Transit call
M	Mobile terminating call
N	Outgoing call
O	GSM mobile terminating call
P	WCDMA mobile terminating call

This KPI shall only run against the MSC-S NE object class.

KPI name

Successful mobile traffic.

Description

This KPI provides the MSC-S NE successful mobile traffic.

Unit

Erlangs

KPI formula

$$\sum CC.SuccIncCallTraf - \sum CC.SuccTransCallTraf + \sum CC.SuccOrigiCallTraf =$$
$$(\sum CC.SuccIncCallTraf.Voice + \sum CC.SuccIncCallTraf.Data) -$$
$$(\sum CC.SuccTransCallTraf.Voice + \sum SuccTransCallTraf.Data) +$$
$$(\sum CC.SuccOrigiCallTraf.Voice.G + \sum CC.SuccOrigiCallTraf.Voice.U +$$
$$\sum CC.SuccOrigiCallTraf.Data.G + \sum CC.SuccOrigiCallTraf.Data.U)$$

3GPP used counters

- **CC.SuccIncCallTraf.Voice**
  Successful incoming voice call traffic.
- **CC.SuccIncCallTraf.Data**
  Successful incoming data call traffic.
- **CC.SuccTransCallTraf.Voice**
  Holding Traffic of Successful Transferred Call of Voice.
- **CC.SuccTransCallTraf.Data**

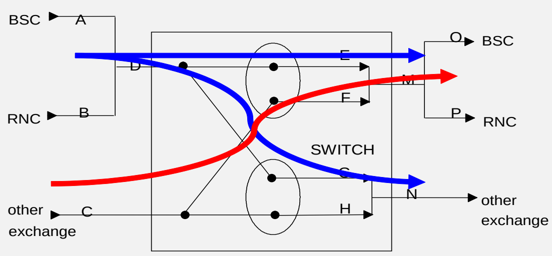
Holding Traffic of Successful Transferred Call of Data.

- **CC.SuccOrigiCallTraf.Voice.G**
  Holding Traffic Successful Originating Call of Voice (GSM related).
- **CC.SuccOrigiCallTraf.Voice.U**
  Holding Traffic Successful Originating Call of Voice (UMTS related).
- **CC.SuccOrigiCallTraf.Data.G**
  Holding Traffic Successful Originating Call of Data (GSM related).
- **CC.SuccOrigiCallTraf.Data.U**
  Holding Traffic Successful Originating Call of Data (UMTS related).
- **CC.SuccIncCallTraf**
  Successful incoming call traffic (Voice + Data).
- **CC.SuccTransCallTraf**
  Holding Traffic Successful Transferred Call (Voice + Data).
- **CC.SuccOrigiCallTraf**
  Holding traffic successful originating call.
  It includes both the UMTS + GSM traffic and the Voice + Data calls.

Special Notes

Since we are here making a NE total traffic analysis, we need to avoid making overlapping traffic counting. Please see next how the double counting traffic was avoid and the final KPI formula achieved.

Please consider the next following traffic path. The blue and red lines depict the various possible paths that a sucessful mobile traffic call can have.



From this model we can depict that total mobile traffic = F + D

We do not have the F traffic counter but we have a way to get it…
C = F + H ⬄ F = C – H

Now, the total mobile traffic is = C – H + D

This means that the MSC-S total mobile traffic can be defined as:
(Incoming Call Traffic) – (Transit Call Traffic) + (Mobile Originating Call Traffic).

This KPI shall only run against the MSC-S NE object class.

KPI name	Answered mobile traffic.
Description	This KPI provides the MSC-S NE answered mobile traffic.
Unit	Erlangs

KPI formula

$$\sum CC.AnswIncCallTraf - \sum CC.AnswTransCallTraf + \sum CC.AnswOrigiCallTraf =$$
$$(\sum CC.AnswIncCallTraf.Voice + \sum CC.AnswIncCallTraf.Data) -$$
$$(\sum CC.AnswTransCallTraf.Voice + \sum AnswTransCallTraf.Data) +$$
$$(\sum CC.AnswOrigiCallTraf.Voice.G + \sum CC.AnswOrigiCallTraf.Voice.U +$$
$$\sum CC.AnswOrigiCallTraf.Data.G + \sum CC.AnswOrigiCallTraf.Data.U)$$

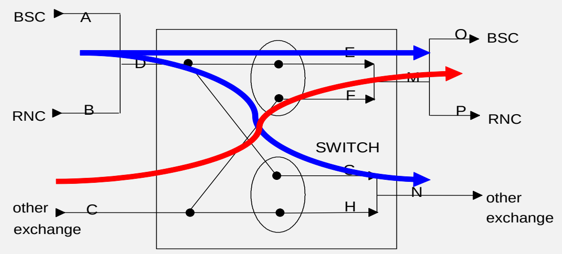
3GPP used counters

- **CC.AnswIncCallTraf.Voice**
  Answered incoming voice call traffic.
- **CC.AnswIncCallTraf.Data**
  Answered incoming data call traffic.
- **CC.AnswTransCallTraf.Voice**
  Voice answered transferred call traffic.
- **CC.AnswTransCallTraf.Data**
  Data answered transferred call traffic.
- **CC.AnswOrigiCallTraf.Voice.G**
  Traffic of answered voice originating call (GSM related).
- **CC.AnswOrigiCallTraf.Voice.U**
  Traffic of answered voice originating call (UMTS related).
- **CC.AnswOrigiCallTraf.Data.G**
  Traffic of answered data originating call (GSM related).
- **CC.AnswOrigiCallTraf.Data.U**
  Traffic of answered data originating call (UMTS related).
- **CC.AnswIncCallTraf**
  Aswered incoming call traffic (Voice + Data).
- **CC.AnswTransCallTraf**
  Answered transferred call traffic (Voice + Data).
- **CC.AnswOrigiCallTraf**
  Traffic of answered originating call.
  It includes both the UMTS + GSM traffic and the Voice + Data calls.

Special Notes

Since we are here making a NE total traffic analysis, we need to avoid making overlapping traffic counting. Please see next how the double counting traffic was avoid and the KPI formula obtained.

Please consider the next following traffic path. The blue and red lines depict the various possible paths that a answered mobile traffic call can have.

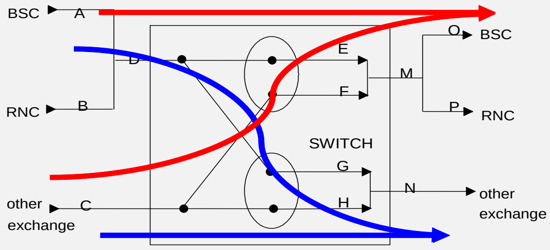


From this model we can depict that total mobile traffic = F + D

We do not have the F traffic counter but we have a way to get it…
C = F + H ⇔ F = C – H

	So we then have that the total mobile traffic = C – H + D This means that the MSC-S total mobile traffic can be defined as: *(Incoming Call Traffic) – (Transit Call Traffic) + (Mobile Originating Call Traffic).* This KPI shall only run against the MSC-S NE object class.

KPI name	NE total successful traffic.
Description	This KPI provides the total MSC-S NE successful traffic.
Unit	Erlangs
KPI formula	$\sum \mathrm{CC.SuccTermiCallTraf} + \sum \mathrm{CC.SuccOutCallTraff} = (\sum \mathrm{CC.SuccTermiCallTraf.Voice.G} + \sum \mathrm{CC.SuccTermiCallTraf.Data.G} + \sum \mathrm{CC.SuccTermiCallTraf.Voice.U} + \sum \mathrm{CC.SuccTermiCallTraf.Data.U}) + (\sum \mathrm{CC.SuccOutCallTraff.Voice} + \sum \mathrm{CC.SuccOutCallTraff.Data})$
3GPP used counters	➢ **CC.SuccTermiCallTraf.Voice.G** Successful mobile terminating call traffic (Voice => GSM). ➢ **CC.SuccTermiCallTraf.Data.G** Successful mobile terminating call traffic (Data => GSM). ➢ **CC.SuccTermiCallTraf.Voice.U** Successful mobile terminating call traffic (Voice => UMTS). ➢ **CC.SuccTermiCallTraf.Data.U** Successful mobile terminating call traffic (Data => UMTS). ➢ **CC.SuccOutCallTraff.Voice** Sucessful outgoing traffic (Voice). ➢ **CC.SuccOutCallTraff.Data** Sucessful outgoing traffic (Data). ➢ **CC.SuccTermiCallTraf** Successful mobile terminating call traffic (Voice + Data) => (UMTS + GSM). ➢ **CC.SuccOutCallTraf** Sucessful outgoing traffic (Voice + Data).
Special Notes	Since we are here making a NE total traffic analysis, we need to avoid making overlapping traffic counting. Let's consider the next following presented traffic path. The blue and red lines depict the various possible paths that a successful call can accomplish.



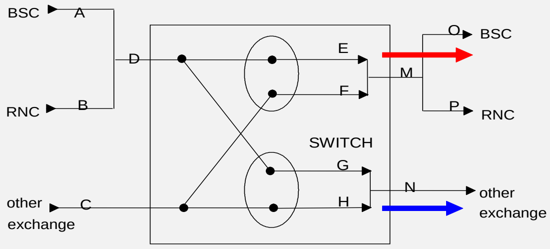
From this model we can see that:
(Mobile terminating call) = (Internal call) + (Terminating incoming call) ⬄ M = E + F

It can also be seen that:
(Outgoing call) = (Originating outgoing call) + (Transit call) ⬄ N = G + H

So the issue is how to reach the “Originating outgoing call” (G)?
N = G + H ⬄ G = N – H = Originating outgoing call

So the MSC-S NE total traffic can be defined as:
M + H + G ⬄ M + H + N – H = M + N

The MSC-S NE total traffic can be defined as =
(Mobile terminating call) + (Outgoing call)



This KPI shall only run against the MSC-S NE object class.

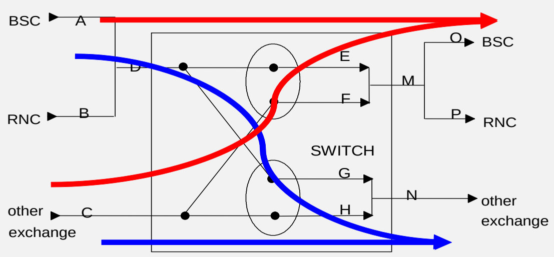
KPI name	NE total answered traffic.
Description	This KPI provides the total MSC-S NE answered traffic.
Unit	Erlangs
KPI formula	$\sum CC.AnswTermiCallTraf + \sum CC.AnswOutCallTraff = (\sum CC.AnswTermiCallTraf.Voice.G + \sum CC.AnswTermiCallTraf.Data.G + \sum CC.AnswTermiCallTraf.Voice.U + \sum CC.AnswTermiCallTraf.Data.U) + (\sum CC.AnswOutCallTraff.Voice + \sum CC.AnswOutCallTraff.Data)$
3GPP used	

counters	➢ **CC.AnswTermiCallTraf.Voice.G** Answered mobile terminating traffic (Voice => GSM). ➢ **CC.AnswTermiCallTraf.Data.G** Answered mobile terminating traffic (Data => GSM). ➢ **CC.AnswTermiCallTraf.Voice.U** Answered mobile terminating traffic (Voice => UMTS). ➢ **CC.AnswTermiCallTraf.Data.U** Answered mobile terminating traffic (Data => UMTS). ➢ **CC.AnswOutCallTraff.Voice** Answered outgoing voice traffic ➢ **CC.AnswOutCallTraff.Data** Answered outgoing data traffic ➢ **CC.AnswTermiCallTraf** Answered mobile terminating traffic (Voice + Data) => (UMTS + GSM). ➢ **CC.AnswOutCallTraf** Answered outgoing traffic (Voice + Data).
Special Notes	See below

Special Notes

Since we are here making a NE total traffic analysis, we need to avoid making overlapping traffic counting.

Let's consider the next following presented traffic path. The blue and red lines depict the various possible paths that a successful call can accomplish.



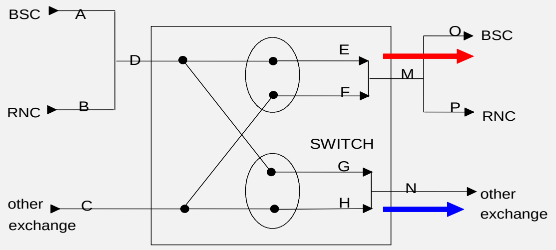
From this model we can see that:
(Mobile terminating call) = (Internal call) + (Terminating incoming call) ⬄ M = E + F

It can also be seen that:
(Outgoing call) = (Originating outgoing call) + (Transit call) ⬄ N = G + H

So the issue is now how to get the "Originating outgoing call" (G)?
N = G + H ⬄ G = N – H = Originating outgoing call

So the MSC-S NE total traffic can be defined as:
M + H + G ⬄ M + H + N – H = M + N

The MSC-S NE total traffic is then defined as =
(Mobile terminating call) + (Outgoing call)



This KPI shall only run against the MSC-S NE object class.

KPI name

Answered call duration.

Description

This KPI provides the mean duration of the calls handled by the MSC-S NE being observed.

Unit

Second

KPI formula

$$\left(\begin{array}{l}\sum CC.AnswTermiCallTraf.Voice.G + \sum CC.AnswTermiCallTraf.Data.G \\ + \\ \sum CC.AnswTermiCallTraf.Voice.U + \sum CC.AnswTermiCallTraf.Data.U \\ + \\ \sum CC.AnswOutCallTraff.Voice + \sum CC.AnswOutCallTraff.Data)\end{array}\right)$$

$$\times (Granularity\_Period) \times 60$$

$$=$$

$$\left(\sum CC.AnswTermiCallTraf + \sum CC.AnswOutCallTraff\right)$$

$$\times (Granularity\_Period) \times 60$$

3GPP used counters

- **CC.AnswTermiCallTraf.Voice.G**
  Answered mobile terminating traffic (Voice => GSM).
- **CC.AnswTermiCallTraf.Data.G**
  Answered mobile terminating traffic (Data => GSM).
- **CC.AnswTermiCallTraf.Voice.U**
  Answered mobile terminating traffic (Voice => UMTS).
- **CC.AnswTermiCallTraf.Data.U**
  Answered mobile terminating traffic (Data => UMTS).
- **CC.AnswOutCallTraff.Voice**
  Answered outgoing voice traffic
- **CC.AnswOutCallTraff.Data**
  Answered outgoing data traffic
- **CC.AnswTermiCallTraf**
  Answered mobile terminating traffic (Voice + Data) => (UMTS + GSM).
- **CC.AnswOutCallTraf**
  Answered outgoing traffic (Voice + Data).

Special Notes

This KPI takes advantage of the previously defined NE total answered traffic.

Granularity_period = Time interval associated with each answered call (answered traffic data). This granularity period is supposed to be provided in minutes time

	unit reference. This counter aggregation shall be defined as be defined as SUM (summarization) for time level and AVG (average) for object/network level. Logical behind the calculation of this KPI: the “Answered Terminating Call Traffic” and the “Answered Outgoing Call Traffic” provide their traffic values in Erlangs. What they provide is relationship between the time of resource occupation (answered calls in this case) and the monitoring period (granularity period). If we now multiply the traffic value by the granularity period, we get the intended occupation period that, for the given counters, is the answered call duration. This KPI shall only run against the MSC-S NE object class.

3.4.2.2. Call failure analysis – Subscriber reason

Taking advantage to the 3GPP TS 32.407 defined PM counters, the following KPIs have been proposed targeting the subscriber call failure analysis:

- Subscriber fail – Intra MSC.
- Subscriber fail – Inter MSC call – Terminating MSC-S.
- Subscriber fail – Inter MSC call – Originating MSC-S.

Intra-MSC call means that we are faced to a mobile to mobile call where both the calling and called parties belong to the same MSC-S (registered in the same MSC-S).

Inter-MSC terminating MSC call means that we are facing to a call where the destination mobile is attached (registered) in the MSC-S that is being observed and the originating party is connected to other MSC.

Inter-MSC originating MSC call means that we are facing to a call where the originating mobile is attached (registered) in the MSC-S that is being observed and the terminating party is attached to other MSC.

KPI name	Subscriber fail – Intra MSC.
Description	Number of Intra-MSC failed mobile calls that are due to subscribers related reasons.
Unit	Integer
KPI formula	$\sum CC.IntraMSCFailedbySubs.UserBusy +$ $\sum CC.IntraMSCFailedbySubs.OrigiRel +$ $\sum CC.IntraMSCFailedbySubs.AlertRel +$ $\sum CC.IntraMSCFailedbySubs.NoAnsw +$ $\sum CC.IntraMSCFailedbySubs.Rej$

3GPP used counters	➢ **CC.IntraMSCFailedbySubs.UserBusy** Number of failed calls caused by user-busy in the case of Intra-MSC call. ➢ **CC.IntraMSCFailedbySubs.OrigiRel** Number of failed calls caused by calling party releasing the call before alerting in the case of Intra-MSC call. ➢ **CC.IntraMSCFailedbySubs.AlertRel** Number of failed calls caused by calling party releasing the call after alerting in the case of Intra-MSC call. ➢ **CC.IntraMSCFailedbySubs.NoAnsw** Number of failed calls caused by no-answering in the case of Intra-MSC call. ➢ **CC.IntraMSCFailedbySubs.Rej** Number of failed calls caused by UDUB or user rejection in the case of Intra-MSC call.
Special Notes	Intra-MSC call means that we are faced to a mobile to mobile call where both the calling and called parties belong to the same MSC-S (registered in the same MSC-S). The failure conditions occurs when: - The calling party **releases the call before alerting**: on receipt of "DISCONNECT" from the calling party when network call states of called party is in N0.1,N6,N9 in the case of Intra-MSC call. - The calling party **releases the call after alerting**: on receipt of "DISCONNECT" from the calling party after transmission of "ALERTING" to the calling party in the case of Intra-MSC call. - **User Busy** case: called party is pre-defined "busy" in VLR when the call is setting up in the case of Intra-MSC call. - **No answer** from the user case: when T301 expires in the case of Intra-MSC call. - **User refused** case: when receipt of "DISCONNECT"(cause #17 "user busy" or cause #21 "call rejected") from called party after receipt of "ALERTING" from called party in the case of Intra-MSC call.

KPI name	Subscriber fail – Inter MSC call – Terminating MSC-S.
Description	Failed mobile calls caused by subscribers related reasons in the terminating MSC-S for Inter MSC call.
Unit	Integer

KPI formula	$\sum$ CC.TermiIn terMSCFail edbySubs.U serBusy + $\sum$ CC.TermiIn terMSCFail edbySubs.N oAnsw + $\sum$ CC.TermiIn terMSCFail edbySubs.R ef + $\sum$ CC.TermiIn terMSCFail edbySubs.T ermiRel + $\sum$ CC.TermiIn terMSCFail edbySubs.A lertRel
3GPP used counters	➢ **CC.TermiInterMSCFailedbySubs.UserBusy.** Number of failed calls caused by user-busy in the case of Inter-MSC call. ➢ **CC.TermiInterMSCFailedbySubs.NoAnsw.** Number of failed calls caused by no-answering in the case of Inter-MSC call. ➢ **CC.TermiInterMSCFailedbySubs.Ref.** Number of failed calls caused by UDUB or user rejection in the case of Inter-MSC call. ➢ **CC.TermiInterMSCFailedbySubs.TermiRel.** Number of failed calls caused by calling party releasing the call before alerting in the case of Inter-MSC call. ➢ **CC.TermiInterMSCFailedbySubs.AlertRel.** Number of failed calls caused by calling party releasing the call after alerting in the case of Inter-MSC call.
Special Notes	Inter-MSC terminating MSC call means that we are facing to a call where the destination mobile is attached (registered) in the MSC-S that is being observed and the originating party is connected to other MSC. The failure condition occurs when: - The calling party **releases call after alerting**: on transmission of "DISCONNECT"(cause #16 "normal call clearing") to called party after receipt of " ALERTING" from called party in the case of Inter-MSC call. - The calling party **releasing the call before alerting**: on receipt of "REL"(cause value=normal unspecified or normal call clearing) from originating MSC-S when Network call states of called party is in N0.1,N6,N9 in the case of Inter-MSC call. - **User busy** case: the called party is pre-defined "busy" in VLR when receipt of "IAM" in the case of Inter-MSC call. - **No answer** from the user condition: when T301 expires in the case of Inter-MSC call. - **User refused** case: when receipt of "DISCONNECT"(cause #17 "user busy" or cause #21 "call rejected") from called party after receipt of "ALERTING" from called party in the case of Inter-MSC call.

KPI name	Subscriber fail – Inter MSC call – Originating MSC-S.
Description	This KPI provides the number of failed mobile calls caused by subscribers in

	originating MSC-S for Inter-MSC call.
Unit	Integer
KPI formula	$\sum \text{CC.OrigiInterMSCFailedbySubs.OrigiRel}$ + $\sum \text{CC.OrigiInterMSCFailedbySubs.AlertRel}$
3GPP used counters	➢ **CC.OrigiInterMSCFailedbySubs.OrigiRel** Number of failed calls caused by calling party releasing the call before alerting in the case of Inter-MSC call. ➢ **CC.OrigiInterMSCFailedbySubs.AlertRel** Number of failed calls caused by calling party releasing the call after alerting in the case of Inter-MSC call.
Special Notes	Inter-MSC originating MSC call means that we are facing to a call where the originating mobile is attached (registered) in the MSC-S that is being observed and the terminating party is attached to other MSC. The failure condition occurs when: - Calling party **releases the call before alerting**: on receipt of "DISCONNECT" (cause #16 "normal call clearing") from calling party when "Network call states" of calling party is in N0.2~N0.6,N1,N3 in the case of Inter-MSC call. - Calling party **releases the call after alerting**: on receipt of "DISCONNECT" (cause #16" normal call clearing") from calling party after transmission of "ALERTING" to calling party in the case of Inter-MSC call. Since ISUP does not differentiate cause value clearly, the causes of user busy, no-answering and user refused are not included.

3.4.2.3. Unit Load analysis

This unit processing load is architecture system vendor dependent. Therefore, a general wide approach is here proposed. These KPIs can later be customized from vendor to vendor in order to accomplish their specific hardware and architecture specific details.

Please note that, in the distributed control architecture approach, the load analysis shall be made against specific purpose unit processors. The overall NE load is difficult to get. How to weight the various processor loads? Some processors are more critical than others to the overall processing NE load. The NE constraints are mainly focused on critical processors.

The proposed KPIs are:

- Maximum unit load (distributed architecture approach).
- Maximum unit load (centralized architecture approach).

KPI name	Maximum unit load (distributed architecture approach).
Description	This KPI provides the maximum unit load for a distributed control architecture.
Unit	%
KPI formula	$MAX\_over\_time(\text{EQPT.CPUUsageMean.}[\text{CPUid}])$
3GPP used counters	➢ **EQPT.CPUUsage.CPUid** Load of each processor for distributed controlled mode. Average CPU load during the measurement period. ➢ **CPUid** IDs of the active specific purpose processor units. *#CPUid* Number of CPUs considered in the analysis.
Special Notes	This KPI has in mind a distributed controlled processor units. This KPI provides the NE maximum special purpose processor unit load value (percentage value). This maximum value, retrieved from the mean over time samples, can alert the user for a malfunction or lack of resources. Typically a processor charge shall not exceed 70%. In this distributed approach, it makes sense to make specific purpose unit load analysis. Such units are thought to be specific purpose processors units like the VLR unit load (unit responsible for the Visitor Location Register), the statistical unit load (unit in charge of collecting performance and measurement data from the network [9]), the Signalling Unit Load (unit that handles the signalling functions towards the network elements in the NSS), the charging unit load (unit in charge of collecting and storing the charging data), etc. Please note that this unit list is hardware and NE architecture dependant, consequently, vendor dependant.

KPI name	Maximum unit load (centralized architecture approach).
Description	This KPIs provides the maximum over mean unit load samples for a centralized control architecture.

[9] Signalling Unit Load – Although NE vendor hardware and architecture dependant, possible CPUs to be considered maybe the ones in charge of the SIGTRAN related protocols processing, BSSAP and/or RANAP protocols processing, CCS7 related protocols processing (MTP/MAP/CAP).

Unit	%
KPI formula	$MAX\_over\_time(\text{EQPT.CPUUsageMean})$
3GPP used counters	➢ **EQPT.CPUUsageMean** Processor load for centralized mode architecture. Average CPU load during the measurement period.
Special Notes	This KPI has in mind a centralized controlled processor units. This KPI provides the NE's maximum centralized processor Unit load (percentage value). This maximum value, retrieved from the mean over time samples, can alert the user for a malfunction or lack of resources.

3.4.2.4. Subscribers analysis

This set of KPIs makes the subscribers analysis by interacting with the Visitor Location Register (VLR) Database and retrieving the subscriber information details (subscribers being served by the MSS ↔ VLR under analysis).

The VLR DB is tightly linked with the MSS and stores the subscriber IMSI information (International Mobile Subscriber Identity = subscriber mobile phone identification), the subscriber Authentication Data, the MSISDN (subscriber's phone number = number that uniquely identify the user inside the network = (Country Code) + (National Destination Code) + (Subscriber Number)), the type of services that the subscriber is allowed to access, the HLR address associated with the given subscriber, among other useful subscriber detailed information.

This set will take advantage of the KPIs that will be following proposed:

- Maximum number of VLR subscribers.
- Ratio of the VLR attach subscribers.
- Ratio of VLR national roamer subscribers.
- Ratio of VLR international roamer subscribers.
- Ratio of VLR international roamer subscribers.

KPI name	Maximum number of VLR subscribers.
Description	This KPI provides the maximum number of VLR subscribers over the intended period of time.
Unit	Integer
KPI formula	$MAX(\text{EQPT.NbrCurrentSubsInVlr})$
3GPP used counters	➢ **EQPT.NbrCurrentSubsInVlr** Number of subscribers registered in the VLR.

Special Notes	The 3GPP TS 32.407 specification has defined a gauge type counter with the current number of registered subscribers in VLR. It is important for the user to know the maximum number of subscriber that are using its network during a given period of time for capacity limit analysis. Here is proposed a KPI to provide the maximum value over the observed time period.

KPI name	Ratio of the VLR attach subscribers.
Description	This KPI provides the ratio of the VLR attach subscribers.
Unit	%
KPI formula	$100 \times \frac{\sum \text{EQPT.NbrAttachedSubsInVlr}}{\sum \text{EQPT.NbrCurrentSubsInVlr}}$
3GPP used counters	➢ **EQPT.NbrAttachedSubsInVlr** Number of subscribers attached in VLR ➢ **EQPT.NbrCurrentSubsInVlr** Number of subscribers registered in the VLR
Special Notes	

KPI name	Ratio of VLR national roamer subscribers.
Description	This KPI provides the number of national roamer subscribers (VLR retrieved data).
Unit	%
KPI formula	$100 \times \frac{\sum \text{EQPT.NbrNationalRoamingSubsInVlr}}{\sum \text{EQPT.NbrCurrentSubsInVlr}}$
3GPP used counters	➢ **EQPT.NbrNationalRoamingSubsInVlr** Number of registered national roaming subscriber. ➢ **EQPT.NbrCurrentSubsInVlr** Number of subscribers registered in the VLR.
Special Notes	

KPI name	Ratio of VLR international roamer subscribers.
Description	This KPI provides the number of international roamer subscribers (VLR retrieved data).
Unit	%

KPI formula	$100 \times \frac{\sum \text{EQPT.NbrInternationalRoamingSubsInVlr}}{\sum \text{EQPT.NbrCurrentSubsInVlr}}$
3GPP used counters	➢ **EQPT.NbrInternationalRoamingSubsInVlr** Number of registered international subscribers. ➢ **EQPT.NbrCurrentSubsInVlr** Number of subscribers registered in the VLR.
Special Notes	

3.4.2.5. Trunk Group analysis

The KPIs that will be following proposed are useful for the TDM (Time Division Multiplexing) transport analysis. Time Division Multiplexing is a type of multiplexing that combines data streams by assigning each stream a different time slot in a set.

The target audience of this KPI are the operations and maintenance teams and the network planning and optimization teams.

The KPIs proposed targeting this Trunk Group analysis are:

- Trunk Group Total Traffic.
- Seized traffic per Trunk Group.
- Trunk Group occupation.
- Maximum Number of Trunk Group overflow.

KPI name	Trunk Group Total Traffic.
Description	This KPI provides the total traffic of the trunk group.
Unit	Erlangs
KPI formula	$\sum_{CGR} (\text{CC.SuccOutSeizureTrafficCEG} + \text{CC.SuccIncSeizureTrafficTG})$
3GPP used counters	➢ **CC.SuccOutSeizureTrafficCEG** Provides outgoing traffic per trunk group. It is valid to uni-directional and bi-directional trunk group. ➢ **CC.SuccIncSeizureTrafficTG** Provides incoming traffic per trunk group. It is valid to uni-directional and bi-directional trunk group.
Special Notes	

KPI name	Trunk Call Answer Ratio..
Description	This KPI provides the call answer ration from the observed MSS perspective.

Unit	%
KPI formula	$\sum_{CGR}\left(\frac{\sum CC.AnswOutCallsCEG + \sum CC.AnswIncCallsCEG}{\sum CC.SeizedOutCEG + \sum CC.SuccIncSeizuresCEG}\right)$
3GPP used counters	➢ **CC.AnswOutCallsCEG** Number of answered outgoing calls to adjacent network per trunk. It's valid to uni-directional and bi-directional trunk group. ➢ **CC.AnswIncCallsCEG** Number of answered incoming calls from a given adjacent MSC-S per trunk group. ➢ **CC.SeizedOutCEG** Number of seized outgoing calls to adjacent network per trunk group. It's valid to uni-directional and bi-directional trunk group. ➢ **CC.SuccIncSeizuresCEG** Provides number of seized incoming calls per trunk group. Combined. Valid for uni + bi-directional trunk groups.

Special Notes	⇨ Logical formula:
	`(Incoming + Outgoing Answered Calls)`
	`-----------------------------------`
	`(Incoming + Outgoing Call Attempts)`

KPI name	Seized traffic per Trunk Group.
Description	This KPI provides the trunk group load by taking advantage of the seized traffic per trunk group analysis.
Unit	Erlangs
KPI formula	$\sum CC.SuccOutSeizureTrafficCEG + \sum CC.SuccIncSeizureTrafficTG$
3GPP used counters	➢ **CC.SuccOutSeizureTrafficCEG** Outgoing traffic per trunk group. It is valid to uni-directional and bi-directional trunk group. ➢ **CC.SuccIncSeizureTrafficTG** Incoming traffic per trunk group. It is valid to uni-directional and bi-directional trunk group.

Special Notes	The *CC.SuccOutSeizureTrafficCEG* and *CC.SuccIncSeizureTrafficTG* counters are Erlang unit based. They are a relationship between the used capacity (seizure traffic) and the available capacity.
	⇨ Logical formula:
	`For the given Trunk Group:`
	`(Seized Outgoing Call Traffic + Seized Incoming Call Traffic)`

KPI name	Trunk Group occupation.
Description	This KPI provides the selected trunk group occupation.
Unit	Second
KPI formula	$\left(\begin{array}{l}\sum \text{CC.SuccOutSeizureTrafficCEG} \\ + \\ \sum \text{CC.SuccIncSeizureTrafficTG}\end{array}\right) \times (Granularity\_Period \times 60)$
3GPP used counters	➢ **CC.SuccOutSeizureTrafficCEG** Outgoing traffic per trunk group. It is valid to uni-directional and bi-directional trunk group. ➢ **CC.SuccIncSeizureTrafficTG** Incoming traffic per trunk group. It is valid to uni-directional and bi-directional trunk group.
Special Notes	*CC.SuccOutSeizureTrafficCEG* => Erlang traffic *CC.SuccIncSeizureTrafficTG* => Erlang traffic *Granularity_period* => Time intervals for all successful UEs. This time frame is associated with the previous Seizure Erlangs values. It is considered to be provided in minutes. This counter aggregation shall be defined as be defined as SUM (summarization) for time level and AVG (average) for object/network level. The *CC.SuccOutSeizureTrafficCEG* and *CC.SuccIncSeizureTrafficTG* counters are Erlang unit based. They are a relationship between the resource occupied period and the measured period (granularity period).

KPI name	Maximum Number of Trunk Group overflow.
Description	This KPI provides the maximum number of trunk group overflows.
Unit	Integer
KPI formula	$MaxOverCGR(\text{CC.NbrCEGOverFlow})$
3GPP used counters	➢ **CC.NbrCEGOverFlow** Number of trunk overflow. It's valid to uni-directional and bi-directional trunk group.
Special Notes	

3.4.2.6. Signalling analysis

The next MSS KPIs targeting the signalling analysis will be based on the M3UA and MTP3 protocol inspection.

3.4.2.6.1. M3UA analysis

M3UA protocol is a quite important protocol for the MSS Rls.4 NE. In fact, M3UA works inside most of the MSS Rls.4 interfaces at network level layer (OSI model equivalent reference).

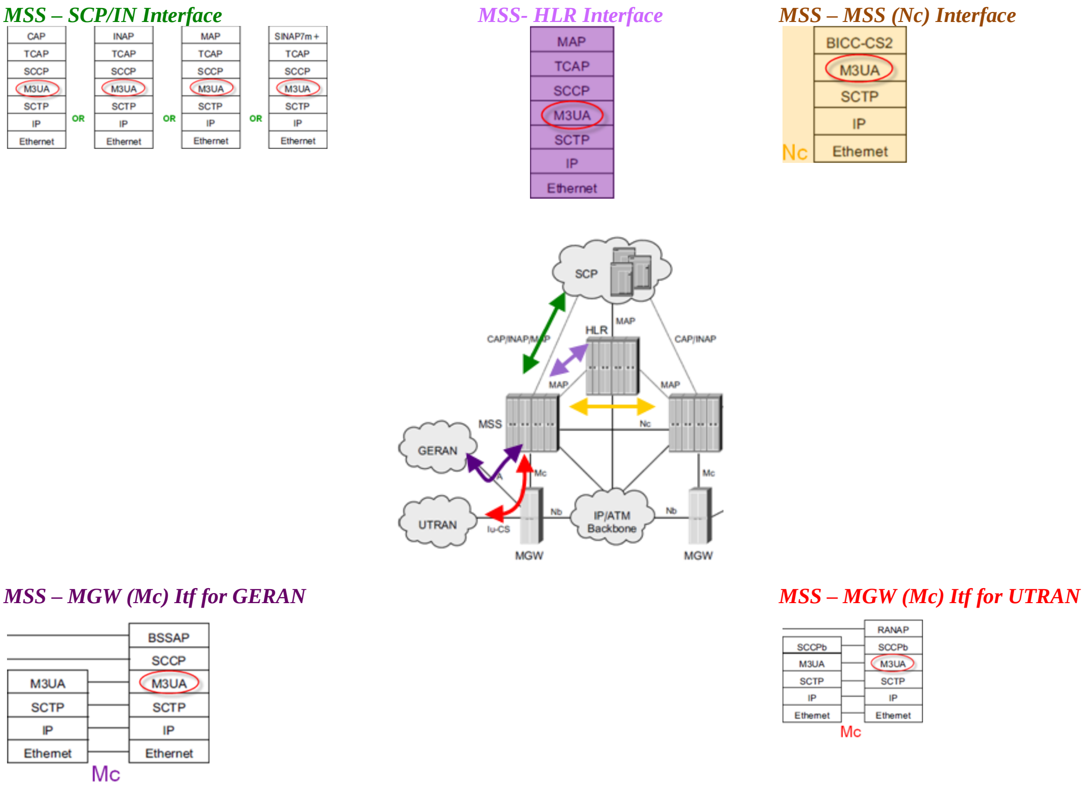


Figure 41 - M3UA protocol in MSS
Picture adapted from [2]

M3UA (MTP3 User Adaptation Layer) replaces MTP3 in an IP Network. It is a protocol used for support transport of any SS7 MTP3-User signalling over the IP network.

M3UA uses the services of SCTP protocol (Stream Control Transport Protocol) as the transport Layer. M3UA and SCTP protocol layers provide an illusion for user parts that they are sitting on top of the regular MTP3 service. M3UA link is based on SCTP association.

The KPIs that make the MSS M3UA analysis are:

- M3UA signalling exchanged messages.
- M3UA signalling link messages rate.
- Average M3UA signalling usage throughput.
- M3UA signalling link availability ratio.
- M3UA total failure duration.
- M3UA link failure duration ratio.

KPI name	M3UA signalling exchanged messages.
Description	This KPI provide s the total M3UA exchanged messages.
Unit	Integer
KPI formula	$\sum SIG.M3UALKPktSent + \sum SIG.M3UALKPktReceived$
3GPP used counters	➢ **SIG.M3UALKPktReceived** Number of messages received on each M3UA link. ➢ **SIG.M3UALKPktSent** Number of messages sent on each M3UA link.
Special Notes	This KPI is to run against M3UA link object level.

KPI name	M3UA signalling link messages rate.
Description	This KPI provides the M3UA signalling messages exchange rate. This KPI helpful in the Mc link load analysis.
Unit	Msg/sec
KPI formula	$\frac{\sum SIG.M3UALKPktSent + \sum SIG.M3UALKPktReceived}{(Granularity\_Period \times 60)}$
3GPP used counters	➢ **SIG.M3UALKPktReceived** Number of messages received on each M3UA link. ➢ **SIG.M3UALKPktSent** Number of messages sent on each M3UA link.
Special Notes	This KPI is useful for equipment dimensioning and hardware capacity analysis purposes. Granularity_Period is considered to be provided in minutes. This counter aggregation shall be defined as be defined as SUM (summarization) for time level and AVG (average) for object/network level.

KPI name	Average M3UA signalling usage throughput.
Description	This KPI provides the average M3UA usage throughput.
Unit	bits/s

KPI formula	$$AVG_{\sum M3UALink}\left(\frac{\left(8\times\sum SIG.M3UALKOctReceived\right)+\left(8\times\sum SIG.M3UALKOctSent\right)}{(Granularity\_Period\times 60)}\right)$$
3GPP used counters	➢ **SIG.M3UALKOctReceived** Number of octets received on each M3UA link. ➢ **SIG.M3UALKOctSent** Number of octets sent on each M3UA link.
Special Notes	Granularity_Period is considered to be provided in minutes. This counter aggregation shall be defined as SUM (summarization) for time level and AVG (average) for object/network level.

KPI name	M3UA signalling link availability ratio.
Description	This KPI provides the M3UA signalling link availability ratio.
Unit	%
KPI formula	$$100\times\left(1-\left(\frac{\sum_{M3UALink}\left(\sum SIG.NbrMTP3LKUnavailable\times\sum SIG.MTP3LKUnavailableDuration\right)}{\sum_{M3UALink}(Granularity\_Period\times 60)}\right)\right)$$
3GPP used counters	➢ **SIG.NbrMTP3LKUnavailable** Number of unavailable times of signal link. ➢ **SIG.MTP3LKUnavailableDuration** Duration of MTP3 link being unavailable.
Special Notes	Granularity_Period is considered to be provided in minutes.

KPI name	M3UA total failure duration.
Description	This KPI provides the total duration of the M3UA failures.
Unit	Seconds

KPI formula	$$\sum_{M3UALink}\begin{pmatrix}\sum \text{SIG.NbrM3UALKUnavailable} \\ \times \\ \sum \text{SIG.M3UALKUnavailableDurationMean}\end{pmatrix}$$
3GPP used counters	➢ **SIG.NbrM3UALKUnavailable** Number of unavailable times of M3UA link. ➢ **SIG.M3UALKUnavailableDurationMean** Unavailable duration of M3UA link.
Special Notes	The M3UA congestion happens when it cannot send messages to SCTP layer.

KPI name	M3UA link failure duration ratio.
Description	This KPI provides the M3UA link failure duration ratio.
Unit	%
KPI formula	$$100\times\frac{\begin{pmatrix}\sum \text{SIG.NbrM3UALKCongestion} \\ \times \\ \sum \text{SIG.M3UALKCongestionDurationMean}\end{pmatrix}}{(Granularity\_Period\times 60)}$$
3GPP used counters	➢ **SIG.NbrM3UALKCongestion** Number of M3UA link congestion times. ➢ **SIG.M3UALKCongestionDurationMean** Mean congestion duration of M3UA link. M3UA link is based on SCTP association, The M3UA congestion happens when it cannot send messages to SCTP layer
Special Notes	M3UA link is based on SCTP association, The M3UA congestion happens when it cannot send messages to SCTP layer. Granularity_Period is considered to be provided in minutes. This counter aggregation shall be defined as SUM (summarization) for time level and AVG (average) for object/network level.

3.4.2.6.2. MTP3 analysis

MTP3 (Message Transfer Part 3) protocol handles the network interface, information transfer, message handling and routing to the higher protocol levels. MTP Level 3 is equivalent in function to the OSI Network Layer.

At MSC/MSS level, the MTP3 layer is used in the MSS ↔ HLR interconnection when this connection is SS7 based.

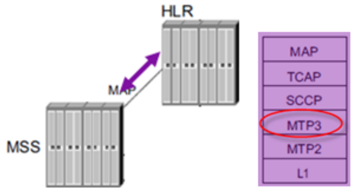


Figure 42 - MTP3 protocol usage (MSS - HLR)
Picture adapted from [2]

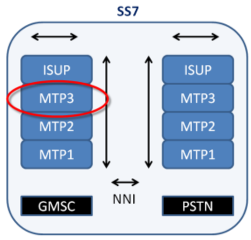


Figure 43 - MSS acting as GMCS (MSS - PSTN)

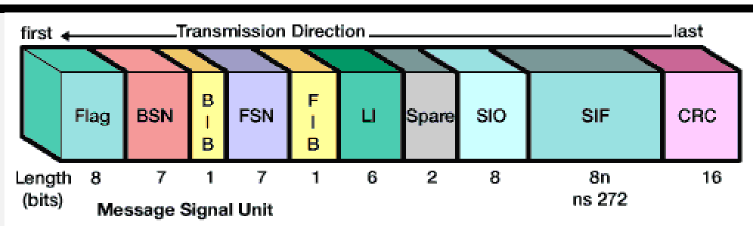
The MTP3 protocol can also be found in some MSS usages in the MSS ↔ PSTN interconnection when the MSS is acting as network gateway, and in some not "pure" Release 4 networks (example in integrated MSCs – these are special cases), when the MSS is directly connected to the BSC (GERAN) via its direct A over TDM interface (A TDM termination).

The KPIs that are used in the MTP3 analysis are:

- MTP3 MSU exchanged messages.
- MTP3 usage throughput – bit rate analysis.
- MTP3 usage throughput – message rate analysis.
- MTP3 unavailability.
- MTP3 signalling link total unavailable time.

Some of the listed KPIs are in charge of providing an overview regarding the capacity and others of making a health check analysis.

KPI name	MTP3 MSU exchanged messages.
Description	Total number of MSUs (Message Signalling Units) exchanged through the MTP3 signalling links.
Unit	Integer
KPI formula	$\sum \text{SIG.NbrMTP 3MSUSent} + \sum \text{SIG.NbrMTP 3MSUReceiv ed}$
3GPP used counters	➢ **SIG.NbrMTP3MSUSent** Number of message signal units sent on signalling link. ➢ **SIG.NbrMTP3MSUReceived** Number of message signal units received on MTP3 signalling link.
Special Notes	A Message Signal Units (MSUs) carry all call control, database query and response, network management, and network maintenance data in the Signalling Information Field (SIF). MSUs have a routing label which allows an originating signalling point to send information to a destination signalling point across the network.

	 The number of MSU messages reflect the real exchanged payload volume.

KPI name	MTP3 usage throughput – bit rate analysis.
Description	This KPI provides the average MTP3 usage throughput.
Unit	bits/s
KPI formula	$\frac{8\times\sum SIG.MTP3Oc\ tSent + 8\times\sum SIG.MTP3Oc\ tReceived}{(Granularity\_Period \times 60}$
3GPP used counters	➢ **SIG.MTP3OctSent** Number of SIF and SIO octets sent on signalling link. ➢ **SIG.MTP3OctReceived** Number of SIF and SIO octets received on signalling link.
Special Notes	Granularity_Period is considered to be provided in minutes. This counter aggregation shall be defined as SUM (summarization) for time level and AVG (average) for object/network level.

KPI name	MTP3 usage throughput – message rate analysis.
Description	This KPI provides the MTP3 signalling messages exchange rate. This KPI helpful in the A interface signalling link load analysis.
Unit	Msg/sec
KPI formula	$\frac{\left(\sum SIG.NbrMTP\ 3MSUSent\right)+\left(\sum SIG.NbrMTP\ 3MSUReceiv\ ed\right)}{(Granularity\_Period \times 60)}$
3GPP used counters	➢ **SIG.NbrMTP3MSUSent** Number of message signalling units sent on signalling link (MSUs/SL, ITU-T Recommendation Q.752). ➢ **SIG.NbrMTP3MSUReceived** Number of message signalling units received on signalling link (MSUs/SL, ITU-T Recommendation Q.752).
Special Notes	This KPI is useful for equipment dimensioning and hardware capacity analysis purposes as well as operations and maintenance support activities. Granularity_Period is considered to be provided in minutes. This counter

	aggregation shall be defined as be defined as SUM (summarization) for time level and AVG (average) for object/network level.

KPI name	MTP3 unavailability.
Description	This KPI provides the total MTP3 unavailability time. This KPI helpful in the A signalling link load analysis.
Unit	Second
KPI formula	$\sum \text{SIG.NbrMTP 3LKUnavail able} \times \sum \text{SIG.MTP3LK Unavailabl eDurationM ean}$
3GPP used counters	➢ **SIG.NbrMTP3LKUnavailable** Number of unavailable time of MTP3 signalling link ➢ **SIG.MTP3LKUnavailableDurationMean** Mean duration of unavailable of MTP3 signalling link.
Special Notes	This KPI is useful for equipment operations and maintenance support activities. This KPI is useful for equipment availability analysis purpose.

KPI name	MTP3 signalling link total unavailable time.
Description	This KPI provides the MTP3 Signalling Link Total Unavailable Time.
Unit	Second
KPI formula	$\sum_{AllSigLk} \left(\sum \text{SIG.NbrMTP 3LKUnavail able} \times \sum \text{SIG.MTP3LK Unavailabl eDurationM ean} \right)$
3GPP used counters	➢ **SIG.NbrMTP3LKUnavailable** Number of unavailable times of MTP3 signalling link. ➢ **SIG.MTP3LKUnavailableDurationMean** The mean duration of unavailable of MTP3 signalling link
Special Notes	This KPI is useful for equipment operations and maintenance support activities. This KPI is useful for equipment availability analysis purpose. The idea behind this KPI is to provide the user the total unavailable time.

3.4.2.6.3. Nc Link analysis

Nc is the interface that is responsible to connect the MSC Servers. It implements the inter-office call service and handover service. Nc interface typically uses the BICC protocol (Bearer Independent Call Control).

BICC signalling protocol (ITU-T Q.1901) is based on N-IUSP used to support ISDN narrow services. BICC uses signalling messages quite similar to ISUP.

KPI name	Total Nc link BICC exchanged messages.
Description	This KPI provides the total number of BICC exchanged messages over the Nc interface.
Unit	Integer
KPI formula	$\sum \text{EQPT.NbrNcMsgReceived.} + \sum \text{EQPT.NbrNcMsgSent.}$
3GPP used counters	➢ **EQPT.NbrNcMsgReceived** Number of BICC messages received on the Nc interface. ➢ **EQPT.NbrNcMsgSent** number of BICC messages sent on the Nc interface.
Special Notes	

KPI name	Total Nc link BICC message rate.
Description	This KPI provides the bit rate of the BICC exchanged messages over the Nc interface.
Unit	bits/s
KPI formula	$\frac{\left(8\times\sum \text{EQPT.NcOctReceived.}\right)+\left(8\times\sum \text{EQPT.NcOctSent}\right)}{(Granularity\_Period\times 60)}$
3GPP used counters	➢ **EQPT.NcOctReceived** Number of octets of BICC message received on Nc interface. ➢ **EQPT.NcOctSent** Number of octets of BICC message sent on Nc interface.
Special Notes	Granularity_Period is considered to be provided in minutes. This counter aggregation shall be defined as SUM (summarization) for time level and AVG (average) for object/network level.

3.4.2.6.4. H.248 analysis - Mc interface

Mc is the interface that interconnects the MSS and the MGW. This interface uses the H.248 protocol. This protocol is used for the MSS to control the MGW NE.

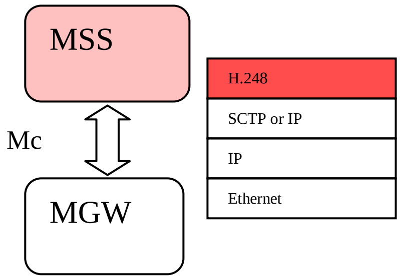


Figure 44 - Mc link H.248 (IP based)

This Mc interface, while shared by both MSS and MGW NEs, is able to be inspected by both. Here, it is proposed the Mc link analysis while using the MSS available metadata (MSS approach).

The following KPIs are here proposed targeting this objective:

- Total Mc link exchanged messages.
- Mc link H.248 messages throughput – message rate analysis.
- Average Mc link H.248 usage throughput – bit rate analysis.

KPI name	Total Mc link exchanged messages.
Description	This KPI provides the total number of exchanged messages over the Mc interface. The analysis is based on the H.248 message check.
Unit	Integer
KPI formula	$\sum \text{EQPT.NbrMcH248MsgReceived} + \sum \text{EQPT.NbrMcH248MsgSent}$
3GPP used counters	➢ **EQPT.NbrMcH248MsgReceived** Number of H.248 messages received on the Mc interface. ➢ **EQPT.NbrMcH248MsgSent** number of H.248 messages sent on the Mc interface.
Special Notes	

KPI name	Mc link H.248 messages throughput – message rate analysis.
Description	This KPI provides the Mc link H.248 messages throughput.
Unit	Msg/s
KPI formula	$\frac{\left(\sum \text{EQPT.NbrMcH248MsgReceived} + \sum \text{EQPT.NbrMcH248MsgSent}\right)}{(\text{Granularity\_Period} \times 60)}$
3GPP used counters	➢ **EQPT.NbrMcH248MsgReceived** Number of H.248 messages received on Mc interface. ➢ **EQPT.NbrH248McMsgSent** Number of H.248 message sent on Mc interface.

Special Notes	This KPI makes the Mc link analysis from MSS perspective. This KPI can be used to check the Mc link capacity. Granularity_Period is considered to be provided in minutes. This counter aggregation shall be defined as SUM (summarization) for time level and AVG (average) for object/network level.

KPI name	Average Mc link H.248 usage throughput – bit rate analysis.
Description	This KPI provides the Mc link usage throughput based on the H.248 analysis.
Unit	bits/s
KPI formula	$\frac{\left(8\times\sum EQPT.McH248OctReceived\right)+\left(8\times\sum EQPT.McH248OctSent\right)}{(Granurity\_Period\times 60)}$
3GPP used counters	➢ **EQPT.McH248OctReceived** Number of H.248 message octets received on Mc interface. ➢ **EQPT.McH248OctSent** Number of H.248 message octets sent on Mc interface.
Special Notes	*Granularity_Period* is considered to be provided in minutes. This counter aggregation shall be defined as SUM (summarization) for time level and AVG (average) for object/network level.

3.4.3. Mobility

Mobility KPI group, as defined by the ITU-T, shall include the KPIs in charge of visualizing the end-user movements. The next presented KPIs aim to accomplish this task.

The mobility related KPIs will be split in three groups:

- Paging analysis
- Location Update analysis
- Handover analysis

3.4.3.1. Paging analysis

Paging is the procedure used by the mobile network to transmit paging information to selected UEs (direct communication between the UE and the base station).

Paging is a method for the network to inform the UE that is willing to contact. Once the network sends a paging to the UE, the UE decodes the content of the paging message and initiates the appropriate procedures.

The paging is broadcasted to every to every base station located in the given location area.

The following KPIs are here proposed targeting this objective:

- Paging per LAC Success Ratio.
- Total Paging Success Ratio.

KPI name	Paging per LAC Success Ratio.
Description	This KPI provides the specific LAC (Location Area Code) total paging success ratio. It considers all the LACs covered by the NE.
Unit	%
KPI formula	$\frac{\sum_{Type} \text{CC.SuccPageReqs.}[type]}{\sum_{Type} \text{CC.AttPageReqs.}[type]}$ Type = GSM + UMTS
3GPP used counters	➢ **CC.SuccPageReqs** Successful number of paging requests per LAC.
Special Notes	

KPI name	Total Paging Success Ratio.
Description	This KPI provides the NE total paging success ratio. It considers all the LACs (Location Area Cods) covered by the NE.
Unit	%
KPI formula	$\frac{\sum_{LAC} \sum_{Type} \text{CC.SuccPageReqs.}[type]}{\sum_{LAC} \sum_{Type} \text{CC.AttPageReqs.}[type]}$ *Type* = GSM + UMTS
3GPP used counters	➢ **CC.SuccPageReqs** Successful number of paging requests per LAC.
Special Notes	

3.4.3.2. Location Update analysis

A location area is a set of base stations that are grouped together to optimise signalling.

To each location area, a unique number called a LAC (Location Area Code) is assigned. The LAC is broadcasted by each base station, known as BTS (Base Transceiver Station - GSM networks) or a Node-B (UMTS networks), at regular intervals.

A GSM or UMTS network is a radio network of individual cells, known as base stations [62]. Each base station covers a small geographical area which is part of a uniquely identified location area. By integrating the coverage of each of these base stations, a cellular network provides a radio coverage over a much wider area. A group of base stations is named a location area (voice related part).

The location update procedure allows a mobile device to inform the cellular network, whenever it moves from one location area to the next. Mobile nodes are responsible for detecting location area codes. When a mobile node finds that the location area code is different from its last update, it performs another update by sending to the network, a location update request, together with its previous location, and its Temporary Mobile Subscriber Identity (TMSI).

There are several reasons why a mobile node may provide updated location information to the network. Whenever a mobile node is switched on or off, the network may require it to perform an IMSI attach or IMSI detach location update procedure. Also, each mobile node is required to regularly report its location at a set time interval using a periodic location update procedure. Whenever a mobile node moves from one location area to the next while not on a call, a random location update is required. This is also required if a stationary mobile node that reselects coverage from a cell in a different location area, because of signal fade. Thus, a subscriber has reliable access to the network and may be reached with a call, while enjoying the freedom of mobility within the whole coverage area.

The following KPIs are proposed targeting the LAC analysis:

- Location Update per LAC.
- Total Location Updates.

KPI name	Location Update per LAC.
Description	This KPI provides the number of location updates per location area code.
Unit	Integer
KPI formula	$\frac{\sum_{Type}(\text{MM.SuccIntraVlrLU.}[type] + \text{MM.SuccInterVlrLU.}[type])}{\sum_{Type}(\text{MM AttIntraVlrLU.}[type] + \text{MM.AttInterVlrLU.}[type])}$ Type = GSM + UMTS
3GPP used counters	➢ **MM.SuccIntraVlrLU** Number of successful location updates to be performed by the MSC-S per location area.

	Location update type: Normal Intra-VLR location update. ➢ **MM.SuccInterVlrLU** Number of successful location updates to be performed by the MSC-S per location area. Location update type: Normal Inter-VLR location update ➢ **MM AttIntraVlrLU** Number of attempted location updates to be performed by the MSC-S per location area. Location update type: Normal Intra-VLR location update. ➢ **MM.AttInterVlrLU** Number of attempted location updates to be performed by the MSC-S per location area. Location update type: Normal Inter-VLR location update.
Special Notes	A separate UMTS or GSM analysis can be easily derived from this KPI proposal. It is just a question of using the proper access type: GSM or UMTS.

KPI name	Total Location Updates.
Description	This KPI provides the total number of location updates from all location area codes.
Unit	Integer
KPI formula	$\frac{\sum_{LAC}\sum_{Type}\left(\text{MM.SuccInt raVlrLU}.[type]+\text{MM.SuccInt erVlrLU}.[type]\right)}{\sum_{LAC}\sum_{Type}\left(\text{MM AttIntraVlrLU}.[type]+\text{MM.AttInte rVlrLU}.[type]\right)}$ Type = GSM + UMTS
3GPP used counters	➢ **MM.SuccIntraVlrLU** Number of successful location updates to be performed by the MSC-S per location area. Location update type: Normal Intra-VLR location update. ➢ **MM.SuccInterVlrLU** Number of successful location updates to be performed by the MSC-S per location area. Location update type: Normal Inter-VLR location update ➢ **MM AttIntraVlrLU** Number of attempted location updates to be performed by the MSC-S per location area. Location update type: Normal Intra-VLR location update. ➢ **MM.AttInterVlrLU** Number of attempted location updates to be performed by the MSC-S per location area. Location update type: Normal Inter-VLR location update.
Special Notes	A separate UMTS or GSM analysis can be easily derived from this KPI proposal. It is just a question of using the proper access type: GSM or UMTS.

3.4.3.3. Handover analysis

In cellular telecommunications networks, handover is the process of transferring an ongoing call from one channel connected to the core network to another [63].

A handover can occur due to many reasons. For example when a mobile user is moving from one cell area to other cell area (avoid the call loss due to initial cell range limit exceed), when the cell where the mobile is attached has reached its capacity limit and the same area has overlap coverage (covered by more than one cell at the same time => the mobile node in this case is transferred to the new less charged cell in order to release some capacity from the initial one), etc.

The 3GPP TS 32.407 only specifies performance indicators for the inter MSC-S handovers so the analysis will be restricted to such type of handovers.

The following KPIs are here proposed targeting this objective:

- UMTS inter MSC-S Handovers.
- Subsequent handover back to MSCa success ratio.
- Subsequent handover back to MSCc success ratio.

KPI name	UMTS inter MSC-S Handovers.
Description	This KPI provides the total number of UMTS inter MSC-S handovers.
Unit	%
KPI formula	$$\frac{\left(\begin{array}{l}\sum \text{MM.SuccInc3GHo3GInterMsc} + \\ \sum \text{MM.SuccOut3GHo3GInterMsc} + \\ \sum \text{MM.SuccInc3GHo2GInterMsc} + \\ \sum \text{MM.SuccOut3GHo2GInterMsc}\end{array}\right)}{\left(\begin{array}{l}\sum \text{MM.AttInc3GHo3GInterMsc} + \\ \sum \text{MM.AttOut3GHo3GInterMsc} + \\ \sum \text{MM.AttInc3GHo2GInterMsc} + \\ \sum \text{MM.AttOut3GHo2GInterMsc}\end{array}\right)}$$
3GPP used counters	➢ **MM.SuccInc3GHo3GInterMsc** Number of attempted incoming Handovers into the observed UTRAN CELL from the related adjacent UTRAN CELLs NOT controlled by this MSC-S. ➢ **MM.SuccOut3GHo3GInterMsc** Number of successful outgoing Handovers into the observed UTRAN CELL from the related adjacent UTRAN CELLs NOT controlled by this MSC-S. ➢ **MM.SuccInc3GHo2GInterMsc** Number of successful incoming Handovers into the observed GSM CELL from

	the related adjacent UTRAN CELLs NOT controlled by this MSC-S. ➢ **MM.SuccOut3GHo2GInterMsc** Number of successful outgoing Handovers into the observed GSM CELL from the related adjacent UTRAN CELLs NOT controlled by this MSC-S. ➢ **MM.AttInc3GHo3GInterMsc** Number of attempted incoming Handovers into the observed UTRAN CELL from the related adjacent UTRAN CELLs NOT controlled by this MSC-S. ➢ **MM.AttOut3GHo3GInterMsc** Number of attempted outgoing Handovers into the observed UTRAN CELL from the related adjacent UTRAN CELLs NOT controlled by this MSC-S. ➢ **MM.AttInc3GHo2GInterMsc** Number of attempted incoming Handovers into the observed GSM CELL from the related adjacent UTRAN CELLs NOT controlled by this MSC-S ➢ **MM.AttOut3GHo2GInterMsc** Number of attempted outgoing Handovers into the observed GSM CELL from the related adjacent UTRAN CELLs NOT controlled by this MSC-S.

Special Notes	Logical formula:
	`( Successful incoming handovers inter MSC-S from UMTS to UMTS ) +`
	`( Successful outgoing handovers inter MSC-S from UMTS to UMTS ) +`
	`( Successful incoming handovers inter MSC-S from UMTS to GSM ) +`
	`( Successful outgoing handovers inter MSC-S from UMTS to GSM )`
	`-----------------------------------------------------------------`
	`( Attempted incoming handovers inter MSC-S from UMTS to UMTS ) +`
	`( Attempted outgoing handovers inter MSC-S from UMTS to UMTS ) +`
	`( Attempted incoming handovers inter MSC-S from UMTS to GSM ) +`
	`( Attempted outgoing handovers inter MSC-S from UMTS to GSM )`
	This KPI makes Handovers analysis for a UMTS network (from UMTS to UMTS and from UMTS to GSM networks).

KPI name	Subsequent handover back to MSCa success ratio.
Description	This KPI provides the Success Ratio of the inter-MSC handovers where the call is handed back to the anchor MSC (MSCa), . i.e. the first hand over takes place from MSCa to MSCb then the call is subsequently successfully handed back to MSCa.
Unit	%
KPI formula	$\frac{\sum \text{MM.AttSubsequentHosToMsca}}{\sum \text{MM.SuccSubsequentHosToMsca}}$
3GPP used counters	➢ **MM.AttSubsequentHosToMsca** Number of attempted subsequent inter-MSC Handovers, where the call is handed back to the anchor MSC (MSCa), i.e. the first handover takes place from MSCa to MSCb then the call is subsequently successfully handed back to MSCa. ➢ **MM.SuccSubsequentHosToMsca** Number of successful subsequent inter-MSC Handovers, where the call is handed back to the anchor MSC (MSCa), i.e. the first handover takes place from MSCa to MSCb then the call is subsequently successfully handed back to MSCa.

Special Notes	

KPI name	Subsequent handover back to MSCc success ratio.
Description	This KPI provides the Success Ratio of the inter-MSC handovers where the call is handed back to the anchor MSCc, i.e. the first handover takes place from MSCa to MSCb then subsequently an attempt is made to hand over to MSCc.
Unit	%
KPI formula	$\frac{\sum \text{MM.AttSubsequentHosToMscc}}{\sum \text{MM.SuccSubsequentHosToMscc}}$
3GPP used counters	➢ **MM.AttSubsequentHosToMscc** Number of attempted subsequent inter-MSC Handovers, where the call is handed over to MSCc, i.e. the first hand over takes place from MSCa to MSCb then subsequently an attempt is made to hand over to MSCc. ➢ **MM.SuccSubsequentHosToMscc** Number of successful subsequent inter-MSC Handovers, where the call is handed over to MSCc, i.e. the first hand over takes place from MSCa to MSCb then the call is subsequently successfully handed over to MSCc.
Special Notes	

3.5 . MGW - KPI proposal

This chapter presents the MGW related KPIs. These KPIs take advantage of the Performance Management measures defined in chapter 5 ("*Measurements related to the CS MGW*") of the 3GPP TS 43.407 source document.

The idea behind is that, by using the available 3GPP TS 43.407 PM data, it inspects some more significant MGW NE interfaces and protocols and it gets a detailed understanding about how the MGW Network Element is performing. This analysis will be made through the accessibility, integrity and usage MGW NE inspection.

The accessibility inspection is made by analyzing the capacity of the MGW NE to provide the requested User Plane services.

The integrity inspection is achieved through the delay and Jitter Nb and Iu interface check.

Finally, there is the usage inspection that is performed via the unit load check, Mc interface/M3UA protocol analysis, the MTP3 (A interface) and the MTP3b (Iu-CS interface) protocol check , the H.248 protocol analysis (Mc interface associated), route set check, specific Iu interface (may it be ATM or IP based) and Nb interface analysis (may it be ATM or IP based).

3.5.1. Accessibility

The accessibility is the ability of a service to be obtained within specified tolerances and other given conditions when requested by the user.

This MGW accessibility section is the ability of the MGW NE to provide the User Plane requested services. The service completion analysis is made based on the H.248 exchanged messages analysis that flows via the MSS vs MGW NEs connection**.**

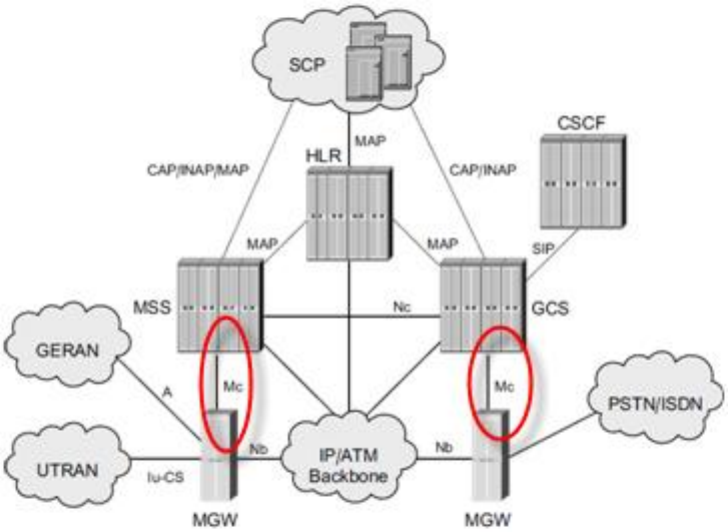


Figure 45 - Mc link

H.248
SCTP or TCP
IP
Ethernet

Figure 46 - Mc over IP interface protocol stack
Picture retrieved from [2]

The User Plane services that are here being dealt with are the ones presented in the 3GPP TS 32.407 Performance Management CN CS domain Release 10 document. The eventual seizure failure of these services may lead to call loss.

For more details about the listed services please refer to the following Technical Specifications:

- **CC, Continuity Check (CC)** - ITU-T Q.724 [64]
  => SS7 – TUP Signalling Procedures.
- **DTMF, DTMF Sending and Detection** - TS 23.014 [65]
  => 3GPP Support of Dual Tone Multi-Frequency (DTMF) signalling.
- **GTT, Global Text Telephony** - TS 22.226 [66]
  => 3GPP Global Text Telephony - Stage 1.
- **MFH, Media Frame Handler** - TS 25.415 [67], TS 29.415 [68]
  => 3GPP UTRAN Iu interface user plane protocols (Release 1999)
  => 3GPP Core Network Nb Interface User Plane Protocols (Release 4)
- **MPC, Multiparty Call** - ITU-T I.254.1 [69]
  => ITU-T Recommendation I.254.1. Integrated Services Digital Network (ISDN) Services Capabilities. Multiparty Supplementary Services: Conference Calling (CONF).
- **SC, Speech Coder** - TS 23.071 [70], TS 23.153 [71], TS 26.090 [72]
  => 3GPP AMR speech CODEC; General description (Release 9).
  => Out of band transcoder control; Stage 2 (Release 4).
  => Adaptive Multi-Rate (AMR) speech codec; Transcoding functions (Release 5).
- **TS, Tone Sender or Line Test** - ITU-T E.182 [73]
  => ITU-T E.182 - Operation, numbering, routing and mobile services – International operation – Tones in national signalling systems. Application of tones and recorded announcements in telephone services.

The proposed KPIs are:

- Continuity Check Success Ratio.
- DTMF sending and detection Success Ration.
- Global Text Telephony (GTT) Success Ratio.
- Media Frame Handler Success Ratio.
- Multiparty Call Success Ratio.
- Speech Coder Success Ratio.
- Tone Sender or Line Test Success Ratio.
- Failures ratio due lack of transcoder.

KPI name	Continuity Check Success Ratio.
Description	This KPI provides the continuity check success ratio.
Unit	%
KPI formula	$\frac{\sum EQPT.NbrSeizureSuccCC}{\sum EQPT.NbrSeizureAttCC}$
3GPP used counters	➢ **EQPT.NbrSeizureSuccCC** Number of successful attempts to seize CC services. ➢ **EQPT.NbrSeizureAttCC** Number of attempts to seize CC services.
Special Notes	The Continuity Check success condition is achieved when H.248 sends commands "*Add Reply*" or "*Modify Reply*" after the "*Add Request*" or "*Modify Request*" for a CC (Continuity Check) service has been successfully executed without any failure such as congestion.

KPI name	DTMF[10] sending and detection Success Ratio.
Description	This KPI provides the DTMF sending and detection success ratio.
Unit	%
KPI formula	$\frac{\sum EQPT.NbrSeizureSuccDTMF}{\sum EQPT.NbrSeizureAttDTMF}$
3GPP used counters	➢ **EQPT.NbrSeizureSuccDTMF** Number of successful attempts to seize DTMF services. ➢ **EQPT.NbrSeizureAttDTMF** Number of attempts to seize DTMF services.

[10] DTMF (Dual Tone Multi Frequency) is an in-band one out of four plus one out of four signalling system, primarily used from terminal instruments in telecommunication networks. In the 3GPP system the MSC must support DTMF in the mobile to land direction. The support of this facility in the land to mobile direction is for further study.

Special Notes	The success condition is achieved when H.248 sends commands "*Add Reply*" or "*Modify Reply*" after the "*Add Request*" or "*Modify Request*" for DTMF Sending and Detection service has been successfully executed without any failure such as congestion.

KPI name	Global Text Telephony (GTT[11]) Success Ratio.
Description	This KPI provides the Global Text Telephony (GTT) success ratio.
Unit	%
KPI formula	$\frac{\sum \text{EQPT.NbrSeizureSuccGTT}}{\sum \text{EQPT.NbrSeizureAttGTT}}$
3GPP used counters	➢ **EQPT.NbrSeizureSuccGTT** Number of successful attempts to seize GTT services. ➢ **EQPT.NbrSeizureAttGTT** Number of attempts to seize GTT services.
Special Notes	The success condition is achieved when H.248 sends commands "*Add Reply*" or "*Modify Reply*" after the "*Add Request*" or "*Modify Request*" for Global Text Telephony (GTT) service has been successfully executed without any failure such as congestion.

KPI name	Media Frame Handler[12] Success Ratio.
Description	This KPI provides the Media Frame handler success ratio.
Unit	%
KPI formula	$\frac{\sum \text{EQPT.NbrSeizureSuccMFH}}{\sum \text{EQPT.NbrSeizureAttMFH}}$
3GPP used counters	➢ **EQPT.NbrSeizureSuccMFH** Number of successful attempts to seize MFH services. ➢ **EQPT.NbrSeizureAttMFH** Number of attempts to seize MFH services.

[11] Global Text Telephony is a feature that adds the capability to use a text conversation component in a session. One important reason to offer the Global Text feature is to enable emergency service access to people who are depending on a written dialogue.

[12] This function is responsible for framing and de-framing the different parts of an Iu UP protocol frame. It takes the different parts of the Iu UP protocol frame and set the control part field to the correct values, including the handling of the frame number. It also ensures that the frame control part is semantically correct. It is responsible for interacting with the Transport layers, responsible for the CRC check of the Iu UP frame header. The Iu UP frame with header CRC check error is discarded.

Special Notes	The success condition is achieved when H.248 sends commands "*Add Reply*" or "*Modify Reply*" after the "*Add Request*" or "*Modify Request*" for Media Frame Handler (MFH) service has been successfully executed without any failure such as congestion.

KPI name	Multiparty Call[13] Success Ratio.
Description	This KPI provides the Multiparty Call success ratio.
Unit	%
KPI formula	$\frac{\sum \text{EQPT.NbrSeizureSuccMPC}}{\sum \text{EQPT.NbrSeizureAttMPC}}$
3GPP used counters	➢ **EQPT.NbrSeizureSuccMPC** Number of successful attempts to seize MPC services. ➢ **EQPT.NbrSeizureAttMPC** Number of attempts to seize MPC services.
Special Notes	The success condition is achieved when H.248 sends "*Add Reply*" or "*Modify Reply*" after the "*Add Request*" or "*Modify Request*" for Multiparty Call (MPC) service has been successfully executed without any failure such as congestion.

KPI name	Speech Coder[14] Success Ratio.
Description	This KPI provides the Speech Coder success ratio.
Unit	%
KPI formula	$\frac{\sum \text{EQPT.NbrSeizureSuccSC}}{\sum \text{EQPT.NbrSeizureAttSC}}$
3GPP used counters	➢ **EQPT.NbrSeizureSuccSC** Number of successful attempts to seize SC services. ➢ **EQPT.NbrSeizureAttSC** Number of attempts to seize SC services.
Special Notes	The success condition is achieved when H.248 sends "*Add Reply*" or "*Modify Reply*" after the "*Add Request*" or "*Modify Request*" for Speech Coder (SC) service has been successfully executed without any failure such as congestion.

[13] Conference Calling is an ISDN supplementary service which allows a user to communicate simultaneously with multiple parties, which may also communicate among themselves.

[14] This has to do with the success of codec changing (encoding and/or decoding a digital data stream or signal). Many types of codecs do exist: AMR (Adaptative Multirate – 12.2; 10.2; 7.95; 7.40; ... ; 4.75 kbit/s), EFR (12.2 kbit/s), Half Rate (5.6 kbit/s), Full Rate (13 kbit/s).

KPI name	Tone Sender[15] or Line Test Success Ratio.
Description	This KPI provides the Tone Sender or Line Test success ratio.
Unit	%
KPI formula	$\frac{\sum EQPT.NbrSeizureSuccTS}{\sum EQPT.NbrSeizureAttTS}$
3GPP used counters	➢ **EQPT.NbrSeizureSuccTS** Number of successful attempts to seize TS services. ➢ **EQPT.NbrSeizureAttTS** Number of attempts to seize TS services.
Special Notes	The success condition is achieved when H.248 sends "*Add Reply*" or "*Modify Reply*" after the "*Add Request*" or "*Modify Request*" for Tone Sender or Line Test (TS) service has been successfully executed without any failure such as congestion.

KPI name	Failures ratio due lack of transcoder.
Description	This KPI provides the lack of transcoder failure ratio.
Unit	%
KPI formula	$\frac{\sum EQPT.NbrCallFailureOfTCShortage}{\sum EQPT.AttTCSeizure}$
3GPP used counters	➢ **EQPT.NbrCallFailureOfTCShortage** Number of failed calls caused by shortage of Transcoder. ➢ **EQPT.AttTCSeizure** Number of attempted seized transcoder resource.
Special Notes	This KPI checks how many calls failed due to lack of available transcoders. This KPI is of important for NE load check and equipment dimensioning

3.5.2. Integrity

Integrity is defined as the degree (service quality) to which a service is provided without excessive impairments, once obtained.

[15] The possible tones to be used are defined in ITU-T E.182.

Based on the defined 3GPP TS 32.407 Performance Management CN CS domain counters, this MGW service quality analysis is made through the check of the delay and jitter measured on the Nb (MGW ↔ MGW) and Iu (RNC ↔ MGW) interfaces.

The integrity related KPIs will be split in two groups. One that will deal with the "Nb-IP interface analysis" and other with the "Iu-IP interface analysis".

3.5.2.1. Nb-IP interface analysis

The Nb interface connects two MGW Network Equipments and, therefore, it is pure User Part related. The KPIs here proposed are RTP protocol analysis oriented, they are related with IP based Nb interface.

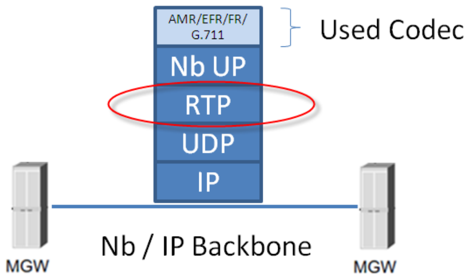


Figure 47 – Nb – IP Intf

It is not possible to propose similar KPIs for Iu-ATM based connections since 3GPP TS 32.407 did not defined the PM measures necessary for such analysis.

The KPIs that are proposed to make the Nb-IP interface analysis are:

- Nb-IP Interface Maximum Delay.
- Nb-IP Interface Maximum Delay Jitter.

KPI name	Nb-IP Interface Maximum Delay.
Description	This KPI provides a MGW bearer transport service quality indicator. It gives the maximum delay on Nb (IP based) interface.
Unit	ms
KPI formula	$MAX_{OverMGWRTPStreams}(BRT.NbRTPDelayMax)$
3GPP used counters	➢ **BRT.NbRTPDelayMax** Maximum delay on Nb interface. This measurement is obtained by Calculating RTP streams in all direction based on RTCP on Nb interface over a granularity period.
Special Notes	This counter value is obtained by calculating RTP streams in all direction based on RTCP on Nb interface over a granularity period (RTCP is an optional protocol).

KPI name	Nb-IP Interface Maximum Delay Jitter.
Description	This KPI provides a MGW bearer transport service quality indicator. It gives the value of the maximum delay Jitter on Nb (IP based) interface.
Unit	ms
KPI formula	$MAX_{OverMGWRTPStreams}(\text{BRT.NbDelayJitterMax})$
3GPP used counters	➢ **BRT.NbDelayJitterMax** Maximum delay jitter on Nb interface.
Special Notes	This counter value is obtained by calculating RTP streams jitter based on RTCP on Nb interface over a granularity period (RTCP is an optional protocol).

3.5.2.2. Iu-IP interface analysis

The Iu interface connects the MGW to the RNC Network Equipments (UTRAN 3G radio network part). The KPIs here proposed are RTP protocol analysis oriented. They are related with IP based Iu-CS interface.

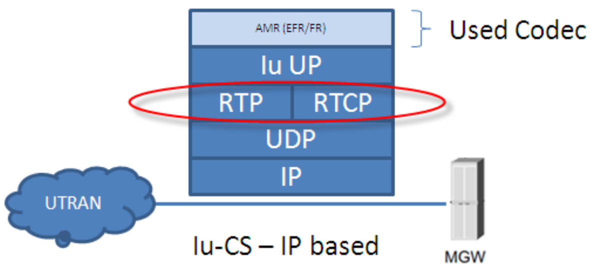


Figure 48 – Nb – IP Intf

It is not possible to propose similar KPIs for Iu-ATM based connections since 3GPP TS 32.407 did not defined the PM measures necessary for such analysis.

The KPIs that are proposed to make the Iu interface analysis are:

- Iu-IP interface maximum delay.
- Iu-IP interface maximum delay jitter.

KPI name	Iu-IP interface maximum delay.
Description	This KPI provides a MGW bearer transport service quality indicator. It gives the maximum delay on Iu (IP based) interface.
Unit	ms
KPI formula	$MAX_{OverMGWRTPStreams}(\text{BRT.IuRTPDelayMax.})$

3GPP used counters	➢ **BRT.IuRTPDelayMax** Maximum delay on Iu interface.
Special Notes	The used PI is obtained by calculating RTP streams in all direction based on RTCP on Iu interface over a granularity period (RTCP is an optional protocol).

KPI name	Iu-IP interface maximum delay jitter.
Description	This KPI provides a MGW bearer transport service quality indicator. It gives the value of the maximum delay Jitter on Iu (IP based) interface.
Unit	ms
KPI formula	$MAX_{OverMGWRTPStreams}(\text{BRT. IuDelayJitterMax})$
3GPP used counters	➢ **BRT. IuDelayJitterMax** Maximum delay jitter on Iu interface.
Special Notes	This counter value is obtained by calculating RTP streams jitter based on RTCP on Iu interface over a granularity period (RTCP is an optional protocol).

3.5.3. Utilization

The MGW utilization group includes all the KPIs in change of measuring the usage of MGW NE and network resources. Throughout this section, many KPIs will be proposed aiming at this objective.

First, it will be presented the ones in charge of measuring the computing processor load.

Then, the KPIs that are supposed to evaluate the MGW Control Plane level are offered. These KPIs will be based on the M3UA (Mc interface) and the MTP3/MTP3B protocols (A/Iu-CS interfaces) analysis. The route set analysis is here also made. The KPIs targeting the Mc link analysis by using the H.248 inspection are next proposed.

Finally, it is presented the KPIs in charge of making the MGW User Plane check (analysis available for both ATM or IP based networks). The Nb interface analysis is also made here with both ATM or IP based.

3.5.3.1. Unit load analysis

This unit processing load is architecture system vendor dependent, therefore, a general wide approach is here proposed. These KPIs can be customized from vendor to vendor in order to accomplish their specific hardware and architecture specific details.

Please note that in the distributed control architecture approach, the load analysis shall be made against specific purpose unit processors. The overall NE load is difficult to get (how to weight the various processor loads? Some processors are more critical than others to the overall processing NE load) and somewhat useless, since the NE constraints are mainly focused on critical processors.

The KPIs defined for MGW NE are basically the same as the ones defined for the MSS NE. The ones defined for the MGW NE will, however, run against a different object structure (MGW processor architecture is expected to be different from the MSS). These similarities are due to the fact that the 3GPP TS 32.407 has equally defined the CPU Load counters for both MSS and MGW NEs still, they deal with different entities and object structures.

The proposed KPIs are:

- Maximum unit load (distributed architecture approach).
- Maximum unit load (centralized architecture approach).

KPI name	Maximum unit load (distributed architecture approach).
Description	This KPI provides the maximum unit load for a distributed control architecture.
Unit	%
KPI formula	$MAX\_over\_time(\text{EQPT.CPUUsageMean.}[\text{CPUid}])$
3GPP used counters	➢ **EQPT.CPUUsage.CPUid** Load of each processor for distributed controlled mode. Average CPU load during the measurement period. ➢ **CPUid** IDs of the active specific purpose processor units. *#CPUid* Number of CPUs considered in the analysis.
Special Notes	This KPI has in mind a distributed controlled processor units. This KPI provides the NE maximum special purpose processor unit load (percentage value). This maximum value, retrieved from the mean over time samples, can alert the user for a malfunction or lack of resources. Typically a processor charge shall not exceed 70%. In this distributed approach, it makes sense to make specific purpose unit load analysis. Such units can be specific purpose processors units like the ones dedicated to OMU interface control (Operation and Maintenance Unit), VANU control (Voice Announcement Unit), ISU processing (Interface Signalling Units – terminates H.248 and Sigtran links), CACU control (Control and Administrative Computer Unit - CACU controls the ATM switching fabric unit and takes care of transmission resources), ATM multiplexer control, etc.

KPI name	Maximum unit load (centralized architecture approach).
Description	This KPI provides the maximum over mean unit load samples for a centralized control architecture.
Unit	%
KPI formula	$MAX\_over\_time(\text{EQPT.CPUUsageMean})$
3GPP used counters	➢ **EQPT.CPUUsageMean** Processor load for centralized mode architecture. Average CPU load during the measurement period.
Special Notes	This KPI has in mind a centralized controlled processor units. This KPI provides the NE's maximum centralized processor Unit load (percentage value). This maximum value retrieved from the mean over time samples can alert the user for a malfunction or lack of resources.

3.5.3.2. M3UA analysis – Mc interface

M3UA (MTP3-user adaptation Layer) is a major important protocol used in the MGW Mc link signalling functions. It is useful in both 3G and 2G access types.

The M3UA protocol provides a seamless operation of the MTP3-User peers in the SS7 and IP domains. It is a protocol for supporting transport of any SS7 MTP3-User signalling (e.g., ISUP, SCCP and TUP messages) over the IP Network.

M3UA replaces MTP3 in an IP Network. It is a flexible protocol that has led to M3UA standard being adopted by the 3GPP for carrying SS7 in IP Networks. M3UA uses the services of SCTP (Stream Control Transport Protocol) as the transport Layer and provides services for BICC protocol.

- ➢ M3UA protocol usage inside a UMTS network: BSC – (MGW) – MSS

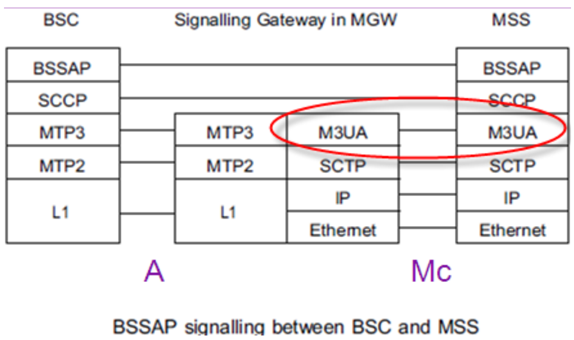


Figure 49 - M3UA protocol usage (GERAN)
Picture adapted from [2]

➢ M3UA protocol usage inside a GERAN network: RNC – (MGW) – MSS

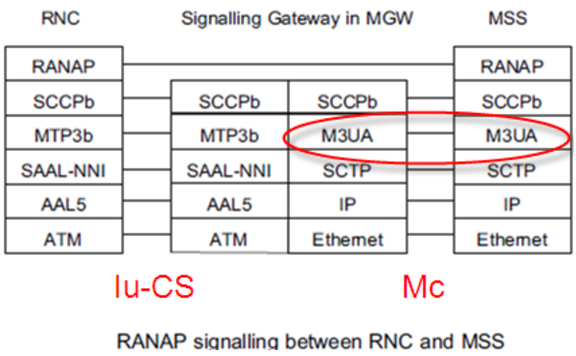


Figure 50 - M3UA protocol usage (UTRAN)
Picture adapted from [2]

It is of a major importance the analysis of this M3UA protocol. The next KPIs were proposed:

- M3UA signalling exchanged messages.
- M3UA signalling link messages rate.
- M3UA average signalling usage throughput.
- M3UA signalling link availability ratio.
- M3UA total failure duration.
- M3UA link failure duration ratio.

KPI name	M3UA signalling exchanged messages.
Description	This KPI provide s the total M3UA exchanged messages.
Unit	Integer
KPI formula	$\sum \text{SIG.M3UALK PktSent} + \sum \text{SIG.M3UALK PktReceive d}$
3GPP used counters	➢ **SIG.M3UALKPktReceived** Number of messages received on each M3UA link. ➢ **SIG.M3UALKPktSent** Number of messages sent on each M3UA link.
Special Notes	This KPI is to run against M3UA link object level.

KPI name	M3UA signalling link messages rate.
Description	This KPI provides the M3UA signalling messages exchange rate. This KPI helpful in the Mc link load analysis.
Unit	Msg/sec
KPI formula	$\frac{\sum \text{SIG.M3UALK PktSent} + \sum \text{SIG.M3UALK PktReceive d}}{(Granularity\_Period \times 60)}$

3GPP used counters	➢ **SIG.M3UALKPktReceived** Number of messages received on each M3UA link. ➢ **SIG.M3UALKPktSent** Number of messages sent on each M3UA link.
Special Notes	This KPI is useful for equipment dimensioning and hardware capacity analysis purposes. Granularity_Period is considered to be provided in minutes. This counter aggregation shall be defined as be defined as SUM (summarization) for time level and AVG (average) for object/network level.

KPI name	M3UA average signalling usage throughput.
Description	This KPI provides the average M3UA usage throughput.
Unit	bits/s
KPI formula	$\frac{\sum_{M3UALink}\left(\frac{\left(8\times\sum \text{SIG.M3UALKOctReceived}\right) + \left(8\times\sum \text{SIG.M3UALKOctSent}\right)}{(Granularity\_Period\times 60)}\right)}{\sum DisctincM3UALink\_Instances}$
3GPP used counters	➢ **SIG.M3UALKOctReceived** Number of octets received on each M3UA link. ➢ **SIG.M3UALKOctSent** Number of octets sent on each M3UA link.
Special Notes	Granularity_Period is considered to be provided in minutes. This counter aggregation shall be defined as SUM (summarization) for time level and AVG (average) for object/network level.

KPI name	M3UA signalling link availability ratio.
Description	This KPI provides the M3UA signalling link availability ratio.
Unit	%

KPI formula	$$100\times\left(1-\left(\frac{\sum_{M3UALink}\left(\begin{array}{l}\sum \text{SIG.NbrMTP3LKUnavailable}\\ \times\\ \sum \text{SIG.MTP3LKUnavailableDuration}\end{array}\right)}{\sum_{M3UALink}(Granularity\_Period\times 60)}\right)\right)$$
3GPP used counters	➢ **SIG.NbrMTP3LKUnavailable** Number of unavailable times of signal link. ➢ **SIG.MTP3LKUnavailableDuration** Duration of MTP3 link being unavailable.
Special Notes	Granularity_Period is considered to be provided in minutes.

KPI name	M3UA total failure duration.
Description	This KPI provides the total duration of the M3UA failures.
Unit	Seconds
KPI formula	$$\sum_{M3UALink}\left(\begin{array}{l}\sum \text{SIG.NbrM3UALKUnavailable}\\ \times\\ \sum \text{SIG.M3UALKUnavailableDurationMean}\end{array}\right)$$
3GPP used counters	➢ **SIG.NbrM3UALKUnavailable** Number of unavailable times of M3UA link. ➢ **SIG.M3UALKUnavailableDurationMean** Unavailable duration of M3UA link.
Special Notes	The M3UA congestion happens when it cannot send messages to SCTP layer.

KPI name	M3UA link failure duration ratio.
Description	This KPI provides the M3UA link failure duration ratio.
Unit	%
KPI formula	$$100\times\frac{\left(\begin{array}{l}\sum \text{SIG.NbrM3UALKCongestion}\\ \times\\ \sum \text{SIG.M3UALKCongestionDurationMean}\end{array}\right)}{(Granularity\_Period\times 60)}$$
3GPP used counters	➢ **SIG.NbrM3UALKCongestion** Number of M3UA link congestion times.

	➢ **SIG.M3UALKCongestionDurationMean** Mean congestion duration of M3UA link. M3UA link is based on SCTP association, The M3UA congestion happens when it cannot send messages to SCTP layer
Special Notes	M3UA link is based on SCTP association, The M3UA congestion happens when it cannot send messages to SCTP layer. Granularity_Period is considered to be provided in minutes. This counter aggregation shall be defined as SUM (summarization) for time level and AVG (average) for object/network level.

3.5.3.3. MTP3/MTP3B analysis – A & Iu-CS interfaces

MTP3 (Message Transfer Part 3) protocol handles the network interface, information transfer, message handling and routing to the higher protocol levels. MTP Level 3 is equivalent in function to the OSI Network Layer.

MTP3B (Message Transfer Part 3b) routes SS7 information. It provides broadband signalling link functions. This protocol is responsible for carrying signalling messages and for managing the signalling network and signalling links. This protocol specification was designed for ATM features on the basis of the MTP3; in fact this protocol is similar to the MTP3.

- MTP3 protocol use inside a GERAN network: BSC – (MGW) – MSS

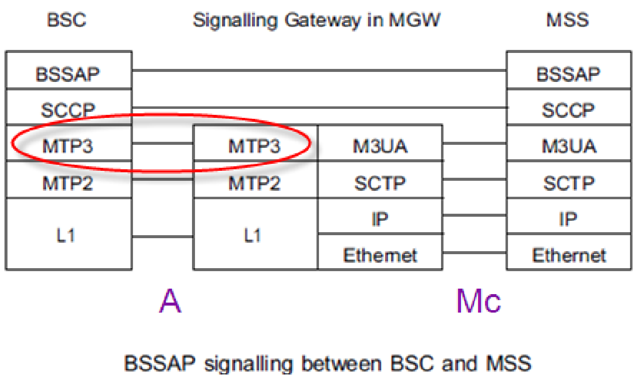


Figure 51 - MTP3 protocol usage (GERAN)
Picture adapted from [2]

- MTP3B protocol use inside a UMTS network: RNC – (MGW) – MSS

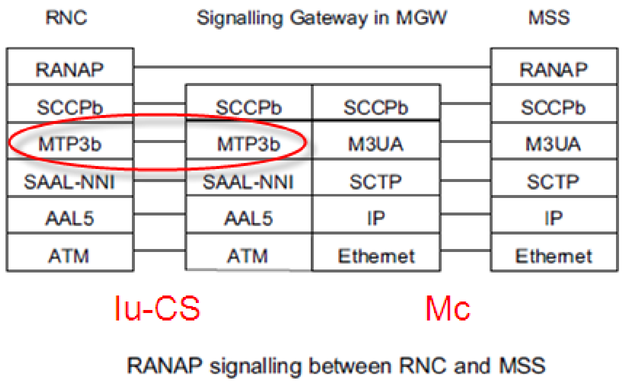


Figure 52 - MTP3b protocol usage (UTRAN)
Picture adapted from [2]

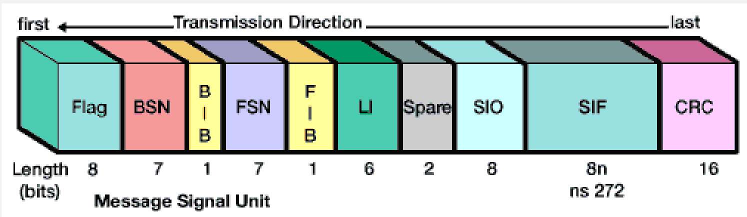
The MTP3/MTP3B are protocols used in the MGW signalling functions for the radio side connections (BSC/RNC). Due to this, it is important to make their analysis.

The KPIs that are used in the MTP3/MT3B analysis are:

- MTP3/MTP3B MSU exchanged messages.
- MTP3/MTP3B usage throughput – bit rate analysis.
- MTP3/MTP3B usage throughput – message rate analysis.
- MTP3/MTP3B unavailability.
- MTP3/MTP3B Signalling Link Total Unavailable Time.

Some are in charge of providing an overview regarding the capacity and others of making an health check analysis.

KPI name	MTP3/MTP3B MSU exchanged messages.
Description	Total number of MSUs (Message Signalling Units) exchanged through the MTP3/MTP3B signalling links.
Unit	Integer
KPI formula	For MTP3: $\sum SIG.NbrMTP3MSUSent + \sum SIG.NbrMTP3MSUReceived$ For MTP3B: $\sum SIG.NbrMTP3BMSUSent + \sum SIG.NbrMTP3BMSUReceived$
3GPP used counters	For MTP3: ➢ **SIG.NbrMTP3MSUSent** Number of message signal units sent on signalling link. ➢ **SIG.NbrMTP3MSUReceived** Number of message signal units received on MTP3 signalling link.

	For MTP3B: ➢ **SIG.NbrMTP3BMSUSent** Number of message signal units sent on signalling link. ➢ **SIG.NbrMTP3BMSUReceived** Number of message signal units received on MTP3B signalling link.
Special Notes	A Message Signal Units (MSUs) carry all call control, database query and response, network management, and network maintenance data in the Signalling Information Field (SIF). MSUs have a routing label which allows an originating signalling point to send information to a destination signalling point across the network.  The number of MSU messages reflect the real exchanged payload volume.

KPI name	MTP3/MTP3B usage throughput – bit rate analysis.
Description	This KPI provides the average MTP3/MTP3B usage throughput.
Unit	bits/s
KPI formula	For MTP3: $\frac{8 \times \sum \text{SIG.MTP3OctSent} + 8 \times \sum \text{SIG.MTP3OctReceived}}{(Granularity\_Period \times 60)}$ For MTP3B: $\frac{8 \times \sum \text{SIG.MTP3BOctSent} + 8 \times \sum \text{SIG.MTP3BOctReceived}}{(Granularity\_Period \times 60)}$
3GPP used counters	For MTP3: ➢ **SIG.MTP3OctSent** Number of SIF and SIO octets sent on signalling link. ➢ **SIG.MTP3OctReceived** Number of SIF and SIO octets received on signalling link. For MTP3B: ➢ **SIG.MTP3BOctSent**

	Number of SIF and SIO octets sent on signalling link. ➢ **SIG.MTP3BOctReceived** Number of SIF and SIO octets received on signalling link.
Special Notes	Granularity_Period is considered to be provided in minutes. This counter aggregation shall be defined as SUM (summarization) for time level and AVG (average) for object/network level.

KPI name	MTP3/MTP3B usage throughput – message rate analysis.
Description	This KPI provides the MTP3/MTP3B signalling messages exchange rate. This KPI helpful in the A (MTP3) and Iu-CS (MTP3B) interface signalling link load analysis.
Unit	Msg/sec
KPI formula	For MTP3: $\frac{\left(\sum \text{SIG.NbrMTP3MSUSent}\right)+\left(\sum \text{SIG.NbrMTP3MSUReceived}\right)}{(Granularity\_Period \times 60)}$ For MTP3B: $\frac{\left(\sum \text{SIG.NbrMTP3BMSUSent}\right)+\left(\sum \text{SIG.NbrMTP3BMSUReceived}\right)}{(Granularity\_Period \times 60)}$
3GPP used counters	For MTP3: ➢ **SIG.NbrMTP3MSUSent** Number of message signalling units sent on signalling link (MSUs/SL, ITU-T Recommendation Q.752). ➢ **SIG.NbrMTP3MSUReceived** Number of message signalling units received on signalling link (MSUs/SL, ITU-T Recommendation Q.752). For MTP3B: ➢ **SIG.NbrMTP3BMSUSent** Number of message signalling units sent on signalling link (MSUs/SL, ITU-T Recommendation Q.752). ➢ **SIG.NbrMTP3BMSUReceived** Number of message signalling units received on signalling link (MSUs/SL, ITU-T Recommendation Q.752).
Special Notes	This KPI is useful for equipment dimensioning and hardware capacity analysis purposes as well as operations and maintenance support activities. Granularity_Period is considered to be provided in minutes. This counter aggregation shall be defined as be defined as SUM (summarization) for time

	level and AVG (average) for object/network level.

KPI name	MTP3/MTP3B unavailability.
Description	This KPI provides the total MTP3/MTP3B unavailability time. This KPI helpful in the A (MTP3) and Iu-CS (MTP3B) signalling link load analysis.
Unit	Second
KPI formula	For MTP3: $\sum \text{SIG.NbrMTP3LKUnavailable} \times \sum \text{SIG.MTP3LKUnavailableDurationMean}$ For MTP3B: $\sum \text{SIG.NbrMTP3BLKUnavailable} \times \sum \text{SIG.MTP3BLKUnavailableDurationMean}$
3GPP used counters	For MTP3: ➢ **SIG.NbrMTP3LKUnavailable** Number of unavailable time of MTP3 signalling link ➢ **SIG.MTP3LKUnavailableDurationMean** Mean duration of unavailable of MTP3 signalling link. For MTP3B: ➢ **SIG.NbrMTP3BLKUnavailable** Number of unavailable time of MTP3B signalling link ➢ **SIG.MTP3BLKUnavailableDurationMean** Mean duration of unavailable of MTP3B signalling link.
Special Notes	This KPI is useful for equipment operations and maintenance support activities. This KPI is useful for equipment availability analysis purpose.

KPI name	MTP3/MTP3B Signalling Link Total Unavailable Time.
Description	This KPI provides the MTP3/MTP3B Signalling Link Total Unavailable Time.
Unit	Second
KPI formula	For MTP3: $\sum_{AllSigLk} \left(\sum \text{SIG.NbrMTP3LKUnavailable} \times \sum \text{SIG.MTP3LKUnavailableDurationMean} \right)$ For MTP3B:

	$\sum_{AllSigLk}\left(\sum \text{SIG.NbrMTP3LKUnavailable} \times \sum \text{SIG.MTP3LKUnavailableDurationMean}\right)$
3GPP used counters	For MTP3: ➢ **SIG.NbrMTP3LKUnavailable** Number of unavailable times of MTP3 signalling link. ➢ **SIG.MTP3LKUnavailableDurationMean** The mean duration of unavailable of MTP3 signalling link For MTP3B: ➢ **SIG.NbrMTP3BLKUnavailable** Number of unavailable times of MTP3B signalling link. ➢ **SIG.MTP3BLKUnavailableDurationMean** The mean duration of unavailable of MTP3B signalling link
Special Notes	This KPI is useful for equipment operations and maintenance support activities. This KPI is useful for equipment availability analysis purpose. The idea behind this KPI is to provide the user the total unavailable time.

3.5.3.4. H.248 analysis – Mc interface

The H.248 (ITU-T), sometimes also named as MeGaCo (IETF), is a bearer control protocol that is used in the MSC Server vs MGW communication.

Under control of MSC Server and by using this H.248 protocol, MGW NE terminates the user plane from different kind of interfaces, performs conversion between TDM, ATM and IP transmission technologies, and connects the user plane between access/core networks.

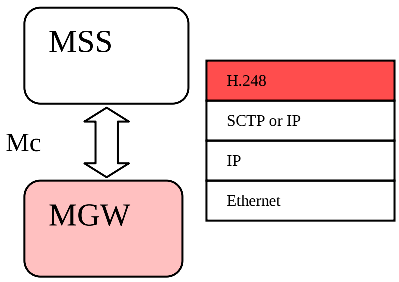


Figure 53 - Mc link H.248 (IP based)

As can be easily shown, it is of major importance to control this Mc link. The success of the communication procedure depends on it.

Having this target in mind, the next KPIs were proposed:

- Total Mc link exchanged messages.

- Mc link H.248 messages throughput – message rate analysis.
- Average Mc link H.248 usage throughput – bit rate analysis.

KPI name	Total Mc link exchanged messages.
Description	This KPI provides the total number of exchanged messages over the Mc interface. The analysis is based on the H.248 message check.
Unit	Integer
KPI formula	$\sum \text{EQPT.NbrMcH248MsgReceived} + \sum \text{EQPT.NbrMcH248MsgSent}$
3GPP used counters	➢ **EQPT.NbrMcMsgReceived** Number of H.248 messages received on Mc interface from MGW's prespective. ➢ **EQPT.NbrMcMsgSent** Number of H.248 message sent on Mc interface from MGW's perspective.
Special Notes	

KPI name	Mc link H.248 messages throughput – message rate analysis.
Description	This KPI provides the Mc link H.248 messages throughput.
Unit	Msg/s
KPI formula	$\frac{\left(\sum \text{EQPT.NbrMcMsgReceived} + \sum \text{EQPT.NbrMsgSent}\right)}{(Granularity\_Period \times 60)}$
3GPP used counters	➢ **EQPT.NbrMcMsgReceived** Number of H.248 messages received on Mc interface from MGW's prespective. ➢ **EQPT.NbrMcMsgSent** Number of H.248 message sent on Mc interface from MGW's perspective.
Special Notes	This KPI makes the Mc link analysis from MSS perspective. This KPI can be used to check the Mc link capacity. Granularity_Period is considered to be provided in minutes. This counter aggregation shall be defined as SUM (summarization) for time level and AVG (average) for object/network level.

KPI name	Average Mc link H.248 usage throughput – bit rate analysis.
Description	This KPI provides the Mc link usage throughput based on the H.248 analysis.
Unit	bits/s

KPI formula	$$\frac{\left(8\times\sum \text{EQPT.NbrMcH248OctReceived}\right)+\left(8\times\sum \text{EQPT.NbrMcH248OctSent}\right)}{(Granurity\_Period\times 60)}$$
3GPP used counters	➢ **EQPT.NbrMcH248OctReceived** Number of H.248 message octets received on Mc interface from MGW's perspective. ➢ **EQPT.NbrMcH248OctSent** Number of H.248 message octets sent on Mc interface from MGW's perspective.
Special Notes	*Granularity_Period* is considered to be provided in minutes. This counter aggregation shall be defined as SUM (summarization) for time level and AVG (average) for object/network level.

3.5.3.5. Route Set analysis

This Route Set KPIs take advantage of the counters defined in the ITU-T Rec. Q.752 [74] and makes the MTP Signalling Route Set analysis.

When no signalling route is available for traffic towards a particular destination, an indication is given from the Message Transfer Part (MTP) to the local user parts informing them that signalling messages destined to the particular signalling point cannot be transferred via the signalling network [75]. Each user then takes appropriate actions in order to stop the generation of signalling information destined for the inaccessible signalling point.

The next KPIs were proposed targeting the route set analysis:

- Route Set Unavailability Duration.
- Mean Route Set Unavailability.

KPI name	Route Set Unavailability Duration.
Description	This KPI provides the route set unavailability duration.
Unit	Second
KPI formula	$$\sum_{RouteSetDest} \text{SIG.DurationRoutesetUnavailable}$$
3GPP used counters	➢ **SIG.DurationRoutesetUnvailable** Duration of unavailability of a routeset to a given destination in seconds.
Special Notes	This KPI provides the total route set unavailability duration for a given MGW. It sums all the route set unavailable durations.

KPI name	Mean Route Set Unavailability.

Description	This KPI provides the mean route set unavailability.
Unit	Second
KPI formula	$$\frac{\sum_{RouteSetDest} SIG.DurationRoutesetUnavailable}{\sum_{RouteSetDest} SIG.NbrRoutesetUnvailable}$$
3GPP used counters	➢ **SIG.DurationRoutesetUnvailable** Duration of unavailability of a routeset to a given destination in seconds. ➢ **SIF.NbrRoutesetUnvailable** Number of occurrences of unavailability of a routeset to a given destination.
Special Notes	This KPI is based on previous presented one and provides a weight analysis of the route set unavailability.

3.5.3.6. Iu-CS interface analysis (ATM + IP based)

This section will present the KPIs that will be used to make the Iu-CS interface analysis (UTRAN network connection towards the Rls.4 CS CN => deals with the RNC vs MGW connection).

The 3GPP release 5 enables the use of Internet Protocol (IP) as the transport for user plane in the Iu-CS interface. The KPIs here proposed already test two possible types of Iu-CS interfaces: the ATM and the IP based ones.

In case of the Iu-CS ATM based interface, the KPI control is made by the Iu UP, and ATM AAL2 protocols inspection.

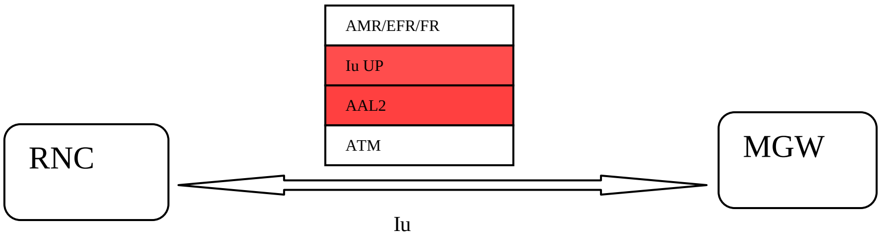


Figure 54 - Iu-CS ATM interface

In case of the Iu-CS IP based interface, the control is made by the RTP protocol analysis.

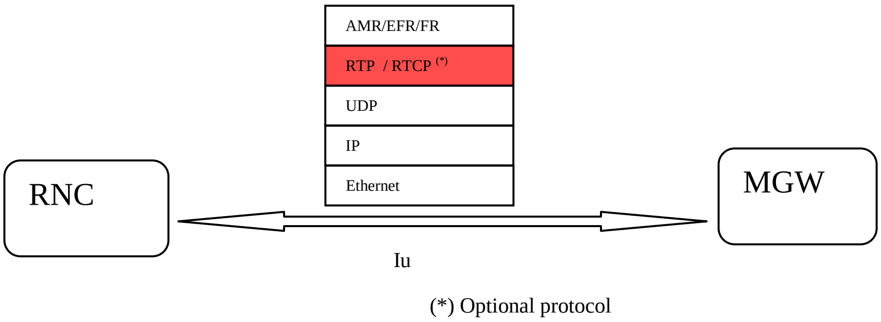


Figure 55 - Iu-CS IP interface

The KPIs that will be following proposed aim to accomplish the intended objective:

- Iu User Plane Initialisation Analysis.
- Iu CS Interface AAL2 Connection Setup Ratio.
- Iu CS Interface AAL2 Throughput – bit rate analysis.
- Iu CS Interface AAL2 Throughput – packet analysis.

- Iu CS interface RTP link throughput – bit rate analysis.
- Iu CS Interface RTP Link Throughput – message rate analysis.
- Iu CS Interface RTP Lost Messages Rate.

KPI name	Iu User Plane Initialisation Analysis.
Description	This KPI provides the Iu User Plane initialisation analysis.
Unit	%
KPI formula	$\frac{\sum BC.SuccOutIuUPInit + \sum BC.SuccIuUPPassiveInit}{\sum BC.AttOutIuUPInit + \sum BC.AttIncIuUPInit}$
3GPP used counters	➢ **BC.SuccOutIuUPInit** Successful outgoing initialization of UP on the Iu interface. ➢ **BC.AttOutIuUPInit** Attempted outgoing initialization of UP on the Iu interface. ➢ **BC.AttIncIuUPInit** Attempted incoming initialization of UP on the Iu interface. ➢ **BC.SuccIncUPInit** Successful incoming initialization of UP on the Iu interface.
Special Notes	This KPI intends to make the analysis of the User Plane Iu initialization. This KPI stands at the bearer control level.

KPI name	Iu CS Interface AAL2 Connection Setup Ratio.
Description	This KPI provides the IuCS ATM AAL2 connection setup ratio.

Unit	%
KPI formula	$\frac{\sum \text{BC.SuccAAL2ConnSetup}}{\sum \text{BC.AttAAL2ConnSetup}}$
3GPP used counters	➢ **BC.SuccAAL2ConnSetup** Attempted connection setup on the Iu interface from RNC to MGW ➢ **BC.AttAAL2ConnSetup** Successful AAL2 connection setup on the Iu interface from MGW to RNC
Special Notes	This KPI makes the ATM AAL2 level MGW bearer control analysis (RNC vs MGW NE User Plane). This KPI stands at the bearer control level.

KPI name	Iu CS Interface AAL2 Throughput – bit rate analysis.
Description	This KPI provides the Iu CS Interface AAL2 bit rate throughput.
Unit	bit/s
KPI formula	$\frac{\left(\sum \text{BRT.IuCSAAL2OctReceived} + \sum \text{BRT.IuCSAAL2OctSent}\right) \times 8}{Granularity\_Period.}$
3GPP used counters	➢ **BRT.IuCSAAL2OctReceived** Nbr of AAL2 packet octets rcvd on IuCS AAL2 conn ➢ **BRT.IuCSAAL2OctSent** Nbr of AAL2 packet octets sent on IuCS AAL2 connection.
Special Notes	This KPI provides the AAL2 throughput on Iu CS interface.

KPI name	Iu CS Interface AAL2 Throughput – packet analysis.
Description	This KPI provides the Iu CS Interface AAL2 packet rate throughput.
Unit	Packet/s
KPI formula	$\frac{\left(\sum \text{BRT.NbrIuCSAAL2PktReceived} + \sum \text{BRT.NbrIuCSAAL2PktSent}\right)}{\left(Granularity\_Period \times 60\right)}$
3GPP used counters	➢ **BRT.NbrIuCSAAL2PktReceived** Number of ATM AAL2 packets received on IuCS AAL2 connection. ➢ **BRT.NbrIuCSAAL2PktSent** Number of ATM AAL2 packets sent on IuCS AAL2 connection.
Special Notes	This KPI provides the AAL2 throughput on Iu CS interface. *Granularity_Period* is considered to be provided in minutes. This counter aggregation shall be defined as SUM (summarization) for time level and AVG (average) for object/network level.

KPI name	Iu CS interface RTP link throughput – bit rate analysis.
Description	This KPI provides the Iu CS interface RTP link throughput – bit rate analysis.
Unit	bit/s
KPI formula	$\frac{\left(\sum BRT.IuOctRTPReceived + \sum BRT.IuOctRTPSent\right) \times 8}{\left(Granularity\_Period \times 60\right)}$
3GPP used counters	➢ **BRT.IuOctRTPReceived** Number of octets received on Iu interface. ➢ **BRT.IuOctRTPSent** Number of RTP octets sent on Iu interface.
Special Notes	This KPI makes a bearer transport analysis. It provides the Iu CS interface RTP link throughput. *Granularity_Period* is considered to be provided in minutes. This counter aggregation shall be defined as SUM (summarization) for time level and AVG (average) for object/network level.

KPI name	Iu CS Interface RTP Link Throughput – message rate analysis.
Description	This KPI provides the Iu CS interface RTP link throughput – message rate analysis.
Unit	Msg/s
KPI formula	$\frac{\left(\sum BRT.NbrIuRTPPktReceived + \sum BRT.NbrIuRTPPktSent\right)}{\left(Granularity\_Period \times 60\right)}$
3GPP used counters	➢ **BRT.NbrIuRTPPktReceived** Total number of RTP messages received on all Iu interface in one MGW. ➢ **BRT.NbrIuRTPPktSent** Number of RTP messages sent on Iu interface.
Special Notes	*Granularity_Period* is considered to be provided in minutes. This counter aggregation shall be defined as SUM (summarization) for time level and AVG (average) for object/network level.

KPI name	Iu CS Interface RTP Lost Messages Rate.
Description	This KPI provides the Iu CS Interface RTP Lost Messages Rate.
Unit	%

KPI formula	$$\frac{\left(\sum \text{BRT.NbrIuR TPLostPkt}\right)}{\left(\sum \text{BRT.NbrIuR TPPktReceived} + \sum \text{BRT.NbrIuR TPPktSent}\right)}$$
3GPP used counters	➢ **BRT.NbrIuRTPLostPkt** Number of lost RTP messages on Iu interface. ➢ **BRT.NbrIuRTPPktReceived** Total number of RTP messages received on all Iu interface in one MGW. ➢ **BRT.NbrIuRTPPktSent** Number of RTP messages sent on Iu interface.
Special Notes	This KPI makes a bearer transport analysis. It provides the weight of the lost RTP messages on Iu interface.

3.5.3.7. Nb interface analysis

This section presents the KPIs that will be used to make the Nb interface analysis (MGW NEs interconnection).

Two types of MGW backbone interconnections are possible to be used: the ATM and the IP based ones.

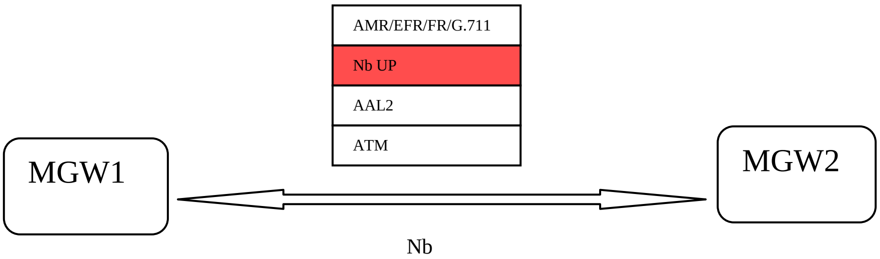


Figure 56 - Nb interface – ATM based

In the ATM based Nb interface, the network analysis will be made through the Nb User Plane initialisation analysis.

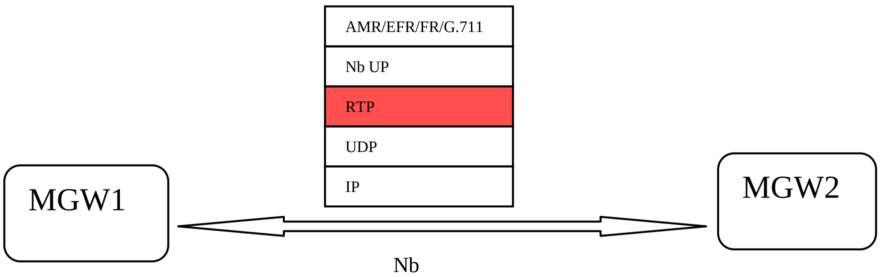


Figure 57 - Nb interface – IP based

The IP based Nb interface, the network analysis will be made through the Nb User Plane initialisation check and the RTP (Real Time Protocol) protocol inspection.

The KPIs that will be following proposed aim to accomplish the described objective:

- Nb User Plane Initialisation Analysis.
- Nb Interface IP RTP Connection Setup Ratio.
- Nb Interface RTP Link Throughput.
- Nb Interface RTP Lost Messages Rate.

KPI name	Nb User Plane Initialisation Analysis.
Description	This KPI provides the Nb User Plane initialisation analysis.
Unit	%
KPI formula	$\frac{\sum BC.SuccOutNbUPInit + \sum BC.SuccIncNbUPInit}{\sum BC.AttOutNbUPInit + B\sum C.AttIncNbUPInit}$
3GPP used counters	➢ **BC.SuccOutNbUPInit** Successful outgoing initialization of UP on the Nb interface. ➢ **BC.SuccIncNbUPInit** Successful incoming initialization of UP on the Nb interface. ➢ **BC.AttOutNbUPInit** Outgoing attempted initialization of UP on Nb interface. ➢ **BC.AttIncNbUPInit** Attempted incoming initialization of UP on the Nb interface.
Special Notes	This KPI makes the User Plane Nb interface initialization analysis. It stands at the bearer control level.

KPI name	Nb Interface IP RTP Connection Setup Ratio.
Description	This KPI provides the IP RTP connection setup ratio.
Unit	%
KPI formula	$\frac{\sum BC.SuccOutIpSetup + \sum BC.SuccIncIpsetup}{\sum BC.AttOutIpSetup + \sum BC.AttIncIpSetup}$
3GPP used counters	➢ **BC.SuccOutIpSetup** Successful outgoing connection setup on the Nb interface. ➢ **BC.SuccIncIpSetup** Successful incoming connection setup on the Nb interface. ➢ **BC.AttOutIpSetup** Attempted outgoing connection setup on the Nb interface. ➢ **BC.AttIncIpSetup** Attempted incoming connection setup on the Nb interface. **Note:** these counters are updated based on IPBCP (IP Bearer Control Protocol) messages (BICC IP). IPBCP makes use of the Session Description Protocol (SDP). [76]

Special Notes	This KPI makes the IP RTP MGW vs MGW (Nb interface) user plane analysis. This KPI stands at the bearer control level.

KPI name	Nb Interface RTP Link Throughput.
Description	This KPI makes a bearer transport analysis. It provides the Nb interface RTP link throughput.
Unit	bit/s
KPI formula	$\frac{\left(\sum BRT.NbOctRTPReceived + \sum BRT.NbOctRTPSent\right) \times 8}{\left(Granularity\_Period \times 60\right)}$
3GPP used counters	➢ **BRT.NbOctRTPReceived** Number of RTP octets received on Nb interface. ➢ **BRT.NbOctRTPSent** Number of RTP octets sent on Nb interface.
Special Notes	*Granularity_Period* is considered to be provided in minutes. This counter aggregation shall be defined as SUM (summarization) for time level and AVG (average) for object/network level.

KPI name	Nb Interface RTP Lost Messages Rate.
Description	This KPI provides the Nb Interface RTP lost messages rate.
Unit	%
KPI formula	$\frac{\left(\sum BRT.NbrNbRTPLost\right)}{\left(\sum BRT.NbrNbRTPReceived + \sum BRT.NbrNbRTPSent\right)}$
3GPP used counters	➢ **BRT.NbrNbRTPLost** Number of lost RTP messages on Nb interface. ➢ **BRT.NbrNbRTPSent** Number of RTP messages sent on Nb interface. ➢ **BRT.NbrNbRTPReceived** Number of RTP message received on Nb interface.
Special Notes	This KPI makes a bearer transport analysis. It provides the weight of the lost RTP messages on Nb interface.

3.6. HLR - KPI proposal

This chapter presents the HLR related KPIs. These KPIs take advantage of the Performance Management metrics defined in chapter 6 ("*Measurements related to the HLR*") of the 3GPP TS 43.407 source document.

Since all KPIs proposed in this Thesis were strictly based on the PM metrics defined in the 3GPP TS 43.407 document and since this document provides a scarce number of metrics related with the HLR NE, it was not possible to propose an extended HLR KPI set.

The HLR analysis will be based on NE usage check. Such is performed through the unit load check, MTP3 protocol inspection (used in the HLR vs MSS connection) and network usage profile inspection.

3.6.1. Utilization

By using the KPIs presented in this group, the user will be able to inspect the HLR utilization profile. This group will inspect the Unit Load analysis, network usage analysis and MTP3 link analysis KPIs.

3.6.1.1. Unit Load analysis

This unit processing load is architecture system vendor dependent. Therefore, a general wide approach is here proposed. These KPIs can be customized from vendor to vendor in order to accomplish their specific hardware and architecture specific details.

Please note that in the distributed control architecture approach, the load analysis shall be made against specific purpose unit processors. The overall NE load is difficult to get. How to weight the various processor loads? Some processors are more critical than others to the overall processing NE load. The NE constraints are mainly focused on critical processors.

The KPIs defined for HLR NE are basically the same as the ones defined for the MSS and the MGW NEs. The ones defined for this HLR NE will, however, run against a different object structure (HLR processor architecture is expected to be different from the MSS and MGW). These similarities are due to the fact that the 3GPP TS 32.407 has equally defined the CPU Load counters for both HLR, MSS and MGW NEs still, they deal with different entities and object structures.

The proposed KPIs are:

- Maximum unit load (distributed architecture approach).
- Maximum unit load (centralized architecture approach).

KPI name	Maximum unit load (distributed architecture approach).
Description	This KPIs provides the maximum unit load for a distributed control

	architecture.
Unit	%
KPI formula	$MAX\_over\_time(\mathrm{EQPT.CPUUsageMean.}[\mathrm{CPUid}])$
3GPP used counters	➢ **EQPT.CPUUsage.CPUid** Load of each processor for distributed controlled mode. Average CPU load during the measurement period. ➢ **CPUid** IDs of the active specific purpose processor units. *#CPUid* Number of CPUs considered in the analysis.
Special Notes	The approach here presented has in mind a distributed controlled processor units. This KPI provides the NE maximum Special Purpose Processor Unit load (percentage value). This maximum value, retrieved from the mean over time samples, can alert the user for a malfunction or lack of resources. In this distributed approach, it makes more sense to make specific purpose unit load analysis. Such units can be specific purpose processors units like the ones dedicated to OMU interface control (Operation and Maintenance Unit), STU control (Statistical Unit Control that collects performance and measurement data from the network), HLRU control (Home Location Register unit), etc.

KPI name	Maximum unit load (centralized architecture approach).
Description	This KPIs provides the maximum over mean unit load samples for a centralized control architecture.
Unit	%
KPI formula	$MAX\_over\_time(\mathrm{EQPT.CPUUsageMean})$
3GPP used counters	➢ **EQPT.CPUUsageMean** Processor load for centralized mode architecture. Average CPU load during the measurement period.
Special Notes	The approach next presented is applicable to NEs with centralized controlled processor units. This KPI provides the NE's maximum centralized processor Unit load (percentage value). This maximum value retrieved from the mean over time samples can alert the user for a malfunction or lack of resources.

3.6.1.2. Network usage analysis

The KPIs that will be following proposed allow the operator to know for what and by whom is the network being used based on HLR provided information derived from the 3GPP TS PM counters.

The proposed KPIs are:

- 3G subscribers share.
- 3G CS subscribers share.
- 3G IN subscribers share.
- 3G LCS data subscribers share.
- 3G GPRS data subscribers share.
- 3G national roaming subscribers share.
- 3G international roaming subscribers share.
- 2G subscribers share.
- 2G IN subscribers share.
- 2G GPRS subscribers share.
- 2G national roaming subscribers share.
- 2G international roaming subscribers share.

KPI name	3G subscribers share.
Description	This KPI provides the share of 3G subscribers registered in the HLR.
Unit	%
KPI formula	$\frac{\sum \text{EQPT.NbrSubsInHlr.3Gsubs}}{\sum \text{EQPT.NbrSubsInHlr}}$
3GPP used counters	➢ **EQPT.NbrSubsInHlr.3Gsubs** Total number of 3G subscribers in HLR. ➢ **EQPT.NbrSubsInHlr** Number of subscribers in the HLR.
Special Notes	

KPI name	3G CS subscribers share.
Description	This KPI provides the share of 3G circuit switch service usage subscribers registered in the HLR.
Unit	%
KPI formula	$\frac{\sum \text{EQPT.NbrSubsInHlr.3GsubsForCsData}}{\sum \text{EQPT.NbrSubsInHlr}}$

3GPP used counters	➢ **EQPT.NbrSubsInHlr.3GsubsForCsData** Number of Circuit Switch Data subscribers in HLR. ➢ **EQPT.NbrSubsInHlr** Number of subscribers in the HLR.
Special Notes	

KPI name	3G IN subscribers share.
Description	This KPI provides the share of subscribers registered in the HLR that use Intelligent Network services.
Unit	%
KPI formula	$\frac{\sum EQPT.NbrSubsInHlr.3GsubsforIN}{\sum EQPT.NbrSubsInHlr}$
3GPP used counters	➢ **EQPT.NbrSubsInHlr.3GsubsforIN** Number of Intelligent Network subscribers in HLR. ➢ **EQPT.NbrSubsInHlr** Number of subscribers in the HLR.
Special Notes	

KPI name	3G LCS data subscribers share.
Description	This KPI provides the share of the subscribers registered in the HLR that use Location Based Services.
Unit	%
KPI formula	$\frac{\sum EQPT.NbrSubsInHlr.3GSubsforLCS}{\sum EQPT.NbrSubsInHlr}$
3GPP used counters	➢ **EQPT.NbrSubsInHlr** Number of subscribers in the HLR. ➢ **EQPT.NbrSubsInHlr.3GSubsforLCS** Number of Location Services subscribers in HLR.
Special Notes	

KPI name	3G GPRS data subscribers share.
Description	This KPI provides the share of the subscribers registered in the HLR that use GPRS Services.

Unit	%
KPI formula	$$\frac{\sum \text{EQPT.NbrSubsInHlr.3GSubsforGPRS}}{\sum \text{EQPT.NbrSubsInHlr}}$$
3GPP used counters	➢ **EQPT.NbrSubsInHlr** Number of subscribers in the HLR. ➢ **EQPT.NbrSubsInHlr.3GSubsforGPRS** Number of GPRS 3G subscribers in HLR.
Special Notes	

KPI name	3G national roaming subscribers share.
Description	This KPI provides the share of the subscribers registered in the HLR that are 3G national roaming subscribers.
Unit	%
KPI formula	$$\frac{\sum \text{EQPT.NbrSubsInHlr.3GsubsForRoamingNational}}{\sum \text{EQPT.NbrSubsInHlr}}$$
3GPP used counters	➢ **EQPT.NbrSubsInHlr.3GsubsForRoamingNational** Number of 3G subscribers in national roaming in the HLR. ➢ **EQPT.NbrSubsInHlr** Number of subscribers in the HLR.
Special Notes	

KPI name	3G international roaming subscribers share.
Description	This KPI provides the share of the 3G subscribers registered in the HLR that are 3G international roaming subscribers.
Unit	%
KPI formula	$$\frac{\sum \text{EQPT.NbrSubsInHlr.3GsubsForRoamingInternational}}{\sum \text{EQPT.NbrSubsInHlr}}$$
3GPP used counters	➢ **EQPT.NbrSubsInHlr.3GsubsForRoamingInternational** Number of 3G subscribers in international roaming in the HLR. ➢ **EQPT.NbrSubsInHlr** Number of subscribers in the HLR.
Special Notes	

KPI name	2G subscribers share.
Description	This KPI provides the share of the 2G subscribers registered in the HLR.
Unit	%
KPI formula	$\frac{\sum EQPT.NbrSubsInHlr.2Gsubs}{\sum EQPT.NbrSubsInHlr}$
3GPP used counters	➢ **EQPT.NbrSubsInHlr.2Gsubs** Total number of 2G subscribers in HLR. ➢ **EQPT.NbrSubsInHlr** Number of subscribers in the HLR.
Special Notes	

KPI name	2G IN subscribers share.
Description	This KPI provides the share of the subscribers registered in the HLR that use 2G IN services.
Unit	%
KPI formula	$\frac{\sum EQPT.NbrSubsInHlr.2GsubsForIN}{\sum EQPT.NbrSubsInHlr}$
3GPP used counters	➢ **EQPT.NbrSubsInHlr** Number of subscribers in the HLR. ➢ **EQPT.NbrSubsInHlr.2GsubsForIN** Number of 2G subscribers using Intelligent Network services, in the HLR.
Special Notes	

KPI name	2G GPRS subscribers share.
Description	This KPI provides the share of the subscribers registered in the HLR that use 2G GPRS Services.
Unit	%
KPI formula	$\frac{\sum EQPT.NbrSubsInHlr.2GSubsForGPRS}{\sum EQPT.NbrSubsInHlr}$
3GPP used counters	➢ **EQPT.NbrSubsInHlr.2GSubsForGPRS** Number of 2G subscribers using GPRS service, in the HLR. ➢ **EQPT.NbrSubsInHlr** Number of subscribers in the HLR.

Special Notes	

KPI name	2G national roaming subscribers share.
Description	This KPI provides the share of the subscribers registered in the HLR that are 2G national roaming subscribers.
Unit	%
KPI formula	$\frac{\sum \text{EQPT.NbrSubsInHlr.2GsubsForRoamingNational}}{\sum \text{EQPT.NbrSubsInHlr}}$
3GPP used counters	➢ **EQPT.NbrSubsInHlr.2GsubsForRoamingNational** Number of 2G subscribers in National Roaming, in the HLR. ➢ **EQPT.NbrSubsInHlr** Number of subscribers in the HLR.
Special Notes	

KPI name	2G international roaming subscribers share.
Description	This KPI provides the share of the subscribers registered in the HLR that are 2G international roaming subscribers.
Unit	%
KPI formula	$\frac{\sum \text{EQPT.NbrSubsInHlr.2GsubsForRoamingInternational}}{\sum \text{EQPT.NbrSubsInHlr}}$
3GPP used counters	➢ **EQPT.NbrSubsInHlr.2GsubsForRoamingInternational** Number of 2G subscribers in International Roaming, in the HLR. ➢ **EQPT.NbrSubsInHlr** Number of subscribers in the HLR.
Special Notes	

3.6.1.3. MTP3 link analysis

The HLR may be linked to the MSC/MSS by taking advantage of the next depicted protocol stack (SS7 connection):

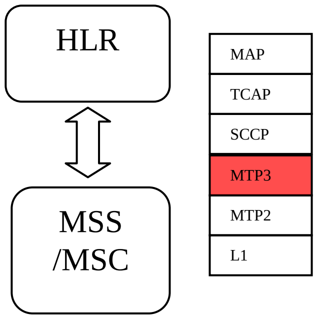


Figure 58 - HLR ↔ MSS link

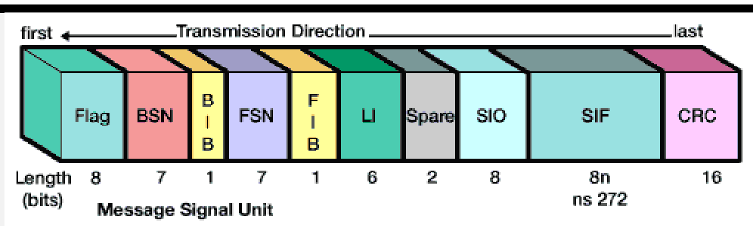
By using the 3GPP TS PM counters, it is possible to define some KPIs that make the health check analysis of the MTP3 protocol stack.

The KPIs that are used in the MTP3 analysis are:

- MTP3 MSU exchanged messages.
- MTP3 usage throughput – bit rate analysis.
- MTP3 usage throughput – message rate analysis.
- MTP3 unavailability.
- MTP3 Signalling Link Total Unavailable Time.

Some are in charge of providing an overview regarding the capacity, and others of making a health check analysis.

KPI name	MTP3 MSU exchanged messages.
Description	Total number of MSUs (Message Signalling Units) exchanged through the MTP3 signalling links.
Unit	Integer
KPI formula	$\sum \text{SIG.NbrMTP3MSUSent} + \sum \text{SIG.NbrMTP3MSUReceived}$
3GPP used counters	➢ **SIG.NbrMTP3MSUSent** Number of message signal units sent on signalling link. ➢ **SIG.NbrMTP3MSUReceived** Number of message signal units received on MTP3 signalling link.
Special Notes	A Message Signal Units (MSUs) carry all call control, database query and response, network management, and network maintenance data in the Signalling Information Field (SIF). MSUs have a routing label which allows an originating signalling point to send information to a destination signalling point across the network.



The number of MSU messages reflect the real exchanged payload volume.

KPI name	MTP3 usage throughput – bit rate analysis.
Description	This KPI provides the average MTP3 usage throughput.
Unit	bits/s
KPI formula	$\frac{8\times\sum \text{SIG.MTP3OctSent} + 8\times\sum \text{SIG.MTP3OctReceived}}{(Granularity\_Period\times 60)}$
3GPP used counters	➢ **SIG.MTP3OctSent** Number of SIF and SIO octets sent on signalling link. ➢ **SIG.MTP3OctReceived** Number of SIF and SIO octets received on signalling link.
Special Notes	Granularity_Period is considered to be provided in minutes. This counter aggregation shall be defined as SUM (summarization) for time level and AVG (average) for object/network level.

KPI name	MTP3 usage throughput – message rate analysis.
Description	This KPI provides the MTP3 signalling messages exchange rate. This KPI helpful in the A interface signalling link load analysis.
Unit	Msg/sec
KPI formula	$\frac{\left(\sum \text{SIG.NbrMTP3MSUSent}\right)+\left(\sum \text{SIG.NbrMTP3MSUReceived}\right)}{(Granularity\_Period\times 60)}$
3GPP used counters	➢ **SIG.NbrMTP3MSUSent** Number of message signalling units sent on signalling link (MSUs/SL, ITU-T Recommendation Q.752). ➢ **SIG.NbrMTP3MSUReceived** Number of message signalling units received on signalling link (MSUs/SL, ITU-T Recommendation Q.752).
Special Notes	This KPI is useful for equipment dimensioning and hardware capacity analysis purposes as well as operations and maintenance support activities. Granularity_Period is considered to be provided in minutes. This counter

	aggregation shall be defined as be defined as SUM (summarization) for time level and AVG (average) for object/network level.

KPI name	MTP3 unavailability.
Description	This KPI provides the total MTP3 unavailability time. This KPI helpful in the A signalling link load analysis.
Unit	Second
KPI formula	$\sum \text{SIG.NbrMTP3LKUnavailable} \times \sum \text{SIG.MTP3LKUnavailableDurationMean}$
3GPP used counters	➢ **SIG.NbrMTP3LKUnavailable** Number of unavailable time of MTP3 signalling link ➢ **SIG.MTP3BLKUnavailableDurationMean** Mean duration of unavailable of MTP3 signalling link.
Special Notes	This KPI is useful for equipment operations and maintenance support activities. This KPI is useful for equipment availability analysis purpose.

KPI name	MTP3 Signalling Link Total Unavailable Time.
Description	This KPI provides the MTP3 Signalling Link Total Unavailable Time.
Unit	Second
KPI formula	$\sum_{AllSigLk} \left(\sum \text{SIG.NbrMTP3LKUnavailable} \times \sum \text{SIG.MTP3LKUnavailableDurationMean} \right)$
3GPP used counters	➢ **SIG.NbrMTP3LKUnavailable** Number of unavailable times of MTP3 signalling link. ➢ **SIG.MTP3LKUnavailableDurationMean** The mean duration of unavailable of MTP3 signalling link
Special Notes	This KPI is useful for equipment operations and maintenance support activities. This KPI is useful for equipment availability analysis purpose. The idea behind this KPI is to provide the user the total unavailable time.

3.7. Conclusion

One of the conclusions can be reached after the deep analysis made against the 3GPP TS 32.407, is that the current existing metadata, namely the defined Performance Indicators set, could and should be extended. The absence of some important PIs is preventing to reach deeper in terms of 3GPP KPI proposals. One area where the absence of such PIs was especially felt was in the handover analysis. PIs to count the number of intra-MSC handovers, the number of inter-PLMN handovers and neighbour cells handovers are of most importance to get an accurate handover overview; however such performance indicators (PIs) are missing in the 3GPP TS32.407 CN CS metrics proposal. In this Release 4, networks are dealing with a 2G and 3G mixed traffic; therefore, it is unclear why in the inter MSC-S handovers, there are no counters to get the GSM to UMTS and GSM to GSM related ones.

Unfortunately, the missing PIs are not exclusive of handover issue. In the call performance analysis, it was particularly felt the lack of the PI to count the number of "*normally terminated*" calls. 3GPP has presented PIs to count the number of "*attempted*", "*successful*" (reaching the alerting phase) and "*answered*" calls, but not the "*normally terminated*" calls. This PI should also definitely be made available. This "*normally terminated*" calls is of major importance to get the MSC-S call retainability and consequently the call drop ratio *(1- retainability)*. The retainability is defined as the network capacity to retain a call until it is normally released and its KPI is defined as *(Successful calls / Started call)*. The problem here is that, as just referred, the *Successful calls* PI (that provides the normally terminated calls) is a missing PI.

One of the challenges during the execution of these proposals was the need to created generic KPIs not dependent on vendor specific NE Hardware and architecture implementations. This objective was achieved but had a payoff, which was the impossibility to create quite sophisticated KPIs where different data sources could be integrated since such cases are typically more subject to vendor specific details.

Anyway, despite the just referred constraints, we can say that based on current 3GPP standards, namely on the presently defined Performance Management (PM) Core Network (CN) Circuit Switched (CS) domain document (3GPP TS 32.407), it is already possible to create a coherent and useful set of CS Rel.4 KPIs. The final achieved set is able to make the overall network analysis based on Network Elements (MSS + MGW + HLR) accessibility, usage, integrity and mobility analysis, NE interface protocol review, traffic load and flow check.

4. Conclusion

There is a true need for this KPI set definition. By implementing these CS CN Release 4 KPIs in their own networks, the telecommunication mobile network operators will be able to define common rules for a performance benchmark comparison, and will be able to compare the performance of their Network Equipment suppliers. All NE equipment vendors will then be "*talking the same language*" and, as consequence, it will be easier to check the overall network bottle-necks and to simplify the network system interconnection. This will result in gains for the telecommunication mobile network operators in terms of performance and network profitability.

Still, some issues were raised during this Thesis that should be addressed next to 3GPP. One of the most important is the need to extend the proposed 3GPP TS 32.407 CS CN Release 4 counters. Some relevant PIs are missing in the TS which is leading to the impossibility of creating a better and more extensive KPI set.

The KPIs proposed on this Thesis can already be used by any network operator and Network Element equipment vendor. First, the network equipment vendor shall try to map their NE existing counters into the ones defined by the 3GPP TS 32.407 (special care must be taken in what the defined trigger points and object metadata model is concerned. To get a valid equivalence, it may not be an easy process and may lead to workaround solutions in order to cope with the specific NE technology with the 3GPP intended outcome). Once this mapping is achieved, the network operator or equipment vendor can create the KPIs proposed in this Thesis by using the KPI formula details enclosed in this document and implementing them in their own existing reporting tool. Some reporting products where this information is possible to already be implemented from the beginning are the NSN (Nokia Siemens Networks) Reporting Suite and SPOTS products.

A network operator, while having all of its network equipment suppliers supporting these 3GPP CS KPIs, can create useful network multi-vendor dashboards to support their operations, which may be in terms of network management, planning or optimization.

By using this end-to-end wide dashboards, the network operator will be able to have a real and sustainable idea about its own overall CS network performance. It will be easy for the operator to compare network equipment suppliers performance and to easily and earlier find the network equipment interconnection problems which typically is a grey area where, very frequently, each party tries to handover the problem to the other. In resume, it can be referred that, by coping with these CS KPIs, the network operator will gain more control on the network, and the equipment vendor communication process will be made easier.

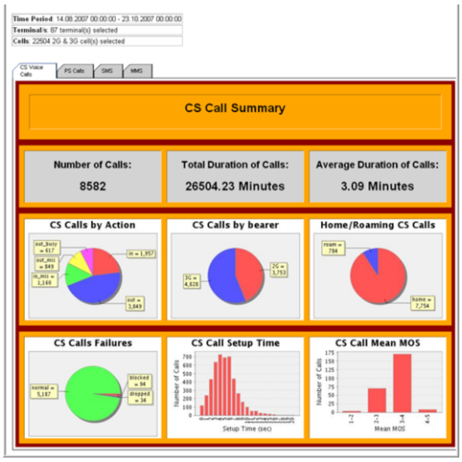


Figure 59 - Current CS network dashboard

Currently, this kind of dashboards are already possible to be implemented but, when extended to the overall network analysis with many Network Equipment vendors involved, the provided information, while not following common standard models and pre-defined KPIs approach, will lead to overall results that may be error prone and misleading results.

The result of this Thesis will then be able to reduce the probability of misleading results, and consequently, provide a better management of the multi-vendor architecture and elements.

5. Future Work

As previously referred, some issues were raised during this Thesis regarding the necessity for 3GPP to create more Performance Management metrics and indicators. 3GPP should extend the current set and append it into the 3GPP TS 32.407 CS CN Release 4 technical specification. The non-existence of these important performance indicators is preventing the creation of a better and more extensive set of KPIs.

The set of CS CN Release 4 KPIs proposed in this Thesis should be implemented and tested in a real network by using standard commercial reporting products. Once confirmed the KPI set feasibility, such shall be proposed to the 3GPP aiming its approval.

The challenge of having a CS Release 4 “common KPI language“ will, however, not be over. To have a common defined KPI set is just part of the problem. The next challenge is to implement such KPIs in the field by following a similar and common network equipment to network equipment vendor approach. Most likely, each vendor will implement them differently. This has to do with the way that each Network Equipment vendor has evolved at hardware and software level. From vendor to vendor, for the same counter purposes, we have different trigger points, sometimes different object models, significantly different metadata, different ways of input data processing different ways of making the data collection and data processing. It will be a challenge to cope with all these different inputs and try to define rules in order to get a common comparable outcome that can be helpful for the final user.

Suggestions for the future work:

Study the most important current Network Equipment vendors' metadata (object model, measures and counters). It is suggested to include in this analysis Ericsson, NSN, Alcatel Lucent, Huawei and ZTE..

For similar counters' outcome it is required to check their trigger points and analyse if they are comparable, their differences and how to cope them.

Based on the 3GPP approved CS KPI set, it is required to cope the inputs and generate equivalent implementations, checking the outcome against a common live network data source and study what can be improved to get a better coping.

In the end, it is required to define a set of rules to be followed by all NE vendors in order to get a common vendor to vendor comparable KPI implementation.

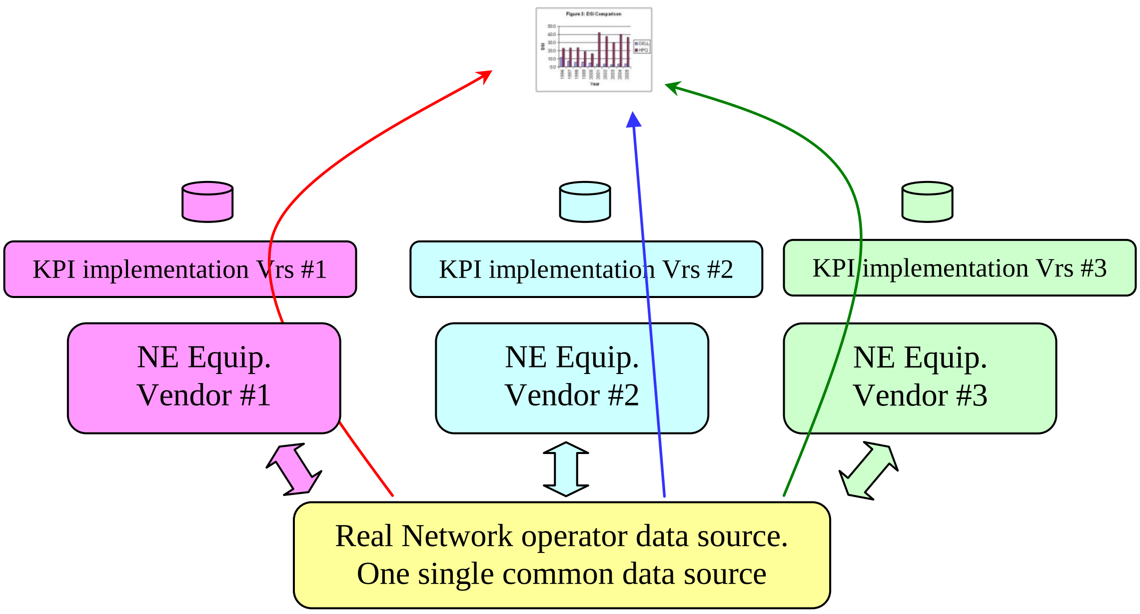


Figure 60 - Future work proposal

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