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Analysis of Core Aspects in Migration towards the Next Generation Network

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TTÜ PRESS

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Declaration:
Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology, has not been previously submitted for doctoral or equivalent academic degree.

Sven Pärand _____________________
signature

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Võtmeaspektide analüüs migreerimisel järgmise põlvkonna sidevõrgule

SVEN PÄRAND

TTÜ KIRJASTUS

CONTENTS

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C Pärand, Sven (2015). A Migration Decision for Users and Services Towards and Within the IMS. International Journal of Advances in Computer Science and Its Applications (IJCSIA), Volume 5, Issue 1, pp. 125-130.

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AUTHOR'S CONTRIBUTION TO THE PUBLICATIONS

Contribution of the author to the papers this thesis is based on:

- A Defining the problem of studying migration strategies, completing the study, writing the paper.
- B Defining the problem of studying migration strategies, completing the study, writing the paper.
- C Defining a need for a general migration process, creating and describing the four-step migration process, writing the paper.
- D First author, defining the central role of OSS/BSS in migration from legacy networks, writing the paper.

ABBREVIATIONS

3GPP - Third Generation Partnership Project
3GPP2 - Third Generation Partnership Project 2
AAA - Authentication, Authorization and Accounting
ABMF - Account Balance Management Function
ACCM - Accounting Module
ACM - Alarm Collection Module
ACRM - Accrual Module
AES - Advanced Encryption Standard
AG - Access Gateway
AKA - Authentication and Key Agreement
AMN - Alarm and Measurement Node
AP - Authentication Proxy
API - Application Programming Interface
AS - Application Server
ASCF - Access Security Control Function
ASST - Application Server Support Tables
BAK - Bill-and-Keep
BGCF - Border Gateway Control Function
CAMEL - Customized Applications for Mobile Enhanced Logic
CAP - CAMEL Application Protocol
CAPTCHA - Completely Automated Public Turing test to tell Computers and Humans Apart
CBR - Case Based Reasoning
CCSM - Call Center Statistics Module
CDF - Charging Data Function
CDR - Call Detail Record
CG - Command Generator
CGF - Charging Gateway Function
CID - Command Identifier
CLAIM - Client Claim Module
CLIM - Client Management
CLM - Configuration Log Module
COMM - Communication Means
CONS - Contract System
COPS - Common Open Policy Service
CoS - Class of Service
CRCO - Credit Control
CRM - Customer Relationship Management
CS - Circuit Switched
CSCF - Call Session Control Function
CSI - Customer Satisfaction Index
CTF - Charging Trigger Function
DB - Database
DE - Digital Exchange

DECC - Digital Exchange CDR Collection
DEMM - Digital Exchange Measurement Module
DES - Data Encryption Standard
DEVM - Devices Module
DiffServ - Differentiated Services
DMOD - Distribution Module
DNS - Domain Name System
DoS - Denial of Service
ENC - External Node Communication
ENUM - Electronic Numbering
ESP - Encapsulating Security Payload
eTOM - enhanced Telecom Operations Map
ETSI - European Telecommunications Standards Institute
FMC - Fixed Mobile Convergence
FQDN - Fully Qualified Domain Name
GDP - Gross Domestic Product
GGSN - Gateway GPRS Serving Node
GPRS - General Packet Radio System
GSM - Global System for Mobile
HLR - Home Location Register
HSS - Home Subscriber Server
HTTP - Hyper Text Transfer Protocol
HTTPS - HTTP – Secure (HTTP over TLS)
IASS - IMS Application Server Statistics
ICC - IMS CDR Collection
ICMP - Internet Control Message Protocol
ICT - Information and Communications Technology
I-CSCF - Interrogating Call Session Control Function
ID - Identity
IETF - Internet Engineering Task Force
IFC - Initial Filter Criteria
IFM - Initial Filtering Module
IKE - Internet Key Exchange
IM - Instant Messaging
IM - Input Mediation (starting from Chapter 5)
IMM - IMS Measurement Module
IMPI - IP Multimedia Private Identity
IMPU - IP Multimedia Public Identity
IMS - IP Multimedia Subsystem
IMSI - International Mobile Subscriber Identity
IN - Intelligent Network
IntServ - Integrated Services
IP - Internet Protocol
IPNP - Initiating Party's Network Pays
IPsec - IP Security
ISC - IP Multimedia Service Control
ISDN - Integrated Services Digital Network

ISIM - IP Multimedia Services Identity Module
ISMS - IMS-SDP Management Server
ISMST - IMS application Server Management Support Tables
ISP - Internet Service Provider
ISSI - IN Services Statistics Import
ISST - IN application Server Support Tables
ISUP - ISDN User Part
IT - Information Technology
ITU International Telecommunications Union
ITU-T - International Telecommunications Union - Terrestrial
IVR - Interactive Voice Response
KQI - Key Quality Indicator
LAI - Location Area Identification
LDS - Load Distribution Server
LNP - Local Number Portability
LS - Local Switch
MAP- Mobile Application Protocol
MCC - Mediation CDR Collection
MD - Message Digest
ME - Mobile Equipment
MML - Man-Machine Language
MO - Managed Object
MPLS - Multiprotocol Label Switching
MRF - Media Resource Function
MRFC - Media Resource Function Controller
MRFP - Media Resource Function Processor
MTOSI - Multi Technology Operations Systems Interface
MWOM - Mobile Work Order Management
NAT - Network Address Translation
NGN - Next Generation Network
NGNI - Next Generation Network Integration
NMAN - Number Management Module
NMS - Network Management System
NPM - Number Provisioning Module
NPOR - Number Portability Module
OCF - Online Charging Function
OCPW - Operator Communication Platform Web
OCS - Online Charging System
OECD - Organisation for Economic Co-operation and Development
OFCS - Offline Charging System
OREG - Offerings Register
OMA - Open Mobile Alliance
OSA - Open Service Access
OSS/J - OSS through Java
O&M - Operations and Maintenance
P-CSCF - Proxy Call Session Control Function
PBNM - Policy Based Network Management

PCC - Policy and Charging Control
PCRF - Policy and Charging Rules Function
PDP - Packet Data Protocol
PDF - Policy Decision Function
PD-FE - Policy Decision Functional Entity
PDP - Policy Decision Point
PEP - Policy Enforcement Point
PIN - Personal Identification Number
PoC - PTT over Cellular
POTS - Plain Old Telephony Service
PREG - Product Register
PS - Packet Switched
PT - Provisioning Tool
PTT - Push-To-Talk
QoP - Quality of Protection
QoS - Quality of Service
QoSB - Quality of Service Broker
RADIUS - Remote Authentication Dial In User Service
RCA - Root Cause Analysis
REQM - Request Module
RF - Rating Function
RFC - Request for Comments
RTP - Real-time Transport Protocol
SBC - Session Border Controller
SCPs - Service Control Points
SDP - Session Description Protocol
SGSN - Serving GPRS Support Node
SHA - Secure Hash Algorithm
SIP - Session Initiation Protocol
SLA - Service Level Agreement
SMM - Service Management Module
SMO - Service Managed Object
SNMP - Simple Network Management Protocol
SOA - Service Oriented Architecture
SOAP - Simple Object Access Protocol
SPIT - Spam over Internet Telephony
SRVB - Services Base
SS7 - Signaling System Number 7
TCP - Transmission Control Protocol
TCR-FE - Transport Resource Control Functional Entity
TISPAN - Telecoms & Internet converged Services & Protocols for Advanced Networks
TLS - Transport Layer Security
TMSI - Temporary Mobile Subscriber Identity
TMFE - Telco Management Front End
TPLM - Time Planning Module
UAC - User Agent Client

UA - User Agent
UAS - User Agent Server
UC - Unified Communications
UDP - User Datagram Protocol
UE - User Equipment
UICC - Universal Integrated Circuit Card
UMTS - Universal Mobile Telecommunication Standard
URI - Uniform Resource Locator
USIM - Universal Subscriber Identity Module
VLR - Visited Location Register
VMM - Voicemail Management
VoIP - Voice over Internet Protocol
VoLTE - Voice over Long Term Evolution
WebDAV - Web Distributed Authoring and Versioning
WLAN - Wireless Local Area Network
WO - Work Order
WOM - Work Order Management
XML - eXtensible Markup Language

INTRODUCTION

The number of people consuming modern multimedia services is ever-increasing. This can be illustrated by looking at the sales figures of smart devices supplied by manufacturers, telecom operators and service providers worldwide. According to [1] and [2] the number of smartphones shipped across the globe surpassed, for the first time in history, 1 billion units in 2014, having just been 174 million units in 2009. People are no longer content with communicating via traditional methods only, such as voice and text messages and would like to use unified communication (UC) tools, such as real-time messaging, multimedia messages, video calls, presence, web browsing, social networks etc, to their advantage in business and personal life.

Although the shrinking of legacy telco markets has been going on for at least a decade, the operators and service providers are globally still struggling to cope with this trend. Keeping a telecommunications company profitable in todays market requires coming up with innovative services, coaxing new and retaining old customers while accumulating the resources needed to make the change in paradigm towards a next generation network. During the course of this thesis the emphasis is directed to the migration from PSTN to the most popular service delivery platform (SDP) in NGN, the IP Multimedia Subsystem. However, as there will always be a next “Next Generation Network”, the principles discussed in the thesis should be, as much as possible, expanded upon these as well.

Motivation and Problem Formulation

Initially, two notions already mentioned in previous sections must be defined. These are service provider and telecommunications operator, or simply operator. The reason for this is that these will be frequently used during the course of this thesis and making the distinction will help the reader understand the context of the writing better.

According to [3] a service provider is an entity which delivers its services to customers using the physical networks of incumbent telecom operators. In essence an operator is, usually, an old company with its infrastructure in place and can therefore provide interfaces towards service providers to link them with their networks – a classical rental situation. This imposes a problem for the SPs in a sense that they do not have full control over the quality of the service they provide for their own customers. The created service may have been produced according to the highest standards but the experience perceived by the customer also depends on the underlying physical network which they do not manage.

It can therefore be said that an operator, if aggressive enough, can have a substantial advantage compared to SPs. Not only will it be able to control the whole chain of its service offerings but also create new services more effectively according to the knowledge of restrictions in its network. Additionally, it is possible for an operator to control the market via rental agreements.

10-15 years ago telecom operators became familiar with the notion of NGN services. Based on the previous work done by specific focus groups, which will be discussed in future sections of this thesis, the idea of communicating in a way more different than it had been done so far started to spread and terms like video call, multimedia messaging and chatting became widespread. As the number of smart devices and mobile users worldwide are forecasted by [4] to have a 66% compound annual growth rate (CAGR) from 2012 to 2017, the mentioned keywords are taken increasingly more for granted with the expectation that new and exciting services are delivered on a constant basis. For the operators and service providers this means creating services that are not only innovative but also based on platforms which have never been used before [5].

The changing of technologies and similar work has been studied in [6] where a method has been created to predict the time of such changes using different models. These models are based on the appearance of first patents, the birth, death (failure) and the lifespan of a technology. The research also brings forth the main possibilities for the transition of technologies: immediate, separated and overlapped substitution. The difference with these three being that immediate means a new technology will follow the old one immediately, in a separated case the old and new are temporally separated and with an overlapped situation the old and new technologies are both in operation for a period of time.

The change of technology mentioned in the previous section is visible when looking at the demands of the customers today which have put the operators and SPs in a very tense situation. On the one hand it is clear that not losing revenue means keeping up with the times and migrating the services and their users to a next generation network SDP and on the other hand it is known that this task is generally, due to its sheer magnitude, a very long lasting and highly resource encompassing process. As a consequence, the battle for retaining and gaining market share has reached an extremely high level of competitiveness.

Figure 1 indicates that the telecommunications industry is currently developing faster than the needs of the customer and this gap is increasing over time. The authors, responsible for creating the initial version of the figure, did not specify a period in time when this transition occurred, thus only referring to the fact that at some point technology started to precede the desires of customers. The author of the current thesis has elaborated on this period based on his experience of NGNs and knowhow of the industry, indicating the change having taken place around 2012-2013. The figure demonstrates, above all, how difficult it is for operators to invest in future infrastructure. In addition, this development allows new participants to enter the market more easily and more quickly.

The issue with technology moving ahead of customers' needs means the operators must find a balance between their investments and retaining their market share. It is not reasonable to keep investing in services that will not be immediately accepted by the customers but at the same time resources have to be allocated into development in order to keep the competitive edge.

On their way to an NGN, telecommunication operators and service providers are faced with a myriad of issues and there are many factors that dictate the pace of migration either directly or indirectly. One of the key issues is the general direction taken by the SP or operator. This is a matter for the highest management level of the company. A decision to either move or not move forward towards an NGN would have to be based on the outlook of the company, current and predicted market situation, availability of resources and the desired pace for the transition. It is also paramount to clarify the specific list of services and users to be migrated since it might not be reasonable financially, or for any other reason, to make a full transition from legacy networks to a modern service delivery platform.

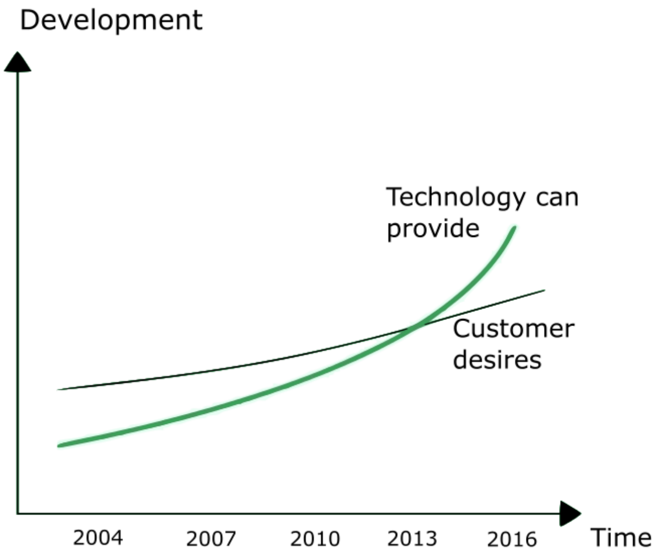

Figure 1. The relationship between the development of technology and what the customer desires [3], adopted and modified by the author

Another crucial factor in migration is the legacy of the operator or service provider. A company with long lasting and extensive background in legacy networks such as PSTN has more problems in their path towards an NGN. This can be attributed to the vast number of systems, technologies and equipment in use and also to the stovepipe nature of the services offered – a logic not coherent with next generation networks. Over time, systems also become increasingly more integrated, making them, or sections of them, more difficult to break apart and move towards a new paradigm.

The issue of financial resources, i.e. capital expenditure (CAPEX) and operational expenditure (OPEX), must also be taken into consideration. Many aspects come into play here. First of all, a company wanting to move towards an NGN will have to consider the substantial capital needed for migration and since the volume of core nodes of NGNs are relatively independent of the size of the operator or service provider, this means that even small or medium size companies will need to have roughly the same initial resources. The total CAPEX for smaller businesses will eventually be smaller but this can be attributed to fewer resources needed in the later stages of migration. Secondly, the matter of when exactly to migrate. At some point providing services on legacy networks will demand higher operational costs. The research done in [7] suggests a saving of nearly 25% from power consumption, personnel and equipment maintenance alone over the period of 5 years when using IMS instead of PSTN. Thirdly, OPEX can be saved by starting the migration process as soon as possible as is shown in [8]. Today, it is highly unlikely that there are companies in the world which have not considered NGN, at least to some extent, so the issue can be reduced to a simple matter of finishing the transition as soon as possible. There are ways of speeding up or simplifying the process by not eliminating the legacy network at once and by offering some services "as is" while going forward with the migration process. This would however require an analysis on the viability of any given service.

The number of strategies for migration are virtually limitless since these are dictated by company specific attributes but there are a few that are adopted by many operators and service providers worldwide. In case of smaller and younger companies there is a possibility for an abrupt transition from legacy networks to a next generation network SDP. The beforementioned lack of a long history and, in essence, the tenuous background of such companies, is what enables the theoretically quick shift in paradigm.

The situation is more complicated when the sudden transition from legacy networks to NGN is not possible and both have to be kept in operation concurrently. These hybrid solutions demand the most of telecommunication companies since nearly every aspect of offering a service to customers needs to be doubled. An SP or operator must have supporting systems for both legacy and contemporary systems, this is not to say there are systems capable of facilitating the needs of both. The human resource needs to possess the knowhow to deal with both worlds as well as is described in [9]. The upside to this overlay solution is the possibility to distribute the CAPEX over a longer period of time. As mentioned earlier, the initial cost for an NGN SDP is considerable no matter the size of the operator or service provider but all the following investments can be managed in a more suitable way.

Regarding the choice of SDP, most incumbent companies do not consider migrating to a softswitch (SS) platform a feasible approach since it is not thought of as a carrier grade solution. Although the CAPEX for such solutions is smaller compared to IMS for example and it is more suitable for starting or young companies, the limitations in scalability and redundancy keep it from getting used by large and more influential participants in the market.

After the operator or SP has made all the non-technical decisions regarding migration to next generation networks, it is time to start solving the technical ones. The problems in the technical domain can be separated into smaller groups and categorized as follows: the SDP itself, supporting systems and the development of adjacent technical networks. As the current thesis focuses on IP Multimedia Subsystem, the major issue seen here is the high degree of complexity of IMS and especially the fact that nearly every operator or service provider has customized and extended their IMS core with different nodes and tailor made services. Although the 3rd Generation Partnership Project (3GPP) and the Internet Engineering Task Force (IETF) have standardized IMS, there is still a lot of problems that different operators create inadvertently. Therefore, migration and the provisioning of users and services is not always straightforward. In addition, the migration process demands the development of not only the SDP but the operations support systems/business support systems (OSS/BSS) as well. The transition of support systems from legacy networks to NGN has been studied in [10, 11, 12, 13] where a future proof solution for operators and SPs was constructed in the form of next generation operational systems and software (NGOSS). This describes a methodology, which is technologically independent, for designing, creating an architecture and following the whole life cycle of the OSS/BSS.

The adjacent technical networks must support the migration process as well. Modern day multimedia services require bandwidth that cannot be supplied by using transmission networks created several decades ago and therefore the evolution of broadband (BB) technology becomes a foundation for operators and service providers on their way to adopting an NGN service delivery platform.

Thesis Outline

To this day a uniform procedure for migration away from legacy networks to NGNs has not been described. The novelty of this thesis is contained in the analysis, description and proof of applicability of a framework capable of facilitating a migration task for a variety of telecom operators, each with their own set of distinctions and constraints. The methodology used for this is twofold. Firstly, worldwide migration strategies and processes are studied to obtain knowledge of best practices. Secondly, field specific research papers and standardization documents are dissected to create, together with relevant knowhow, a comprehensive analysis.

In brief, this thesis contributes to:

1) defining a general problem, in the form of a missing migration procedure, which exists for SPs and operators;
2) analyzing and compiling a framework for migration and thus solving the mentioned problem;
3) demonstrating a working solution based on the issues brought forth during the analysis.

The following considerations are taken into account:

1) the perceivable end user QoS and the performance and reliability of the NGN SDP must remain, at minimum, on the same level as with legacy networks;
2) continuity of legacy services must remain and the amount of new services must increase while their roll-out period must decrease.

To achieve the described end goal of the work, a collection of subtasks have to be completed. Firstly, in Chapters 1 and 2, the essence and main principles of next generation networks and IMS have been assembled by the author along with, as already mentioned, examples of migration scenarios worldwide. This has been done to give the reader background information about the technological realm and to demonstrate different approaches taken by telcos so far with regards to migration.

Chapter 3 contains the core of the thesis - the analysis and synthesis of a migration process created by the author. In order to simplify the analysis, the complete migration task for users and services has been broken down into four phases.

Based on the results acquired in Chapter 3, an operational solution for migration away from legacy networks and within NGNs has been described in Chapter 4 to verify the integrity and soundness of the completed analysis. Chapter 4, as well as many sections in earlier chapters, is based on knowhow, systems and processes applied in real-life scenarios at Telia Estonia Ltd since this is a company that the author is associated with. The final chapter summarizes the research done in the thesis and considers future work in the area.

1 Next Generation Networks

The explosive growth of next generation networks is derived mainly from the needs of people to utilize multimedia services. These needs have increased over time in volume and complexity, ensuring high demands for the operators and SPs and thus making sure the research and development of NGNs has always been driven by the industry.

For the sake of clarity and before dwelling on the main topics of this thesis, the notion of an NGN should therefore be elaborated upon. The following paragraphs discuss the pertinent material published and concentrates on how next generation networks have evolved to their current state. The standardization work done by two main standardization bodies responsible for NGN standardization, International Telecommunication Union (ITU) and European Telecommunications Standards Institute (ETSI), has also been expanded upon in more detail. Additionally, based on the authors' own published work in [29], the latter part of the Chapter focuses on migration scenarios towards NGNs, taken by different telco operators worldwide.

1.1 Basic Concepts

[14] considers next generation networks to be a logical outcome of what is called a second birth of communication technology, the first one being the period when information digitalization was a prevalent trend. After that period the technology in the communication sector has, in essence, been in a state of hiatus until recently with the emergence of broadband, mobile communications and web technologies.

Clearly, a transformation has occurred where the users are no longer passive end-points but rather active components that contribute largely to the layered and meshed networks. Having said that, it is clear that the present era in telecom has evolved into being more user centric with the customer being the core, having a vast array of services at their disposal.

From a technical perspective, there are a few key factors that are considered to be the enablers that have made NGN the dominant trend today. Firstly, the past issues of low bandwidth have now been overcome with broadband, giving the customers more freedom to choose with regards to services and also making it possible for the operators and service providers to implement completely new multimedia infrastructures. The second enabler is considered to be IP which has caused a paradigm shift in fault, configuration, accounting, performance and security (FCAPS) operations and network management.

From an SDP point of view next generation networks can, in essence, be divided into carrier grade solutions and non carrier grade solutions. [15] describes the idea behind unavailable as being a situation when a user is not able to access a system to either retrieve data from it, alter or insert data in it. Since the operation of major telecommunication operators' networks are considered critical, these fault situations are not acceptable and therefore a standardized carrier grade platform, IMS, is used. However, for companies not operating on such a large scale or not needing high versatility in their applications portfolio, this platform is not reasonable and a solution that is not carrier grade can be used. This is called a softswitch solution, where a softswitch is a central programmable node in an SDP and is meant for voice applications. It has two main tasks: firstly, it controls VoIP calls and secondly, it acts as a signaling interface towards the PSTN using special nodes called a signaling gateway and a media gateway.

[16] has elaborated further on this topic, noting software switching technology to be the first evolutionary step towards NGNs. As indicated previously in this thesis, more advanced service delivery platforms than a softswitch exist, however according to [17] softswitch technology helped validate the initial principles of NGNs and therefore helped in founding the base for further developments.

The main components of a softswitch based architecture are depicted in Fig. 1.1. These include:

1) softswitch – the central node responsible for controlling communication between parties. Also controls other network elements and can provide for example call routing, billing and other logical functions.
2) media gateway – manages the transport of media between different networks, deals with media processing operations such as transcoding, processes tones.
3) access gateway – provides an interface from traditional networks to IP networks.
4) signaling gateway – responsible for changing signalization systems between legacy and IP networks.
5) media server – provides media resources and functionalities like tones, media mixing and speech recognition for communicating parties.
6) application server (AS) – an entity which implements specific services and provides service specific call control. Can also be used as a user web interface or for end user management.

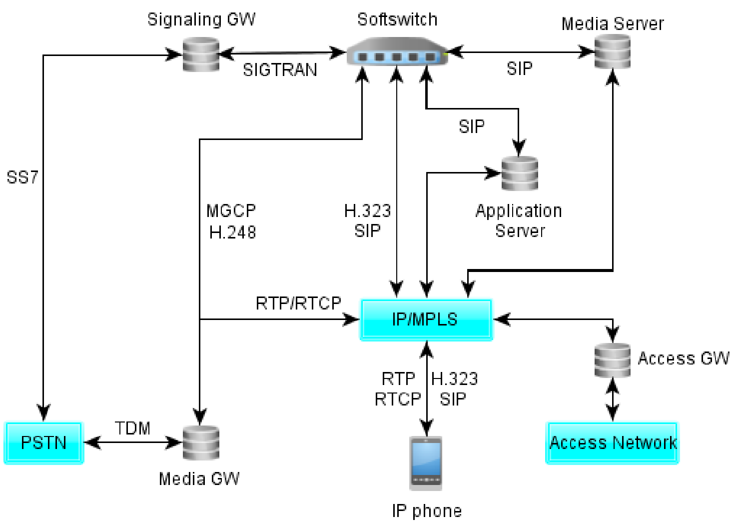

Figure 1.1. Basic overview of a softswitch architecture

1.2 Work Done by ITU

In 2004 the ITU Telecommunication Standardization Sector (ITU-T) created the Focus Group on Next Generation Networks (FGNGN) to compile the input for further standard creation for NGN. The initial goals and deliverables were collected at an early stage in [18] and [19]. These main study topics included:

1) Evolution

The main idea here was to preserve, as much as possible, the work done with PSTN. Since the initial investment to PSTN had been considerable for all the operators, there was no reason to completely discard this resource by simply building a new SDP from scratch, but to use the existing as a basis for further development towards an NGN. The matter of interoperability with legacy networks had to be taken into consideration as well. This was important since different operators had reached different levels of maturity and development in their networks, meaning the start point for migration towards NGNs was different and therefore a platform was needed which enabled the aggregation of legacy networks at different stages of development. All this had to happen in parallel with the implementation of new capabilities on the new service delivery platform.

2) Quality of Service

Quality of service can be considered an extremely subjective matter depending on user satisfaction. This might include for example the speed, reliability or security of a service. However, an operator can have an indication of customer satisfaction by measuring certain parameters within its network. With regards to the initial development phase of NGNs, the task was set to not only identify these parameters but to agree on their acceptable operating levels whilst still maintaining an acceptable QoS.

3) Interoperability

Since next generation networks were seen as platforms with broad possibilities, using a wide range of protocols at signaling and access levels, it was considered essential to guarantee the interoperability between different systems and networks.

4) Security

Security has always been a crucial part of any communications network. It has also encompassed a wide variety of topics. For an NGN this matter includes issues regarding network architecture, management, QoS, mobility and authentication, authorization and accounting (AAA), just to name a few. The initial stage of NGN development saw the emergence of the following key issues: creating an extensive security architecture, creation of security policies and guidelines and finally agreeing upon security protocols.

5) Generalized Mobility

This key concept embraced the idea of merging the fixed and mobile worlds in telecommunication. NGN was seen as something that gives users the ability to access services from any location and any technical network without discontinuation. The kind of availability mentioned here depends on many factors, for example agreements between the users' home network and visited networks, access network capabilities, etc.

Still, the end goal being the possibility to communicate from different locations, using a variety of terminal equipment.

Based on the work done by ITU-T with NGN standards regarding architectures, implementation guidelines and interface specifications, next generation networks have been defined in [20] as packet-based networks that are able to combine several access technologies with a single core and applications plane. In essence this means all the service-related functions are independent. A high level overview in Fig. 1.2 illustrates this principle.

Legacy services in former telephone-centric networks were designed and implemented in a strictly vertical manner. Virtually every service had its own access method and technology. The core or signaling level was implemented as an independent entity and the same applied for the application layer. Creating another service followed the same logic – separate access, core and application.

With the emergence of an NGN, service delivery architecture changed, moving from vertical to horizontal. This implementation creates a platform capable of offering services to customers independent of their access technology. Whether it be universal mobile telecommunications system (UMTS) or digital subscriber line (DSL), the SDP remains uniform, guaranteeing a single layer for access, signaling and applications.

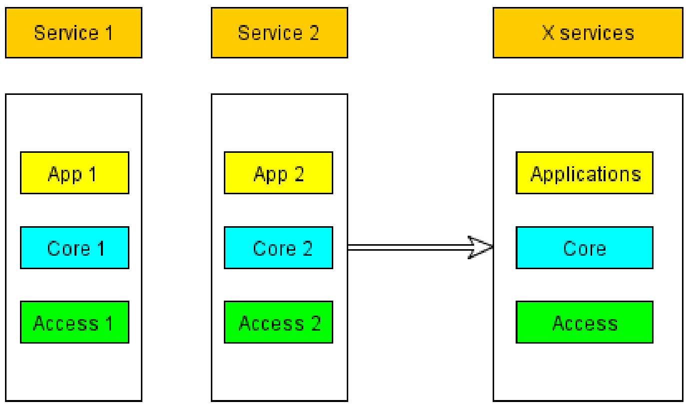

Figure 1.2. Transformation from stovepipe to a common platform ideology

A compendious list of the key aspects of an NGN, compiled by ITU-T has been noted in [19]:

1) packet-based transfer;
2) separation of control functions among bearer capabilities, call/session, and application/service;
3) decoupling of service provision from transport and provision of open interfaces;
4) support for a wide range of services, applications and mechanisms based on service building blocks (including real-time/streaming/non real-time services and multimedia);
5) broadband capabilities with end-to-end quality of service and transparency;
6) interworking with legacy networks via open interfaces;
7) generalized mobility;

8) unfettered access by users to different service providers;
9) a variety of identification schemes which can be resolved to IP addresses for the purposes of routing in IP networks;
10) unified service characteristics for the same service as perceived by the user;
11) converged services between fixed and mobile networks;
12) independence of service-related functions from underlying transport technologies;
13) support of multiple last mile technologies;
14) complying with all regulatory requirements, for example concerning emergency communications and security/privacy.

There are two core issues worth mentioning with regards to this list. Firstly, the emphasis on internet technologies like internet protocol. The tight relationship between next generation networks and IP is why an NGN is sometimes referred to as an all IP network. Secondly, many aspects in the given list refer to the use of a dominant protocol at the application and signaling level which enables the fulfillment of the stated criteria. This protocol is session initiation protocol (SIP). SIP has taken over from the formerly prevalent multimedia signaling protocol H.323 due to the fact that IMS adoption as a preferred service delivery platform has become widespread.

1.3 Work Done by ETSI

A standardization body called Telecommunications and Internet converged Services and Protocols for Advanced Networking (TISPAN), formed in 2003, is the competence center within ETSI that is responsible for fixed networks and their migration to next generation networks, so most of the NGN work matured under ETSI has in fact been produced by TISPAN.

TISPAN has defined an NGN in [21] as a packet-based network able to provide telecom services while making use of multiple broadband, QoS enabled transport technologies and in which service-related functions are independent from underlying transport-related technologies. In essence this definition is identical to the one given by ITU-T. This is however not surprising, considering the fact that TISPAN has based much of their work on work already done by ITU-T NGN Focus Group and added elements which take into account the European view of an NGN.

System components, depicted in Fig. 1.3, for next generation networks are described in [22] as:

1) customer networks (these include enterprise networks);
2) access networks;
3) core network (including the signaling domain, the transport domain and the application domain);
4) interconnect.

The standardization work done by TISPAN for NGN matured into three releases:

1) Release 1, published in 2005 [22] contained the architectural framework and basic specifications for future development. Two main goals were set:

    a. since IMS was already seen as the preferred SDP in NGN, Release 1 was to enable the delivery of services supported in 3GPP IMS to broadband fixed lines;

b. to enable either full or partial PSTN replacement.

Release 1 was made extensible to allow new services to be incorporated into its subsystems.

2) Release 2, published in 2008 added key elements to support IP television (IPTV) [23, 24] and business communications over IMS.
3) In Release 3, according to [25], emphasis was put on IPTV evolution, VoIP consolidation, ultra broadband and interconnection.

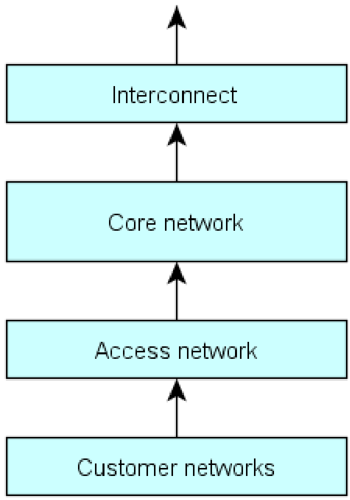

Figure 1.3. NGN system components

1.4 Services

Evolution Path

To expand the already mentioned notion of stovepipe services to networks, it can be said that legacy networks were designed and built for their native services. This means the fixed telecom network was built for voice communications, the mobile network also for voice, keeping in mind the aspect of mobility, the cable network for broadcasting television services etc. With the birth of an NGN however, this partitioning has been broken up. The changes that have taken place during the development towards next generation networks can be summarized as follows:

1) besides its native services, each legacy network tried to provide basic internet services, like email and web browsing, as well;
2) every operator and service provider made an effort to enhance its capabilities in order to provide the services of others. For instance telecom operators entered the broadcasting realm or internet service providers (ISPs) started offering telephony services;
3) emphasis was put on bandwidth increase, wireless access and mobility support.

The evolution from legacy networks to NGN has, according to [3], brought forth the following advantages with regards to services:

1) network-agnostic access to services, applications and content. The serving network will be chosen based on customer subscription, service requirement, terminal capability and network resource availability;
2) utilization of all access and transport networks as possible service access channels or carriers;
3) the possibility of integrating new access networks for the enhancement of access capability;
4) the possibility of integrating new transport networks for the enhancement of transport capability;
5) making the best use of co-existing access and core transport networks in order to utilize the network resources according to the requirements from the service domain;
6) the possibility to create an end-to-end connection that is manageable and also satisfies the QoS and security requirements;
7) and most importantly, the option to deliver and manage services on a common platform which is agnostic of the underlying transport network.

The evolution process itself is still ongoing for many operators and SPs and should ideally follow certain steps in a certain order. The number of these steps and their order, however, is in the hands of the operator or service provider in question.

Main Advantages

The core idea of an NGN, dismissing all the technological advances, is the ability to provide new and innovative services and the volume of these can only be limited by the imagination of its creators. However, there are a few widely mentioned showpiece services in next generation networks. Before taking a closer look at these, two issues regarding services should be highlighted. Firstly, service control. An operator or service provider can restrict the users' behavior on two levels: generally, meaning that the limitations apply to all users in the network and individually, as in the limitations only apply to a certain user. An example of a general restriction might be audio or video codecs. In case of limited bandwidth the operator may choose to deny the usage of a high bandwidth codec like G.722 and enforce the usage of the adaptive multi rate (AMR) codec instead. In legacy networks tailor made limitations were difficult if not impossible to impose but with the development of NGNs this has become a reality. For example the operator may prevent a user from setting up a multimedia session with video on a user-by-user basis irrespective of the fact that the end user terminal supports both audio and video. The key issue here is instead the agreement between the operator and user and whether the user has subscribed to multimedia services.

The second issue is the speed of service creation. The idea here is to not standardize the service itself but to standardize service capabilities and the interfaces towards NGN platforms. This translates into shorter time-to-market for any given service.

Core Services

The essential services of an NGN are as follows:

1) Standard voice

This is considered a default service and is taken for granted by customers. It is mentioned here for the sake of clarity to emphasize the fact that with the evolution of communication networks, the most basic and essential service has not faded away.

2) Presence

Presence can be thought of as a service on its own or as a service which will enhance the messaging service with presence information. To broaden the last notion, presence can be the heart of all communication. Figure 1.4 illustrates, from a general point of view, how presence can be used by not only end users but by other services as well.

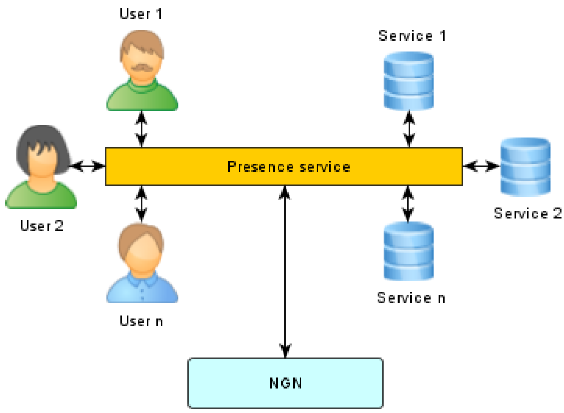

Figure 1.4. Presence as a source of information for users and services

Presence as a service, running on IMS, was initially defined in 3GPP TS 24.141 [26] and has since moved to Open Mobile Alliance (OMA) for further progression. The presence SIMPLE specification [27] describes the main notions within the service:

a. the presence source – an entity which provides presence information to a presence service;
b. publication – an act of revealing information about oneself by the presence source;
c. watcher – an entity which subscribes to presence information about a presentity or a list of presentities (presence list);
d. presence server – an entity which accepts, stores and distributes presence information.

Therefore, in essence the service has a simple design – someone publishes information about themselves and someone else watches that information and uses it according to their needs. Since a single user or a service can watch a number of other users or services, presence requires the need to manage lists. This functionality is provided by the resource list server (RLS) which is an application server from the IMS point of view. The RLS enables a watcher to subscribe to multiple presentities using a single subscription.

The presence information published by a user can be seen as status information. This is always personal and may contain data such as location, terminal capabilities, preferred contact method or even the mood the user is in. Hence, using presence, the user is in a constant outbound communication mode, letting everyone else know when, how and by what means he or she is willing to interact.

3) Messaging

There are two forms of messaging services available in the IMS context. The first one being session based messaging and the second one being immediate messaging which is sometimes referred to as pager mode messaging.

The mandate for IMS terminals to implement the MESSAGE method was first introduced in 3GPP 24.229 [28] to allow its implementation as an optional feature in serving call session control functions (S-CSCFs) and application servers (ASs). Figure 1.5 illustrates a session based messaging flow. This type of messaging differs from pager mode messaging in a sense that whilst in pager mode each message can be considered separate from the previous one, in session based mode, like the name implies, a session is set up before the exchange of messages using a SIP INVITE method and session description protocol. The message session relay protocol (MSRP) is the actual protocol used to transport the messages within the session.

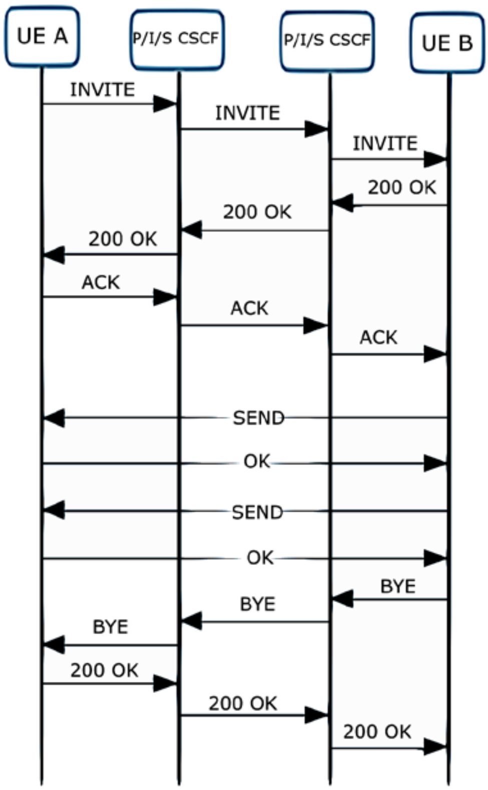

Figure 1.5. Session based messaging flow

Immediate messaging, with the messaging flow depicted in Fig. 1.6, using the SIP MESSAGE method, is a type of messaging where the user equipment (UE) on side A generates a request, fills it with appropriate content and sends it to the UE on side B. The content is not limited to text only but can also contain other types of media such as pictures or sounds. The immediate messaging service also considers a situation when an IMS subscriber is offline or in an unregistered state. In this case the AS holds the messages in storage and delivers them when the subscriber registers to the network.

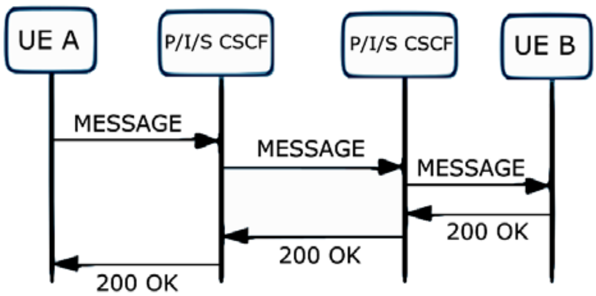

Figure 1.6. Immediate messaging flow

4) Conferencing

With legacy networks conference traditionally meant that a private branch exchange (PBX) user had the possibility to call a small number of other users individually and join them all in a single conference call. In the context of an NGN this service has changed to introduce a possibility for users to dial in to a conference service and be joined into a single conference call. Also, the service is enhanced to offer not only voice communication between multiple participants but also video, images and share desktops. Still, the basic principle of the service has remained the same: to create a multiparty call where every participant can communicate with a number of other participants simultaneously.

The architecture used in an IMS conference is shown in Fig. 1.7. The key entities here are the Media Resource Function Controller (MRFC) which is the central node of the service that controls the signaling related to the conference. All the media in the conference is however terminated in the Media Resource Function Processor (MRFP) which is also known as a mixer since it combines all incoming media streams from all participants and sends the mixed stream back to the participants, so everyone is aware of the media sent by everyone else. The MRFC controls the mixer using the H.248/MEGACO protocol.

Additionally, the MRFP is responsible for transcoding as well since participants can use different audio and video codecs. In order for every conference participant to understand every other participant, a translation between codecs is needed.

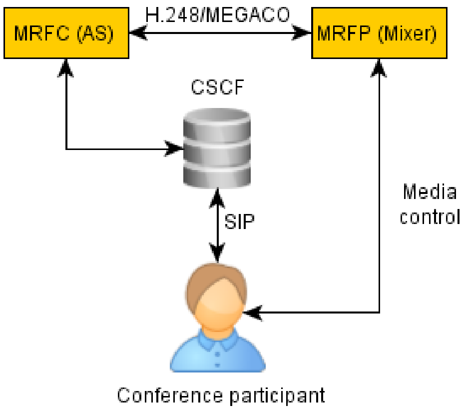

Figure 1.7. The architecture for a conferencing service in IMS

The notion of a conference moderator is also introduced. The moderator is a participant in the conference who has special privileges to give and withdraw the right of other participants to speak – this is called floor control. Floor control is used directly over the media connection, from the user equipment to the MRFP.

5) Multimedia telephony

So far this chapter has discussed services individually. However, users can enrich their communication experience using supplementary services as well as combining the previously mentioned individual services. Collectively, in IMS, this combining is referred to as using multimedia telephony. In a typical situation, a multimedia session enables the user to use voice in conjunction with other types of media and also with different supplementary services like communication barring or communication forwarding unconditional, just to name a few.

With supplementary services, in some cases, due to the similar services used in PSTN/Integrated Services Digital Network (ISDN), the term PSTN/ISDN simulation services is used. A sample list of widely used supplementary services can be found in Appendix B. In IMS the application server is the entity responsible for providing supplementary services which in realization differ from the ones in PSTN/ISDN since SIP is used as a call control protocol. Furthermore, since in SIP the notion of a call does not necessarily only mean voice but it can be broadened with multimedia, subscriptions, messages or notifications, the PSTN/ISDN simulation services refers to communication rather than a call.

1.5 Migration Scenarios Worldwide

Network operators across the world have taken different paths on their way to migrating away from legacy networks. [29] has found that there are two fundamental collection of issues that are facing an operator or service provider before and during migration: non-technical and technical issues. While the technical difficulties are often straightforward, the non-technical ones require more attention and can affect the migration process on a wider scale. These issues include, but are not limited to, for example the cost of migration, resource allocation in general and deciding upon the strategies used for migration. In the current section the author of the thesis has compiled examples of best practices of the work done so far by multiple telecommunication operators and service providers to demonstrate the current state of affairs and to describe how dealing with the mentioned challenges has been resolved.

The Vast Dimensions of the CIS

The Commonwealth of Independent States (CIS) with its 280 million inhabitants and a vast geographical area is an example of a sophisticated migration situation. On the one hand this can be attributed to the mentioned geographical size and on the other hand historical background. [30] describes how a fixed network with a long history may end up being highly hierarchical. In this specific case the telecom network has been historically divided into the international part and the regional areas – in addition, these regional areas are further divided into urban, suburban and combined networks and these in turn are divided into even smaller networks. And just as the communication network has evolved step-by-step, so has the signaling. At one time dozens of signaling protocols were in use, a number that has been reduced to around 5 today. With regards to legacy networks, Signalling System No. 7 (SS7) being the most important one.

Until the end of the 20th century the telecommunications market was controlled by the incumbents but in the beginning of the 21st the CIS market was opened up to new operators and service providers and the current telecom market as such with a combined total of roughly 250 million affiliations (fixed, mobile, broadband) still has room for new players.

The migration process was envisioned as smooth, basically invisible to the customer, however achieving this proved troublesome, especially considering the somewhat isolated status of the rural areas. Investments to these areas were planned and made carefully with the notion of backward compatibility in mind as the investment cycle was known to be very long. The transition to an NGN was started by introducing packet based technology on the transit connections and to the urban areas. This task was rushed since a number of old network nodes had reached their end of life and were therefore discontinued at a swift pace. As planned, urban areas were slowly and constantly inseminated with Class 5 call servers and respective application servers and the notion of MultiService Access Nodes (MSAN) was introduced. An MSAN is a node capable of connecting a variety of last mile access technologies all the while packet based technology is used towards the core of the NGN. With this solution, PSTN subscribers could be ported to the NGN solution and thus provide services from the application servers.

In the rural areas the main issues to tackle were a large number of discontinued PSTN nodes, long distances and different price policies. NGN was clearly seen as the way forward, however it was not thought feasible that large Class 5 call servers could adapt to the needs of both rural and urban users. Hence, nodes called MultiService Control Nodes (MSCN) (also includes AS functionality, so in a way these can be called local ASs) were introduced to offer the same advanced services and functionality as with the core nodes of an NGN but on a local level, thus also adding resilience to the whole communication network solution.

Class 5 servers are currently and will be in the foreseeable future upgraded to CSCFs and the signaling will use IMS specific protocols while Plain Old Telephony Service (POTS) clients are connected to IMS by the use of Access Gateway Control Functions (AGCF) which convert protocols between PSTN and IMS.

The previous sections describe what can be called an overlay solution for migration and it is widely used among operators since it offers a lot of flexibility in planning, resource allocation and execution. For operators operating in large countries, like the ones belonging to CIS, this is the most feasible method for moving away from legacy networks.

Different Strategies Used by the Incumbents

The overlay solution is not the only possible method for migration. Three main strategies can be identified: full PSTN replacement, overlay of an NGN and legacy network and building the NGN from the start. As mentioned earlier in this thesis different telecom operators choose their path towards an NGN based on specific conditions applicable only to them. The following sections illustrate some of these conditions and describe the status to which the operators have arrived to.

In [31] British Telecom (BT) and Verizon are described as examples of full PSTN replacement. BT announced their initial migration plans in 2004. The next generation network was to be known by the acronym 21st Century Network (21CN) and it was to be built over the next six years with a CAPEX of ca £10 million. However, the program is still ongoing today. The trial for 21CN began in 2004 where three major network nodes were connected via IP and 1000 clients were connected via an IP/Multiprotocol Label Switching (MPLS) network. In 2005, additional 3000 subscribers were added. Further development of the NGN saw the construction of an MPLS core network with the use of MSANs, similar to the CIS case.

Large scale migration to the NGN began in 2007 when yearly cost savings were expected to be around £1 billion. Ultimately, in the fear of losing major enterprise clients, BT decided to deflect from the initial plans in favor of a partially overlaid network to retain its client base. So all-in-all the strategy is PSTN replacement, except for the enterprise clients. According to [32], old services and products were to be decommissioned in 2016 at best. British Telecom wholesale figures indicate [33] that today services are provided to nearly 18 million clients.

Verizon, operating in roughly 30 states in the USA and 150 countries worldwide, began the transition to packet based technology already in 1999 in the realm of long distance transit. In 2004 softswitches were installed for local applications within smaller areas and mainly cities. The establishment of an IP backbone started in 2003 with IP/MPLS and 2004 saw the start of a fiber-to-the-premise (FTTP) project with the ultimate goal of a complete replacement of the legacy copper PSTN network. The perceived copper network replacement was envisioned to take place within the next 15 years. Similarly to the BTs case, Verizon saw the cost of maintaining a legacy network as being too high and thus a transition to an NGN was inevitable.

Today the process is still ongoing with remaining parts of legacy networks being replaced by Wavelength Division Multiplexing (WDM) technology while IMS is used as the SDP of choice. Verizon, along with AT&T, is also the main driver of Voice over Long Term Evolution (VoLTE) in the USA with their Advanced Calling 1.0 first generation service suite made available to the market in September 2014. AT&T released a similar package to the general public earlier in 2014. At the time of writing this thesis, both companies are working on VoLTE interoperability [34], said to be released sometime in 2015.

Slovak Telecom (ST) and China Telecom (CT) are considered to have taken the overlay approach to migration. In ST, by the beginning of the 21st century about 70% of the PSTN infrastructure had been digitized and this was mainly in the urban areas of the country. Largely thanks to Deutsche Telekom, a majority owner in ST, a contract was signed in 2004 to start replacing legacy infrastructure with NGN infrastructure. The core network was, like in the previous cases, built using IP/MPLS technology. The fact that a large telecom operator had a stake in ST was a major enabler which made it possible for the migration to start and progress. The resources received were in the form of CAPEX, OPEX and knowhow.

The external support helped ST to initiate a strategy where firstly the rural areas were inseminated with NGN technology. This may seem illogical at first glance, however this step made it possible for ST to gain much social approval and make it possible for a large number of subscribers to be easily added to their network over the next few years. It is highly likely that many operators across the globe adopt a similar approach to migrating – skipping over the digitalization of the PSTN network and moving straight from analog exchanges to next generation networks. Today, the migration process in Slovak Telecom is ongoing with IMS being used as the service delivery platform.

China Telecom is a monopoly in the telecommunication area in a country with more than half a billion people having internet access, roughly 150 million users with broadband access and more than a billion mobile subscribers. CTs PSTN network has a concrete hierarchical structure with the nodes being relatively new (15-20 of age). Keeping the previous statement in mind, it can be said that the primary reason for the migration was and still is the general growth in the economy and the increase in client demand.

The migration to NGN infrastructure began in 2004, with IP/MPLS as a core network. However, all the upgrades were made with the notion that PSTN will exist in the foreseeable future. This kind of an overlay process can be considered the only option for a telecom operator of this magnitude. Every action simply takes a long time and resources dictate that new technology must be deployed in phases. On the positive side, this kind of solution guarantees a fast time-to-market for services in smaller regions. From a negative point of view there is no reduction of network cost since both the PSTN and NGN have to be maintained simultaneously. As the biggest player in the telecom market in China, China Telekom has, similarly to Verizon, already introduced VoLTE to the public as of January 2014 and made a successful VoLTE roaming implementation [35] with KPN in The Netherlands in October 2014.

TeliaSonera in Northern Europe

TeliaSonera, through its subsidiaries, is the market leader in the telecommunications sector in the northern part of Europe, i.e. Scandinavia and the Baltics [36]. The operator has a long history and is providing four main services: mobile, broadband, fixed voice (VoIP) and television.

[29] focuses on the migration away from legacy networks in Estonia and Sweden. At the beginning of the 21st century 90% of the operators' profit in Estonia came from PSTN. By 2011 this number had reduced to 20%. In addition to the declining revenue and profit

numbers the migration was, initially, forced by two additional factors: the dissemination of broadband and the deterioration of legacy hardware and lack of support for the PSTN. Today, the importance of the lastly mentioned issue has diluted, however it is still noteworthy.

In Estonia 2005 saw the first steps being taken towards an NGN and more specifically IMS. A competing softswitch solution was also discussed but a detailed analysis did not justify this. IMS core was set up and it was running by the end of 2006 while the actual large scale migration did not start before 2009. At the time of writing, roughly 250 000 business and private clients have been migrated to IMS and no forceful tactics have been used during this process - the migration decision is up to the customer.

In 2015 specific programs targeting the issue of migration were started, with the goal of accelerating the migration process. It is estimated that the PSTN will be closed in 2016.

The last quarter of 2014 witnessed the merger of the two largest telecom operators in Estonia (one fixed, one mobile), both owned by TeliaSonera. This means issues with technologically bringing the two entities together will have to be tackled which in turn complicates the migration process. The formed company, Telia Estonia Ltd, is currently also working on a VoLTE project, due to be released in the second half on 2016.

The situation in Sweden at the beginning of the millennium was similar to the one described in Estonia – the main reason for the migration to an NGN was the end of the PSTN lifecycle. To mitigate the situation, a successful business case was created and an IMS core was set up in 2007 and migration started in 2009. Currently it is forecasted that the migration process will continue in the foreseeable future with roughly 100 000 customers per year. The biggest problem TeliaSonera in Sweden is facing is the distribution of broadband since it holds a broadband market share of 40% which limits the amount of potential customers. Operators in both countries share concerns about supporting systems with regards to the migration process. Fixed voice traditionally has a longer history, meaning its supporting systems are more voluminous and integrating mobility into the existing may prove to be challenging.

1.6 Summary and Assessment

With the emergence of NGNs, the author of this thesis denotes the following:

1) A shift in service delievery has occurred from the previous stovepipe approach, distinctive to legacy networks, to a situation where the service related functions have been separated from the signaling and access realms, thus moving from a vertical to a horizontal paradigm in offering services to customers.
2) The users have become active contributing entities of a communication network, in essence being the core of an NGN with services built around them and at their disposal.
3) With regards to standardization, looking at the early work done by the mentioned organizations in this Chapter, it is clear that the core keywords for NGN development (QoS, security, evolution etc.) still hold true today. It is the view of the author that this trend will continue in the foreseeable future.
4) From a technical perspective:

a. NGNs cannot be successful without the proliferation of broadband. Most operators today are assigning substantial resources for implementing new BB technologies or updating their legacy networks with these, in order to gain revenue through offering state-of-the-art multimedia services which otherwise would be impossible.

b. For most operators the migration has started with initially implementing an IP core and then deploying MSANs or similar equipment to connect different last mile technologies to the core.

Considering the migration strategies used by the operators, a common cause to initiate migration can be specified as deterioration of legacy equipment and loss of revenue. Although different operators have demonstrated different approaches to migration, the overlay solution is the first choice for most. Taking into account the authors' experience, this can be considered reasonable as it enables a company to spread their resource consumption over a longer period of time. Additionally, the author notes that using the overlay solution also has a downside. Keeping the legacy network and NGN in operation in parallel for a period of time burdens the operator or SP excessively and can result in hasty decisions regarding migration, which in turn may cause problems at later stages of the process.

2 IP Multimedia Subsystem

The IP Multimedia Subsystem is considered in [37] as a next generation service delivery platform which consists of a modular design with open interfaces and enables the provisioning of multimedia services over IP technology. It has been described as a highly complex platform. However, in the view of the author, considering the possibilities and services it offers, this is understandable. A modest list of capabilities include for example managing user terminals, application servers, routers, billing systems, roaming, security policies, authentication and registration. Add to the list the core nodes, which will be expanded upon in later sections of this thesis, with their interfaces and the core idea of IMS becomes clear – creating a platform which is flexible and does not standardize specific services but rather their enablers which make it possible to offer services.

Although not an entirely new concept in the modern world of telecommunications, IMS is still considered to be a very novel and developing technology. While, at the time of writing, most IMS operators gain their majority of income from fixed-line VoIP, it is clear that VoLTE will be the main driver for further IMS deployments. Also, as the world is moving towards becoming even more mobile, Fixed Mobile Convergence (FMC) is another issue to be tackled if one wishes to be a successful operator in today's telecommunication market.

IMS was created and has been considered as the remedy for big telecom operators and service providers to retain and increase their market share. Due to the horizontal layered architecture of the IMS, service creation is fast and management at a later stage of the service's lifecycle is simple. According to [38], even a solution where 3rd party service providers only create and provide services through an application market (similar to Google Play or App Store) to IMS operators, seems very feasible.

Despite the seemingly infinite possibilities that IMS provides it is not without fault. It is in essence an overlay, all IP, technology on top of different access networking. Originally developed by 3GPP for the mobile domain and later expanded by TISPAN for fixed networks, the IP Multimedia Subsystem can therefore provide a seamless service delivery platform for fixed mobile convergence. However, this collection of different access technologies and networks, the usage and integration of multiple protocols on a single platform makes the subsystem vulnerable to security threats.

The following paragraphs will present the authors' view of IMS in an explicit way with regards to the topic of the thesis. The compiled overview starts with standardization and the releases through which IMS has been delivered. This can be considered an addition to Chapter 1 as the releases clarify more specifically how an NGN has developed into its current state. The standardization section is followed by a discussion of the general architecture of IMS along with its core nodes and key protocols. As with the NGN chapter, the author has composed this data in order to give the reader background information to get a deeper understanding of the general topic and how IMS is involved in it.

2.1 Standardization

As mentioned in earlier paragraphs, next generation networks are often called all IP networks. This notion also broadens to IMS, which means the main emphasis with standardization is how to make the internet protocols work in the IP Multimedia Subsystem since these might not provide the full functionality needed in IMS or the functionality does not exist at all.

The biggest and most influential standardization bodies that have contributed to IMS are 3GPP and 3rd Generation Partnership Project 2 (3GPP2). These have been involved with the standardizing process from the beginning and have done similar work with the exception that 3GPP2 has represented the interests of the North American and Asian markets. The basis for their work is, as mentioned, in the form of internet protocols, standardized by the IETF. 3GPP was set up in 1998 to evolve the Global System for Mobile Communication (GSM) network. 3GPP2 emerged at the same time to speed up the development from second generation networks towards third generation (3G) mobile even further. Since there were many participants in the standardization process from the start, arrangements were made to set up formal links between 3GPP, 3GPP2 and the IETF to develop IP standards for third generation networks. The subsystem capable of handling signaling for 3G networks was found to be namely IP Multimedia Subsystem, based on SIP.

In addition to 3GPP and 3GPP2 many other standardization organizations have contributed to IMS of which two deserve mentioning. TISPAN, already expanded upon in earlier sections, has been working on fixed network access based on IMS and Open Mobile Alliance (OMA) has been active in the interoperability realm. OMA, with background in wireless industry, was formed in 2002 and has since consolidated with many mobile service enabler organizations such as the WAP Forum to create service enablers that allow interoperability of services.

Releases

The standardization work done by 3GPP has matured into 13 releases by the time of writing this thesis. A single release is essentially a collection of mobile network standards, rules or definitions, facilitating the development towards a third generation network. IMS was first mentioned in Release 5 and is therefore sometimes referred to as IMS Release 5. This release is the most voluminous when it comes to IMS since all of the basic notions and principles were defined for the first time.

The following paragraphs will give a brief overview of the key issues tackled within the releases regarding IMS. Since the fundamental notions of IMS were addressed in the first few releases (starting from Release 5 as mentioned), the information from the final releases have been consolidated under a single paragraph.

Release 5

According to [39], the objective of IMS is considered to be the support of applications which involve multiple media components like video and audio with the possibility to add and drop components during the session. These applications are defined as IP multimedia applications or services. The efficient support for these services lies in the possibility to disassociate different flows, which have different QoS characteristics, within a multimedia session. As these characteristics are known to the network, it is possible to handle them more efficiently. The necessity to disassociate the session establishment from the bearer establishment was also established.

For the handling of the signaling and user traffic related to services, a set of new dedicated entities was created. This is called the core network. The nodes of the core will be discussed in later sections of this thesis.

Without diminishing the value of other aspects defined in Release 5, the introduction of SIP, defined by IETF, could be considered the fundamental notion. The decision to use SIP was due to its flexible syntax – a property which facilitates the development and interconnectivity between 3GPP and fixed IP networks.

The matter of codecs is also addressed. [40] contains the set of default codecs for multimedia applications within the IMS. The audio and video codecs are addressed separately and are assumed to enable low-delay and real-time functionality. The use of other codecs not included in [40] is not limited, should the end user or application require it.

A list of aspects related to the introduction of the IMS in Release 5 also include:

1) access security for IMS;
2) integrity protection;
3) security of SIP signaling between network nodes;
4) user authentication;
5) lawful interception;
6) SIP Compression;
7) charging;
8) IMS to circuit switched (CS) interworking (basic aspects, others in later releases);
9) Customized Applications for Mobile networks Enhanced Logic (CAMEL) in IMS.

Release 6

[41] lists the additions and amendments to IMS Release 5. The main additions include group management, presence and messaging while the shortcomings of the previous release regarding several items have been addressed. These include for example lawful intercept, enhancing SIP capabilities and interworking between IMS and IP networks.

Messaging, presence and IMS group management have been mentioned for the first time in [42] where it is proposed that the support for messaging be standardized in a way that terminals from different vendors are interoperable. In essence this implies that the requirements for the support of messaging in IMS are such that 3GPP should only specify the capabilities to enable the services in an interoperable way. In addition, messaging in IMS should be based on the services already standardized by 3GPP, such as Short Message Service (SMS) and Multimedia Messaging Service (MMS) and all existing IMS capabilities like privacy, charging, QoS, security be used.

In Release 6, 3GPP also defines the support for Push-to-talk over Cellular (PoC) with the actual feature itself defined by OMA. The PoC was a much anticipated "walky-talky" type of application applied to the mobile realm where users could converse in half-duplex voice communication using voice bursts transfer. [43] specifies the architectural concepts and general notions for the IMS to support the PoC service as specified in OMA.

Although IMS was initially designed in Release 5 for cellular IP networks, Release 6 sees the separation of all access specific issues from the IMS core. This means that the transport services are separated from the signaling and session handling services.

Release 7

Release 5 and Release 6 IMS proved to be successful enough to, ironically, bring about a slight drawback. Namely, the initial approach of 3GPP was to create enablers so that services could be created and used in IMS. However, as this approach turned out to be so successful, it led to the situation where neither the enabler being used nor the media being used was sufficient enough to identify a particular service. [44] lists the reasons why it is necessary to identify the communication service requested:

1) the network is required to identify the correct application server(s) to link into the SIP call path, if required;
2) the media authorization policy may use a communication service identifier as input;
3) it is desirable for the network to be able to authorize the use of a communication service;
4) charging may use a communication service identifier as input;
5) in a multi-UE scenario where a recipient has several UEs with different UE capabilities, it is useful to be able to route the SIP request to the UE(s) supporting a requested communication service;
6) in order to enable the UE to identify the correct application logic, while allowing for many services to be offered using the same enablers and media types;
7) often interworking requires knowledge of the services being interworked, as such interworking between an IMS based service and a non-IMS based service may benefit from the identification of the requested communication service;
8) allowing the network to authorize the use of the service for a particular user;
9) communication service prioritization in the case of network overload;
10) to be an input into inter-operator interconnect service level agreements;
11) provide a scope for the interoperability specifications related to a particular communication service.

Release 7 addresses the issue of identifying the requested service by defining a service identifier (ServID). The ServID also has the advantage, besides the already listed ones, of reducing the coordination between standardization bodies and ensuring that encoding across these bodies is the same. In brief, Release 7 IMS solves a major issue holding back further development and in tight cooperation with TISPAN, an effort is made to making it a truly all IP service delivery platform.

Releases 8 through 13

In addition to paying attention to the known issues of Release 7 IMS, such as security issues, Release 8 [45] continues addressing the matter of voice call continuity (VCC) which started in the previous release. Release 7 only covered voice media transfer between circuit switched and IMS domains within 3GPP and Release 8 expands on this further. Based on [46] and [47] the IMS Centralized Services framework is created to provide service continuity.

Multimedia interworking between IMS and the CS domain also receive further attention. The basic principles were noted already in Release 5 IMS and with Release 8, Media Gateway (MGW) and Media Gateway Control Function (MGCF) functionality is specified to allow interworking between the CSCF and CS networks in the control plane.

Also starting from Release 8 up to Release 13 the main emphasis of 3GPP has shifted to Long Term Evolution (LTE) and the matters regarding IMS are no exception. The world of telecommunications is clearly moving towards a wide spread of LTE networks across the globe and in general, starting from Release 8, this matter has been taken under thorough revision with defining all the basic notions, system architecture and interworking with IMS. The system is further developed in next releases, for example as part of Release 9, based on [48] and [49] the matter of support for IMS emergency calls over LTE is specified.

2.2 General Architecture and Core Nodes

The simplified architecture in Fig. 2.1 illustrates a general view of IMS nodes and their interconnections. Only the nodes of key functionality and relevance to this thesis have been depicted.

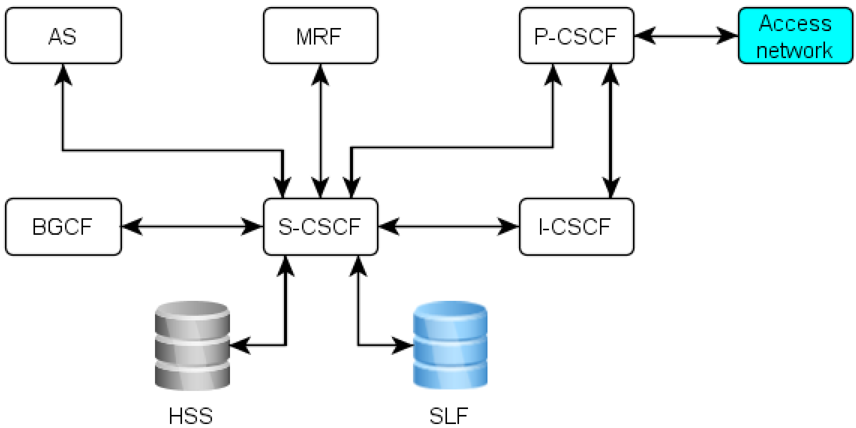

Figure 2.1. A high level overview of an IMS architecture and main nodes

Core Nodes

Call Session Control Function (CSCF)

The CSCF, which is a SIP server, is the central node in the IMS core. Its task is to process the SIP signaling in the IMS and it can be further divided into logical nodes depending on its specific function. Although in literature the mentioned logical nodes are mostly expanded upon separately, these can in fact also be collocated in a single physical node. According to [50] and [51] the CSCF can be divided as follows:

Proxy Call Session Control Function (P-CSCF) – located in the home or visited network, the P-CSCF is the first contact point between the UE and the IMS network and it acts as an outbound/inbound SIP proxy server. It is allocated to the UE during its initial registration and remains constant throughout the whole time the UE is registered.

The P-CSCF also has several roles with regards to security. First of all it establishes the IP security (IPSec) associations, which are used to offer integrity protection, towards the terminal. Secondly, it authenticates the user and asserts the identity of the user to the rest of the nodes in the core. By doing this the other nodes do not need to authenticate the UE each time since they trust the P-CSCF. Finally, the P-CSCF is used to verify the SIP requests sent by the IMS terminal, thus making sure only correct SIP requests are sent towards the core.

Since SIP is a text based protocol, the messages may become large and can therefore cause delays when being transmitted over a narrowband channel. The P-CSCF can mitigate this problem as it includes a compressor and a decompressor to reduce the size of SIP messages. This compression mechanism is called signaling compression (SigComp).

The P-CSCF can also be used to manage QoS over the media plane and generate charging information towards a charging collection node.

Interrogating Call Session Control Function (I-CSCF) – usually located in the home network, the I-CSCF is a SIP proxy at the edge of an administrative domain. There are typically a number of I-CSCFs in a network for the sake of scalability and redundancy. Its address or addresses are listed in the domain name system (DNS).

As the name implies, the I-CSCF is used to find the next contact point for a SIP message. Meaning, when a SIP server follows SIP procedures to find the next SIP hop for a specific message, the server first obtains the address of the I-CSCF of the destination domain. In order to accomplish the mentioned functionality the I-CSCF has an interface towards the subscription locator function (SLF) and the home subscriber server (HSS), based on the Diameter protocol. This interface is used to retrieve user location information and route the SIP request to the appropriate destination.

The I-CSCF also has an interface towards the application servers in the core in case there is a need to route requests that are addressed to services.

Additionally, the I-CSCF may have a functionality called topology hiding inter-network gateway (THIG). This refers to the aptness to encrypt parts of the SIP messages that may contain sensitive data about the domain, such as the number of servers in the domain or their DNS names.

Serving Call Session Control Function (S-CSCF) – a SIP server, always located in the home network, the S-CSCF is the central node on the IMS signaling plane. It performs session control and acts as a SIP registrar. This means it maintains a binding between the location of the user (the IP address the user is logged onto) and the users SIP address of record (AoR) which is also known as a public user identity (PUI). An IMS network typically includes a number of S-CSCFs for the sake of scalability and redundancy.

All the signaling an IMS terminal sends and receives passes through the allocated S-CSCF where the messages are inspected for possible routing to one or several application servers. The ASs could potentially provide a service to the user.

The S-CSCF also, like the I-CSCF, has an interface towards the HSS based on Diameter. HSS contains the authentication vectors of a user trying to access the IMS. The S-CSCF downloads and uses these vectors during the authentication process of the user. In addition, the HSS houses all the user profiles which are a set of triggers telling the S-CSCF which ASs should the SIP messages be routed to. The S-CSCF also uses the interface towards HSS to inform the HSS that this is the S-CSCF allocated to a specific user for the duration of the registration.

The network operator may choose to enforce certain policies to the users. Limiting the establishment of specific sessions or prohibiting a user from using certain types of media may be an example of this. The S-CSCF may be used for this kind of policy enforcing.

The notion of SIP routing services should be mentioned here as well as one of the functions of the S-CSCF is routing. Namely, in an occasion when a user dials a telephone number instead of a SIP uniform resource locator (URI) the S-CSCF provides translation services, based on DNS E.164 number translation and routes the signaling out of the IMS core.

Home Subscriber Server and Subscription Locator Function

An evolution of the Home Location Register (HLR), the HSS is the central database of the IMS containing user related data. This data contains, among other items, the users' authentication and authorization information, location information, user profile and the S-CSCF allocated to the user.

In a situation where the number of users in the network is too high for any single HSS to handle, more HSSs have to be added to distribute the load. It is important to note however that in a multi-HSS situation all the data concerning one user is stored in a single HSS.

With multiple HSSs an SLF is required. The SLF is essentially a simple database which maps the users' addresses to HSSs. Stemming from this, a network with a single HSS does not need an SLF. The SLF is queried with the user's address as input to find out the HSS related to that user as output. The HSS and SLF both implement the Diameter protocol.

Application Server

The application server, residing in the users' home network or in a third-party location, is the node in the IMS architecture that hosts and executes services. It is however not a pure IMS entity, instead it may be thought of as a function on top of IMS.

Keeping in mind that the services offered are not only limited to SIP-based services, Fig. 2.2 illustrates the different types of AS:

1) **SIP AS** – this is a native AS that host and executes IP multimedia services based on SIP.
2) **Open Service Access - Service Capability Server (OSA-SCS)** – this AS provides an interface towards the OSA framework. According to [71] SCS is a synonym for gateway and this is how the SCS should be viewed – a gateway towards the core network. Essentially then, on the one hand the OSA-SCS acts as an AS (interfacing with the S-CSCF using SIP) and on the other hand it provides an interface between the OSA AS and the OSA Application Programming Interface (API).
3) **IP Multimedia Service Switching Function (IM-SSF)** – this type of AS allows the reuse of CAMEL services in IMS that were developed for GSM. The IM-SSF allows the GSM Service Control Function (gsmSCF) to control an IMS session. [72] specifies the IM-SSF – gsmSCF interface and in essence defines the IM-SSF, on one side, as an AS (interfacing with the S-CSCF using SIP) and on the other side as a Service Switching Function that interfaces with the gsmSCF using the CAMEL Application Part (CAP) protocol.

Unless otherwise mentioned, this thesis considers the AS to be a native AS which interfaces with the S-CSCF and I-CSCF using SIP and with the HSS using Diameter.

Additionally, an AS may provide IMS terminals with an interface used for configuration purposes and may be used to retrieve charging information.

The signaling, for both originating and terminating cases, may be routed to the application server by the S-CSCF based on the triggers downloaded upon the users' registration from the HSS. These triggers contain Initial Filter Criteria (IFC) which describe the necessary control logic. With certain services the AS is also capable of initiating an originating call on its own. This is called a Call Out Of Blue (COOB).

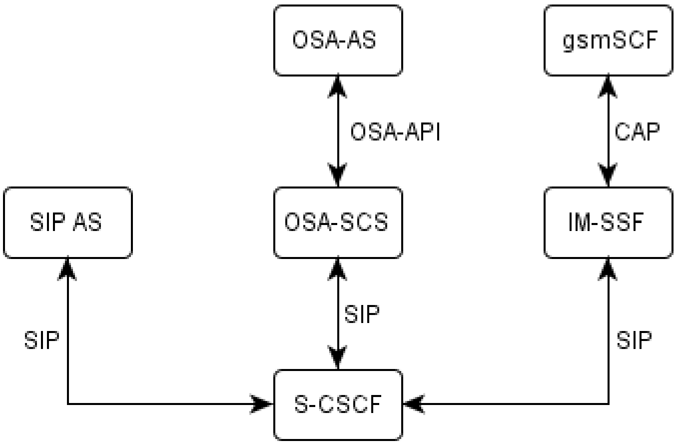

Figure 2.2. Different types of AS

Breakout Gateway Control Function (BGCF)

When an IMS user dials a number belonging to the CS (PSTN for example) domain, the call must be routed out of the packet switched (PS) domain. The BGCF is used for this.

The CS number is dialed in the form of a Telephone URI (TEL URI). When this happens the S-CSCF serving the caller performs an E.164 Number Mapping (ENUM) query to convert the TEL URI into a SIP URI since routing in the IMS is based on SIP URIs. However, in the case of a dialed CS number this conversion fails and hence the S-CSCF knows to route the call out of IMS through a BGCF. The latter has two options: either route the call to a breakout point in the same network or select a different network and route the call there for breakout to the CS domain. Figure 2.3 illustrates this logic.

In the case where a breakout point in the same IMS network is chosen the BGCF selects an MGCF to convert signaling between SIP and ISDN User Part (ISUP) or Bearer Independent Call Control (BICC) and control the MGW. The BGCF also uses a Signaling Gateway (SGW) for transport protocol conversion. When a different IMS network is selected, the BGCF simply routes the call to the BGCF in that network.

Media Resource Function (MRF)

The MRF provides a source of media for the home network where the MRF is always located. It is divided into a signaling node called MRFC and a media plane node called MRFP. As the name implies, the MRFC is tasked with controlling the MRFP via an H.248 interface while the MRFP implements media related functions such as playing and mixing media streams, transcoding between codecs and obtaining statistics.

The MRFC also controls the MGW which is responsible for providing a user-plane connection between the CS domain and IMS. The MGW can provide transcoding and signal processing when necessary and offer announcements and tones to CS users.

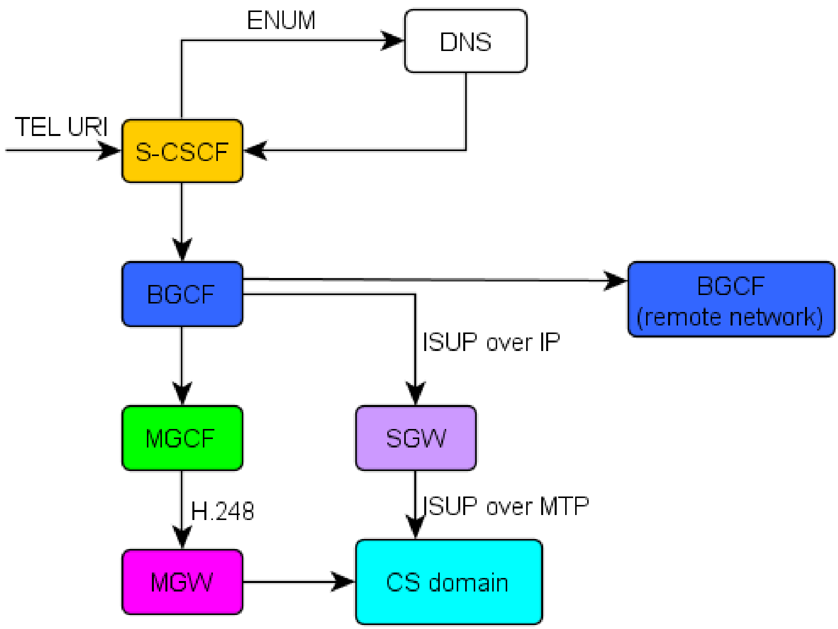

Figure 2.3. Breakout from the IMS network using a BGCF

2.3 Reference Points and Protocols

Compared to the PSTN, where SS7 was and still is the prevalent set of protocols for signaling, multimedia signaling is more complex. This can largely be attributed to the need for the UEs to negotiate and agree upon the media handling between each other. In addition, the terminal and network must settle on the quality of service the UE needs.

In the early stages on VoIP, an existing protocol suite, H.323, was seen as the enabler for multimedia communication, however it was soon deemed inadequate for the task. As a replacement, the IETF developed SIP which has remained as the protocol of choice for multimedia sessions over IP and is the central protocol in IMS together with Diameter and Real-time Transport Protocol (RTP). The next sub-sections will encapsulate the essence of the mentioned core protocols of IMS.

Session Initiation Protocol

The Session Initiation Protocol is an application layer protocol used for setting up, tearing down and modifying multimedia sessions. All of the outcomes when using SIP are defined in [52] through the notion of a method. A method is the primary function that a request invokes on a server. The core method in SIP is INVITE, which is used for establishing sessions. Initially 6 methods were defined in [52], however this number has now increased to 14 with more recent request for comments (RFC) documents.

Based on [53] and [54] SIP has, in essence, the fundamental task of delivering a session description from one user to another at its current location. Once this has been accomplished successfully, further descriptions can be sent to modify or tear down the existing session. Hence, the notion of a session description has been formulated and a standard way of characterizing a session defined. The session description protocol encapsulates a textual representation of a multimedia session, e.g. the IP addresses, different ports and codecs used in the session etc. Although the session description protocol is most often used with SIP it must be noted that the two need not be used together since SIP is essentially independent from the specific session description used.

The session between two endpoints is described in a textual manner. However, it is not enough for one of the communicating parties to simply describe how it is able to communicate. The opposing party may have its own set of demands and requirements as well. For this reason, [55] has elaborated an offer/answer model where firstly the session initiating terminal compiles a session description and sends it to the receiving party who in turn describes its own session description and sends it back. Once a collection of session parameters, that satisfy both sides, has been agreed upon, the session is established.

Diameter

The diameter protocol cannot be discussed before first considering the notion of AAA. Authentication, Authorization and Accounting refers to the fact that AAA is used to control access to and later charge an entity for the use of a certain resource. A resource in this case can have many meanings. For example bandwidth or general access to a network can be considered a resource.

The importance of AAA has increased over time since the evolution of communication networks have made them more personalized towards users which in term means that all of the constraints and rights an entity has must be linked directly to them and hence the correct and accurate use of AAA is crucial. The concepts in AAA also follow a logical path and are closely tied with each other as one cannot be billed for services used before he or she has been authenticated and then authorized to use the service in the first place.

In the late 1990s the IETF defined the Remote Authentication Dial In User Service (RADIUS) protocol [56] to perform AAA on the internet. However, as RADIUS performs well in only small scale network situations and does not run on reliable transport like TCP, the Diameter protocol was introduced to enhance its performance. It has reached a status where it is the core protocol that the IMS relies on for AAA [57].

The Diameter protocol is defined as a base protocol [58] on top of which there is an independent application layer. The advantage of this model lies in the fact that with this kind of structure Diameter is extensible. The base protocol contains all of the basic functionality and is present in every Diameter node while the applications are essentially extensions of the functionality provided by the base protocol. Whenever a telecom operator or service provider develops a service, a separate application can also be added to the application layer of Diameter.

It must also be noted that Diameter does not follow the conventional client-server model of operation but rather the peer-to-peer model, meaning, any peer can send a request to any other peer. In addition to requests, answers are also part of Diameter messages and every request is always replied by an answer to guarantee accurate exchange of information.

Real-time Transport Protocol

For multimedia content delivery, IMS utilizes Real-time Transport Protocol running on User Datagram Protocol (UDP). In addition to RTP, [59] specifies the use of RTP Control Protocol (RTCP) as a means of providing QoS.

Since UDP cannot guarantee the transport and order of packets delivered to the receiving terminal, RTP is using timestamps to mark data packets and place these into a buffer to form a correct sequence and hence enable the correct playback of sent media. Should the need arise to play a packet that has not yet arrived, the receiver uses interpolation to fill in the gap and when the missing packet arrives it is discarded as being unnecessary.

The aforementioned RTCP can attribute to QoS in a manner where RTP senders give out information, using RTCP, on how many packets they have sent to the network and RTP receivers report how many packets they have received. The difference of these numbers can be used to calculate the packet loss. Provided the loss reaches a predetermined threshold, the communicating peers may for example decide to use a different codec which is better suited to handle situations of heavy packet loss. RTCP is also used by the sending peer to map separate media streams in a session to a concrete base clock, a method which helps the receiver to synchronize these streams in the playback phase. An example of this might be a video where a persons' lip movement has to match the audio intended.

Reference Points

3GPP has defined a series of reference points in [60] and later in [61] as the interfaces connecting the different nodes and entities within the IMS service delivery platform. The following listing will highlight and elaborate on the key interfaces regarding the current thesis:

1. Gm interface - connects user equipment to the P-CSCF. The protocol used on the interface is SIP and the communication is related to registration and session control.
2. Cx interface – is used to connect the HSS to the I- or S-CSCF. The interface is used to convey data about authorization, authentication and retrieval of signaling routing information using the Diameter protocol.
3. ISC interface – connects the S-CSCF and the AS. SIP protocol is used here and the communication is related to providing services in the IMS.
4. Sh interface – connects the AS to the HSS, The protocol used on the interface is Diameter. According to [62] the interface transports transparent (not understood by the HSS) and standardized data, for example group lists.
5. Ut interface – located between a UE and an AS. XML Configuration Access Protocol (XCAP) or Hypertext Transfer Protocol (HTTP) can be used on this interface for the user to manage its data directly on the application server.
6. Mr interface – allows the connection between the S-CSCF and the MRFC. SIP is used to enable the interaction between the entities.

7. Mp interface – connects the MRFC and the MRFP nodes. The protocol used on the interface is H.248 and the communication relates to media stream controlling.

The presented data regarding IMS in Chapter 2 represents only the author assembled part of an entirety. In addition, this information should be considered as core knowledge for the following chapter which discusses the actual migration process in detail. The architecture, core nodes and their functionality brought forth in the previous paragraphs was considered from a standardized point of view, however, with the analysis in Chapter 3 this may not always be the case. With real-life scenarios, the purpose or functionality of a node may vary from what was originally envisioned by the standardization bodies.

3 Analysis for the Migration Process

A migration decision to move users and services from legacy networks to an NGN and within an NGN must be based on detailed analysis. As the complete process of migration is complex, it must be broken down into smaller sub-processes which are easier to manage. The idea behind a thorough analysis is twofold: firstly, to avoid failures during the actual migration task and secondly, minimize the activities after the migration has taken place - in a worst case scenario the migration task might have to be re-initialized.

Telecom operators and service providers today are still in the middle of shutting down their legacy communication networks and one of the factors in this delayed process is poor analysis which has caused both short- and long term issues to solve. Stemming from this notion, the aim of the current chapter is to name and analyze the main aspects which have to be considered with regards to the actual migration. This is done by the author from a non-technical and technical point of view with the emphasis on technical issues.

The analysis in each phase starts with a discussion of the authors' own published work on the matter [63], where applicable. The expansion on the mentioned work defines a starting poing that is further developed into a more detailed description. For this, available literature and best practices from experts in the field, telecom operators and SPs worldwide has been utilized. Additionally, technical documents from various standardization organizations have been used. The end result of this chapter aims at being a roadmap to follow for operators and SPs during migration. According to the author, a finite set of notions to consider is, however, impossible to bring forth as this is ultimately dependent on each specific telco company. The analysis done will be summarized and assessed in the final part of the chapter.

Phases of the Process

As stated in [63] by the author of the thesis, with regards to the migration process, a distinction must be made between the complete process and the sub-step of this complete process which is the actual migration of a set of concrete users and services. Figure 3.1 depicts a general four step process for migrating users and services to an NGN environment. The focus of this thesis is placed on the first, second and fourth phase. This is caused by the fact that the third phase, the actual migration activity, is a set of predefined actions which are based mainly on the outcome of the second phase and can be completed either by a human or a machine.

The pre-analysis phase is where a service provider or operator recognizes a need to make a change in its operational behavior. Today, with the proliferation of NGNs, a need to migrate from legacy networks, such as the PSTN, is still present, although not as urgent as around 2010. In addition to the migration from legacy networks, the mentioned inter IMS or more generally, inter NGN migration is omnirpresent. This statement can be further expanded upon whatever technology will be put to use in the future. There are always circumstances where some clients are serviced or services provided on a platform which is not state of the art, making it necessary to migrate.

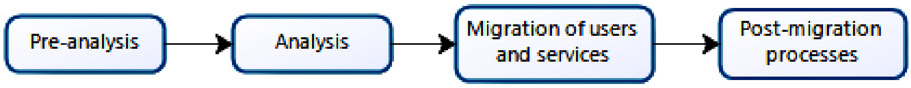

Figure 3.1. A genral four step process for migration [63]

The second phase, analysis, is the most important one in the whole process since the failure or success of the end result will be defined here. Any shortcomings in analysis may cause hard to fix or irreversible damage in the final phases.

The actual migration for users and services takes place in the third phase according to the results obtained in the previous phase and is dependent on its thoroughness. The key aspect here is that any negative effects towards cutomers must be minimized. The author maintains that this means keeping the QoS at least on the pre-migration levels and completing the transition in a seamless way. The activities done in this phase consist of either computers executing determined scripts or humans following elaborated procedures.

The fourth phase, which is usually not emphasized enough, is where the work done so far is checked, assessed and if need be, changes made or communicated to the earlier stages of the migration process. To achieve these tasks, measurement and monitoring systems have to be put in place to guarantee proactive fault management and continuous quality of service enhancement.

3.1 Pre-analysis

The evolution of technologies imposes challenges on both the end users and businesses alike. With any advancement, the availability of choises is increased, making it necessary to research the market before any viable investments can be made by the service provider or operator.

The telecommunication sector can be considered central in any modern society. According to [64] telecom networks can connect disparate groups, enhance the standard of living, empower communities and contribute to national gross domestic product (GDP). The task of any operational telecommunications company during the pre-analysis phase is to comprehend the volatile nature and the significance of the sector and the way people desire to communicate using mobile services. The key phrase here being services since the end user is only interested in the final product and not the way it is technologically delivered to him or her. This was quickly learned for example by NTT DOCOMO in Japan in the early stages of migrating away from legacy networks when the i-mode service was created [65] which has now been launched in over a dozen countries around the world.

Understanding the mentioned central role of telecommunications brings about an initial need for the companies to create business cases which will later be the basis in formulating a sound investment decision that will eventually have to satisfy all of the interested parties: the companies, government and the users. Planning and creating such business cases for an SP or operator is, however, not always straightforward due to the myriad of internal and external variables.

Dissemination of broadband

Based on the experience of the author of this thesis, one of these variables with key significance is the dissemination of broadband. BB has become an important part of the social and economical processes of any given nation for example through areas such as healthcare or education. For this exact reason many policymakers have been monitoring broadband diffusion and influenced the process whenever they have deemed it necessary.

The relationship between governmental regulation and the diffusion of BB has been expanded upon in [66] where a corresponding study in 30 Organisation for Economic Co-operation and Development (OECD) countries was conducted to assess, based on independent variables, whether national regulation has helped in broadband becoming more widely used. The mentioned variables include, but are not limited to, the number of personal computers at home, population density and BB density. The research concludes that although most countries left the diffusion of broadband to be regulated by the free market after the privatization of legacy telephone companies, the countries that saw investments made by the government have been more successful at introducing BB. In addition to the direct financial support, intrusion of the government is also said to diminish the equity problems which have risen due to the fact that telecom companies focus their main effort in developing broadband in areas which are more densly populated.

The notion of political conditions and intervention by policymakers affecting broadband diffusion and overall competition in the market is further supported by the research done in [67]. The study concludes that the actual amount of empirical data to measure the specific impact of governmental influence has been scarce and has mainly focused on regulatory and legal issues. [68] however describes two additional types of activites the government can adopt: supply-based and demand-based. The former encouraging innovative content over BB and the latter, broadband demand from the end-user level.

With the dissemination of broadband the current state of standardization also needs to be assessed. [69] has brougth forth two main challenges facing operators and SPs worldwide: common standards and interoperability. The author of this thesis concurs with the main statement of the mentioned paper that as the services in NGNs are to be provided over a common platform, there is a definite need for a set of global standards to guarantee that different SPs and operators are able to interface with each other. Also, since the migration process takes place over an undefinable number of years, the interoperability between PSTN, an NGN and beyond needs to be regulated.

Impact on the economy

Historically, the information and communications technology (ICT) sector has affected economies worldwide through implemented innovations and improvements which have resulted in, for instance, increased investments, higher salaries and higher quality products being created. The study conducted in [70] indicates that these effects, although noticeable, are difficult to quantify exactly. The authors of [73] have arrived at the same conclusion while emphasizing the necessity of investments made to technology, especially when transforming from one technology group to another.

It is the view of the current author that in the process of compiling business cases, the SPs and operators should firstly consider that direct investments into NGNs are similar to investments made into road construction or healthcare and will ultimately contribute to the GDP of a county. Another issue to consider has been described in [74] as a matter of an NGN being a part of the global internet. According to the authors, internet is essentially a collection of networks joined together based on agreements between internet service providers. An NGN should go beyond this and become an integrated part of the networks that form the internet if any economic gain is to be accomplished.

An exemplary list of the economic impacts of migrating to next generation networks have been listed in [75] through the use of productivity. It is stated that the economic effects can be measured in the best way using the mentioned notion and the reasons for increased productivity include:

1) using increased BB speed means larger data packets can be sent through the network, hence saving time;
2) higher quality information may be collected and distributed which translates into new business opportunities such as managing customers worldwide;
3) higher bandwidth in NGNs facilitates the use of video conferencing, thus directly reducing travelling needs and making it possible to use the saved time for other tasks;
4) increased mobile broadband bandwidth will lead to new opportunities for the workforce such as working while travelling or working at home;
5) enhanced innovations will indirectly lead to new applications being created which in turn will lead to services and economic growth;
6) the ease of service creation will introduce new players in the market, thus increasing competition and reducing prices.

General benefits for end users and service providers

Creating a business case will always raise the question of potential gain. In the pre-analysis phase of the migration process the service providers and telecom operators need to chalk down an initial listing of what is to gain and by whom. Following is a collection, collocated by the current author, of the mentioned notions with the beneficiaries noted. Many of the keywords brought forth in this sub-section will be dissected with greater detail in the analysis phase of the migration process:

1) Reduced network and operational complexity, which should be considered the ultimate purpose for all parties in the service provisioning chain, translates into providing services in a more reliable manner compared to using legacy networks. For the service provider, an NGN enables the integration of voice, data and video on a unitary IP network and as a result of this the users will be able to experience ubiquitous services.
2) Stemming from the previous fact the cost of maintaining a communications network will be reduced and will allow the SP or operator to make additional investments into its network and services. This will enable an enhanced customer experience. Different aspects, contributing to the reduction in OPEX, are compactly listed in [76] and include centralized operations and monitoring, fewer repairs and

field dispatches, enhanced customer self-care, simplified accounting and billing models.

3) An NGN provides a way for the service providers to increase their competitiveness by decoupling the application and network layer thus making it possible to choose from the best available options in the market. Ultimately this will lead to reduced CAPEX and OPEX.
4) As the application and transport layer of NGN are separated, the end user has the flexibility to choose the location where a service is consumed and also the equipment which will be used.
5) As mentioned briefly in the context of broadband dissemination, the transition to an NGN will narrow the gap between rural and urban teledensities. With legacy networks, the coverage in rural areas has a lower teledensity compared to urban areas, however with next generation networks the coverage area is enhanced, making new value added services available to a wider audience.
6) With NGNs, the role of QoS will become essential for SPs and operators in the competition to gain market share, making users the beneficiaries in this case. The synchronization and timing in the service providers' networks are crucial in providing an uninterrupted data flow towards the end user.

A similar list has been compiled in [69]. The following ordering will bring forth notions that were not included in the previous listing and also notions with the emphasis shifted to other focal points:

1) Pricing - the price of services for the users will be decreased since pricing is based on packet based volume and not on the end-to-end resources dedicated to a single user per service.
2) Quality of service - as mentioned, the QoS should be increased from the customer point of view, however there is a threat that the service providers may use configuration in their networks that will only guarantee the minimal acceptable QoS level. To mitigate this threat, regulatory measures have to be taken to make sure that services with above minimal QoS level are accessible nationwide.
3) With the evolution of broadband technology, wireless networks are now able to provide bandwidth comparable to wired BB access. This provides users with the option to choose and have higer data rates in areas where the rates are already substantial.

Challenges, conditions and constraints

According to [69] some of the areas that pose challenges include:

1) Emergency services - the current trend in emergency services is to position the caller as soon as the 112 call has been received by the emergency operator. This trend is further affirmed by the regulators worldwide who are demanding that such systems be put in place. With PSTN this claim was straightforward to solve but with NGNs the task is complex due to the nature of IP addressing and routing.
2) Numbering - the issue here lies in the way the legacy national numbering plan can be made to coexist with an NGN. The IETF has created the electronic numbering system for this, however the increased complexity in numbering may result in

excessive costs for the operators and SPs to update and maintain the relevant routing tables.

Some of the notions already mentioned in this section have been identified in [76] and asserted by the author of this thesis as potential risks to migration. Problems stemming from legacy equipment can be considerable when there are no spare parts or the vendor does not provide support in any manner. This may lead to a situation where the SP or operator is forced to migrate to an NGN without a clear understanding of the business case and possible profits. The research in [76] has also identified the market situation in a specific country as a potential factor affecting migration. This has been done looking at migration from two separate angles - from a competition and a regulatory point of view. Namely, a company may be less interested in migrating when the competition is not gaining market share and thus not forcing them to make a paradigm change through migration. Also, depending on the regulatory situation, a migration task for a company can be more complex or more resource encompassing than they would like it to be.

The current author maintains that the matter of personnel is also a factor in migrating away from legacy networks, however it should be viewed as a driving force rather than a constraint or problem. Since most of the PSTN equipment is 20 to 30 years old, the people most qualified to maintain them are reaching retirement and will be leaving the workforce in the near future.

Strategies

Before a telecom operator or a service provider can proceed to analyze the details of migration, the initial strategies for this process have to be mapped. This thesis has already briefly mentioned some strategies but the following sub-sections will focus on these and additional strategies with greater detail.

There are different approaches with regards to migration strategies. On the one hand migration can be view strictly from a technical perspective. This means figuring out what devices are needed to transition to an NGN and in what order and how exactly to deploy them. On the other hand, migration can be seen as an order of processes. Meaning, when one step of a complete process is complete, the next step can be initiated. Essentially, the four step process described in this thesis illustrates this approach.

Naturally, using one approach without the other will not lead to a satisfactory result for neither the service provider nor the user. A migration towards an NGN cannot take place keeping in mind only the technical aspects and vice versa. Stemming from the previous statement, a combination of the mentioned approaches will have to be elaborated.

In [77] the migration from legacy to a next generation infrastructure has been based on reaching the desired level of customer satisfaction in each of the transition phases. For measuring satisfaction, the customer satisfaction index (CSI) is defined. Additionally, three types of migration are identified and analyzed from the customer satisfaction point of view:

1) Adding NGN services to the legacy infrastructure and thus upgrading it. This approach requires substantial investments in equipment but will ultimately impact the subscribers’ satisfaction.

2) The replacement of the working infrastructure in a single operation. IP-based equipment, which will replace the legacy switches, is put into operation in a manner most suitable for the service provider or operator. However, discontinuities in service may occur which will affect customer satisfaction in a negative manner.
3) The operational infrastructure is overlayed with next generation infrastructure. In this case, traditional voice services and modern services are supported in parallel for the time it takes to decommission legacy hardware and migrate the users and services. As in the first scenario, if conducted accurately, this approach is seamless to the client and requires significant investements to gurantee customer satisfaction.

It is reasonable for an SP or operator to be looking for a strategy with little risk while at the same time having opportunities to develop, so the overlay approach is most often chosen as it protects the investment already made into the legacy network.

The research done in [78] first defines the drivers for PSTN replacement, after which a three stage migration process is described, estimated to extend over a periood of 10 years. The reasons why legacy networks no longer satisfy the needs of service providers are firstly due to competition issues and openness of the internet. As most of the telephony service has migrated to the internet and more services are developed for the packet based networks, PSTN is no longer seen as a viable solution to retain market share or keep the competitive edge. Secondly, aging of PSTN equipment - most of the incumbent operators globally have PSTN equipment that dates back 20 years or more and is now on the critical limit of reliability. The only feasible solution is to replace it and advance to the IP network at the same time. Thirdly, network operation is seen as a concern. The operational costs for modern networks must be reduced in conjunction with simple maintenance and centralized management.

Thus, the proposed migration strategy in [78] consists of the following stages:

1) Local switch (LS) replacement in the initial stage. This means the use of access gateways (AG) is required to house the subscriber lines which will be moved out of the aged local switches. Additionally, trunk gateways (TG) are needed to connect the legacy and new networks which are operational simulataneously for a certain periood of time.
2) Toll switch replacement and reorganization in the transit stage. The LS swapping for NGN equipment will continue in this stage with the toll switches in the charging areas being modified or replaced as well. The number of TGs will increase as more users are moved out of PSTN - this also inflicts the need to reorganize the transmissioon trunks to ensure the efficient use of network resources.
3) Completed PSTN migration in the final stage when no more TGs or toll switches are required for the service providers’ internal communication. However, to connect with other SPs or operators, TGs may be needed since their network might not be fully packet-based.

3.2 Analysis

The actions set out and completed in the analysis phase are the most critical in the complete migration process. This is due to the fact that any shortcomings in analysis are highly resource encompassing to repair in later stages of the complete process. A simplified illustration of the general directions that the analysis should be focused on are depicted in Fig. 3.2. Originally, the author centered the analysis on the technical side around users and services. However, this thesis has further evolved this discussion to a more broad-based consideration. Additionally, QoS and charging have been considered as crucial and thus listed separately. Originally, charging was seen as a sub-section of supporting systems and QoS was excluded from the discussion. In the analysis phase, the technical and non-technical aspects are equally important, however the latter will not be discussed in detail in this section as it has been elaborated upon in earlier chapters and the scope of this thesis in general is more technical than non-technical. The technical aspects in need of analysis contain: quality of service, charging, security and supporting systems which in the context of this thesis also entails management.

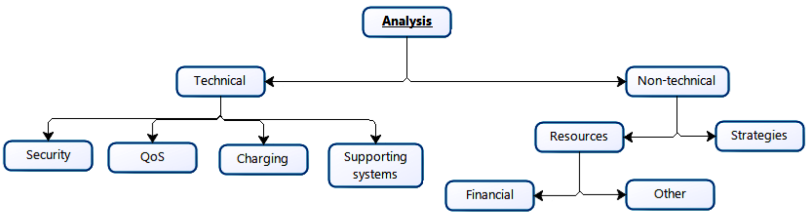

Figure 3.2. Main directions for analysis [63], adopted and modified by the author

Quality of Service

When IP packets are transferred from one network node to another, they are subjected to jitter, delay and packet loss. These can, in real-time scenarios, degrade the user’s perceived quality of any used service.

Today, a generic treatment for QoS in NGNs does not exist although ITU-T has defined tolerable QoS values in [79] for IP networks and for some NGN applications. In general, QoS provisioning in an NGN has targeted access, the core network and the application layer separately which has resulted in inconsistent QoS handling. This is similar to the early stages of NGN development when QoS solutions were technologically dependent. This means that the administrators had to configure them offline and additionally they had no end-to-end significance. Gradually, this paradigm began to change and for example in [80] the authors specified a project in which the design required, among other things, the ability of a user to select the QoS for each separate application. Due to the importance of quality of service in an NGN and to understand how the mentioned notion of having QoS for individual applications has been realized, the author is convinced that the analysis performed by SPs or operators should initially consist of looking at how standardization organizations have envisioned it in operation.

The IETF sees the way to solve end-to-end QoS in IP networks by using either the Integrated Services (IntServ) or Differentiated Services (DiffServ) architectures. The latter, due to its scalability when network traffic increases, has been adopted and has achieved wider usage by equipment vendors and remains the recommended model for QoS provisioning. The DiffServ architecture is essentially a mechanism for classifying and marking IP traffic. Using classification, a traffic flow can be assigned to a specific class of service (CoS) and marking this flow allows it to be processed, based on agreed priorities, by DiffServ aware routers.

The work done in [81], [82] and [83] lists the main principles of QoS management from the standpoint of 3GPP, ITU-T and TISPAN. In [81] DiffServ has been used in a 3GPP scenario. Guaranteeing QoS in IMS involves a series of interactions between the user equipment and different core nodes and is dependent on SIP, Diameter and Common Open Policy Service (COPS). In general, the 3GPP specifications provide standards for dynamically managing the QoS but do not focus on the mechanisms for supervision nor do these provide possibilities to consider the type of customer or the requirements defined in the customers' service level agreement (SLA).

A general scenario for QoS management can be seen in Fig. 3.3. Compared to the original in [81], the figure has been clarified by the author of the thesis to note the user agent (UA) as one of the participants of the dialog. The original paper failed to do so and used a vague notation "user". With regards to SIP, only a user agent can act as a party in a signaling session.

The requirements for quality of service are negotiated on a per-service basis, an attribute which has become one of the key features of IMS. The signaling begins with a SIP INVITE from the originating UA towards the P-CSCF which also contains the desired QoS parameters in the session description part of the request. After reception of the initial request the P-CSCF assumes responsibility for determining the feasibility of the desired QoS for the service. The received QoS information is passed on to the Policy Decision Function (PDF) using Diameter. Upon acknowledgement back to the P-CSCF the initial SIP INVITE is sent to the UA on the receiving side after which a codec negotiation ensues between the P-CSCF and the receiving UA.

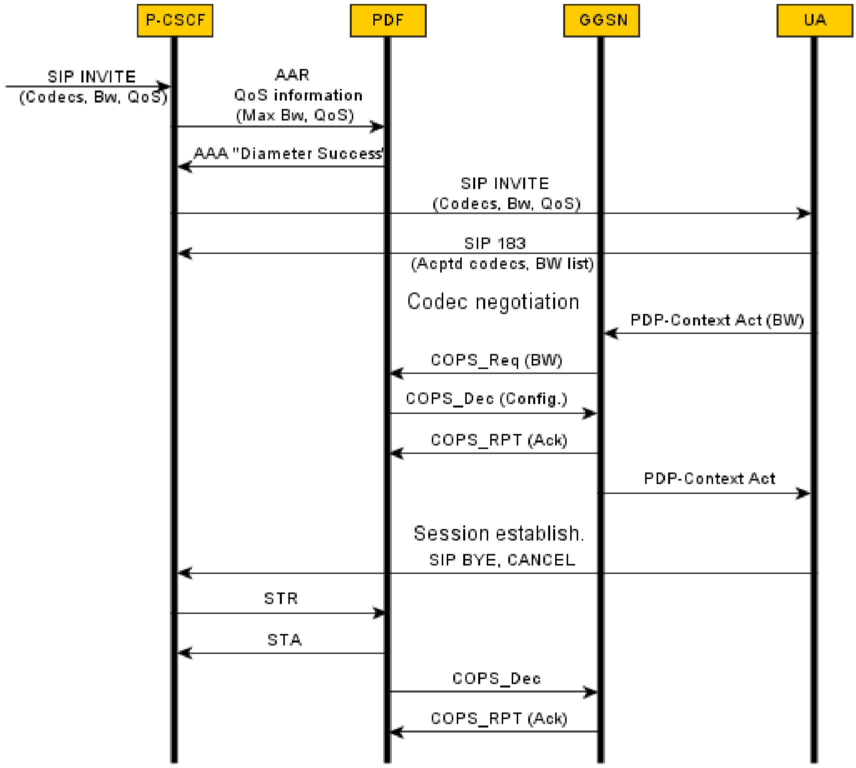

Figure 3.3. General scenario of QoS management in a session [81], adopted and modified by the author

Subsequently, the Gateway GPRS Support Node (GGSN) and the receiving UA negotiate a Packet Data Protocol (PDP) Context. A PDP Context can be considered a structurized collection of data within the GGSN containing the subscribers' session information when the subscriber is involved in an active session. During this step the GGSN acts as a client of the PDF, called a Policy Enforcement Point (PEP). The communication between the PDF and PEP is performed using the COPS protocol. After negotioation, the PDF sends a decision to the GGSN with the agreed QoS parameters. At this stage the actual session may be initiated. As of 3GPP Release 9 [84] charging rules functionality is added to the PDF and hence it is called the Policy and Charging Rules Function (PCRF).

Ending the session with a SIP BYE or SIP CANCEL message demands the release of the previously reserved resources. This is again the responsibility of the P-CSCF. Firstly, the PDF is notified using the session termination request (STR) Diameter message. After replying with a session termination answer (STA) the PDF in turn notifies the GGSN using a COPS Decision message. This is ultimately acknowledged by a COPS Report State.

The views of 3GPP concerning dynamic QoS control and management have been applied in [85]. In it, the authors have introduced a centralized server, IMS-SDP Management Server (ISMS), which gathers parameters from different network elements using Simple Network Management Protocol (SNMP) agents in order to provide network and service management. The previously mentioned COPS protocol is used for QoS management and SIP for signaling. Whenever an element in the network is started, the PEP requests the PDF for DiffServ marking policies using COPS and the PDF replies with either the complete node's QoS configuration or a fraction of it in case of an update of a DiffServ filter.

In this solution the ISMS acts as a service level agreement enforcer which makes sure that the service delivery happens according to the SLAs. The ISMS itself assumes the role of the PDF while the nodes, working as PEPs, make sure that each IP traffic flow is assigned proper QoS parameters and necessary resources.

Similar work to [85] has also been done in [118]. In this case the authors have based their solution on ITU-T specifications rather than the ones from 3GPP. The idea however remains the same. The solution focuses on implementing a QoS Broker (QoSB) which manages the centralized quality of service resources. The QoSB assumes the roles of the Policy Decision Functional Entity (PD-FE) and the Transport Resource Control Functional Entity (TCR-FE). In the 3GPP terms the PD-FE is equal to the PDF. Whenever a service in the network requires resources, the QoSB notifies the edge nodes about the packet flow, its route and QoS attributes. These nodes will subsequently act upon this information by identifying, marking, classifying and encapsulating the flow according to the QoS information provided by the QoSB.

In general, the originating UE may initiate a process to change its QoS within an ongoing session at any time by sending a re-INVITE message to the terminating UE with new QoS parameters. However, [82] has observed two issues with this scenario that are worth considering for an SP or operator:

1) when the desired resources are not available, rather than rejecting the request, it may be reasonable to suggest the next-best collection of parameters to the UE. Also, if the new resources are available, it still may not be effective to automatically provide the UE with these as there could be another set of parameters which are more cost-effective and yet satisfy the request.
2) a UE could be constantly notified of the QoS availability and thus it can make more efficient decisions regarding QoS before actually starting a session to change the current state.

It is the claim of the author of this thesis that analyzing QoS cannot be done without also considering the notion of SLAs in IMS since different services can be separated to a high degree (QoS, management, billing, etc) and hence it makes sense to assign an individual SLA to each service. Additionally, it is important to realize that in NGN a session can be initiated and terminated from and to a myriad of access networks and therefore it is desirable to have dynamic QoS management. This means that the management systems and nodes of the network should be adaptable in order to change the actions of the whole system or parts of it based on specific conditions. All these principles should be factored in to the analysis process.

The policy based network management (PBNM) paradigm, defined by the IETF and adopted by the 3GPP, is a possible solution here. Using PBNM, a networks' operation can be controlled by a set of dynamically introduced rules which are constantly checked and evaluated. According to [83] the most critical component in this setup is an entity which has interfaces to both the signaling and the transport plane. This entity has been named differently by different standardization organizations: Policy Server, Bandwidth Manager or the already mentioned Policy Decision Function. A system based on PBNM is described for example in [86] where a policy based QoS management system has been designed, created and its performance measured. The system uses DiffServ aware Linux-based routers, COPS for interfacing with the network nodes and LDAP to access the directory where the policies are stored. The system also employs policy caching to improve performance.

In [87], two extra solutions, in addition to the already discussed PBNM, have been proposed to solve the issue of end-to-end QoS in heterogeneous networks. Firstly, a strategy which involves sending QoS information from source to destination using signalling protocols. In this case, network nodes reserve resourses that meet the desired QoS requirements of the application. However, problems are seen here in the form of increased signalling load which translates to reduced bandwidth to be used by applications and in the fact that once the connection is established, the applications will not be able to alter their QoS requirements. The second strategy encompasses defining identical QoS metrics on all network nodes along the transmission path. Each node inspects and treats the packets according to predefined QoS requirements - a solution which is based on the DiffServ QoS model.

Another approach worth considering for a migrating SP or operator is related to automatic correcting mechanisms to improve quality of service. Unlike the discussion in the previous sections, the keyword here is case based reasoning (CBR). Battling QoS deterioration has been elaborated on in [86] with a so- called intelligent system which is based on the methodology of recording and grouping similar cases where QoS degradation has occurred and later using this data to repair any other degradation occurrences faster than without the proposed system.

The main advantage of this system, according to the authors, is namely the speed of operation. Initially, a claim is made that any correction operation in the monitored network is costly with regards to resources and execution time. However, with the use of already recorded scenarios, the time spent on QoS improvement will be reduced. The system also integrates the mechanisms of supervision with the requirements of a specific customer, thus enabling to make the correction operations more accurate, on a per customer basis. An argument has even been made that using the CBR paradigm, the system is able to construct new solutions, based on already recorded solutions, to the QoS deterioration occurrences that might happen in the future.

Supporting systems

The complexity of an NGN is an order of magnitude greater compared to traditional telco networks. This is due to, for example, the support for multiple customer premises equipment (CPEs), access independence, third party involvement in service delivery and the requirement to guarantee user centric delivery of services. Additionally, the current market situation dictates a strong OPEX reduction from SPs and operators.

The mentioned notions make management of next generation networks a complex task with the central idea, according to [74], to unify service creation processes, business processes and management processes. To achieve this, management and also fault management must spread across all network layers in an aggregated manner as depicted in Fig. 3.4. Aggregation in this context refers to the existence of a system which is tapped into each layer and can process the information to and from those layers uniformly. This ultimately enables a broad-based management of an NGN.

The key components in the supporting systems analysis chain, according to [63], are illustrated in Fig. 3.5, where similarly to Fig. 3.2 the high level technical aspects have been modified by the current author and now include security, QoS, charging and supporting systems. The analysis here is centered around two main functions which are the customer relationship management (CRM) and the task management. The CRM is meant to be a tool for everyday use by the SP or operator and is essentially an interface between the human user and the technical systems. The task management on the other hand is a system or a collection of systems which work unnoticed to the human user and interprets human input to perform specific commands accordingly or contrary, transforms data into a human readable form.

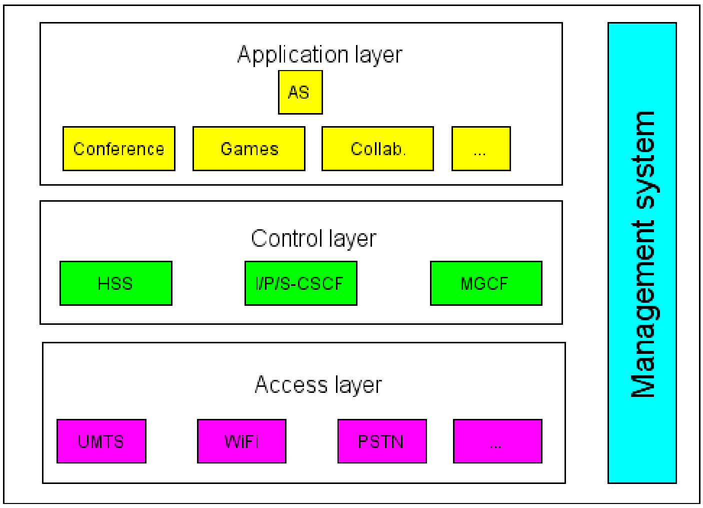

Figure 3.4. The concept of management in an NGN

The product database, although not considered a part of the actual value chain for a company, is a collection of services' descriptions. These are used in the initial stage when a service is built for a specific customer or to further develop the existing service. Hence, the metadata regarding a service should be not only considered thoroughly but also saved in a corresponding database. The main input for the product database is the CRM.

Analysis in the assurance sub-step should focus on ways for the client to communicate with the service provider or operator in case of problems and how these service requests are processed. Generally, a multi-level structure is constructed where the initial point of contact for a customer is a helpdesk. The second level consists of low level specialist and so on - the higher the level the more specialized are the troubleshooters. The interconnections of these service levels must be identified and described in conjunction with the systems and tools used. The analysis of this flow should terminate with feedback since both the customer and the service provider require information on the status of the issue. In a default case, both are notified whether the problem has been resolved or not.

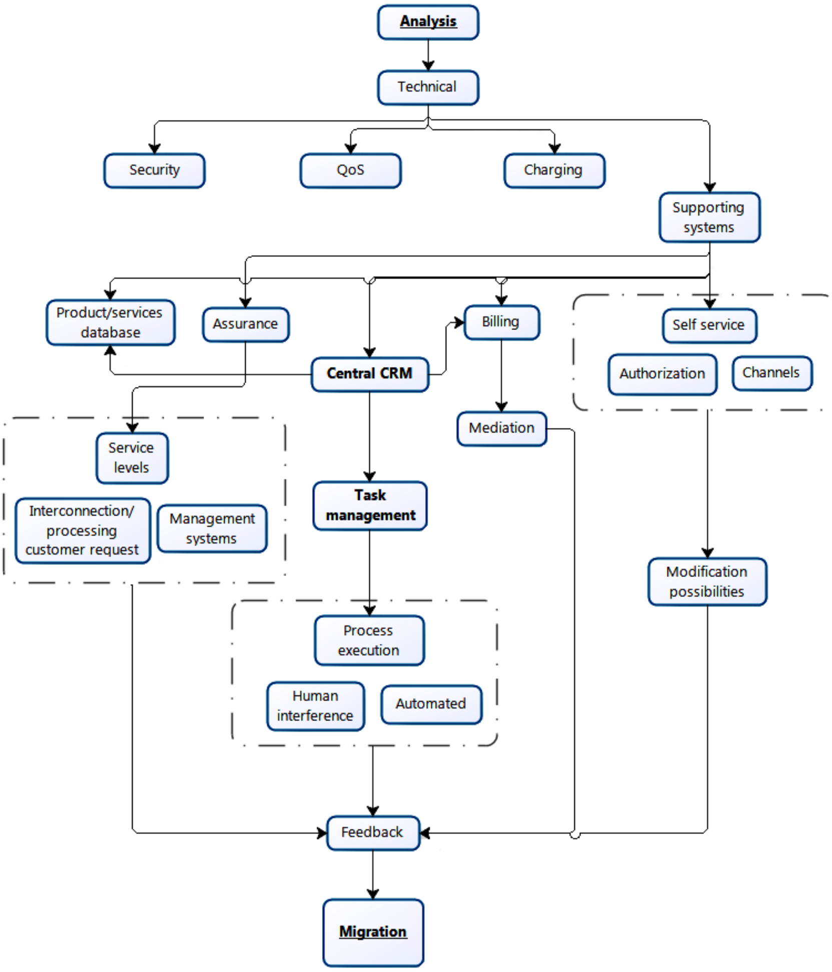

Figure 3.5. Analysis chains for supporting systems [63], adopted and modified by the author

Focus in the task management branch in Fig. 3.5. should be directed to determining how the processes, taken by the technical systems, are executed. This additionally applies to human intervention since migration can be a hybrid task, performed by both man and machine. Throughout the entire branch, feedback is needed within and between different tasks.

In the billing chain focus is on mediation. This is a generic term that refers to an entity which collects and processes call detail records (CDR) originating from different nodes in the NGN. Once the data is collected and processed, it is sent to a predefined location. The nodes exporting CDRs usually create them in a proprietary format, hence the processing task is critical since the operator or SP would like, as an end result, to have these records in a unified form. Finally, as the billing system is the actual basis for the companies' revenue, feedback is considerd extremely important in this chain - in case there is no certainty that the mediation layer is working without issues, there can be no guarantees that invoices are being sent to customers.

Analysis in the self-service realm should focus on ways for customers to modify services and user accounts by themselves. Modern telco operators and SPs have and are still moving towards a paradigm where contact with their clients is minimized with regards to day-to-day operations. This is done to reduce management costs and give the clients more freedom of choice in everyday minor configurations. The analysis must consider at least two issues: first of all, how the customer is authorized to make any changes and secondly, the channels that the customer can use. The latter usually includes a web page or an interactive voice response (IVR) system. After the mentioned issues have been clarified, the actual modification rights must be determined. Giving customers the freedom to delete user accounts may not be prudent, however activating call recording or call forwarding or adding a new user to a companies' VoIP group are a few examples of the activities with a reasonably low impact to other services and users in case done incorrectly. The analysis flow is completed with feedback to assure the client that the changes he or she made were actually successful.

The sophisticated and mature operations support systems in use today which have evolved from legacy networks already support and enable the management of network infrastructures that scale from small corporate to large operator networks. Some of their functionality can be utilized for management of NGNs, especially for the IP based resource layer. Still, adapting a state of the art OSS to an NGN is a complex task. The authors of [88] have brought forth three main attributes which they consider to be essential in an NGN management system:

1) Real-time business strategy support - the functionality in the network management system (NMS) which is supporting future business strategy, should be comprehensive enough to take into account equipment information, customer complaints and inquiries and the data collected from the network. Analyzing this information will facilitate the prediction of future trends and quality aspects in the network. The result of this analysis is in turn the input for the decision makers within the operator or service provider to make investment decisions.
2) Real-time customer care - essential part of proactive behavior which provides the customer with up to date information. The improvement in operational efficiency in NGNs requires that the flows of different operations are reviewed and created as separate scenarios in a flow database. This makes it possible to unify operation flows that vary between services and enable to reduce the time-to-market with new services and the time for customer inquiries.
3) End-to-end management - a similar notion has also been previously mentioned in this thesis regarding the quality of services, however in the current situation the quality of the network itself is meant. In order for the network to operate efficiently, different failures must be detected, as well as the services and users that are affected. In [88] this is done using three subsystems in the networks' end-to-end management part: QoS analysis system, VoIP quality measurement system and a fault localization system. QoS analysis is a passive measurement method to sample IP packets in order to analyze TCP behavior or UDP quality while VoIP quality measurement is an active method which exchanges RTP data between probes in the network to measure voice quality. The fault localization system is tasked with estimating the root cause of a failure in real time using the data retrieved from the QoS analysis and VoIP quality measurement systems.

The hybrid nature of a next generation network calls for a unified approach towards management, starting already from the service workflow creation level. Based on [89] and [90] there are two central notions which help to achieve this - TM Forum's enhanced Telecom Operations Map (eTOM) and Service Oriented Architecture (SOA).

According to [119] the eTOM is an industry-agreed layered view of the business processes required to operate an effective and agile digital company and the key advantages that can be gained using it include:

1) the creation of a common language to be used across different departments, systems, partners and suppliers and thus reducing cost and risks with system implementation and integration;
2) the adoption of a standardized structure and terminology to simplify company internal operations and maximize opportunities for partners;
3) the application of disciplined and consistent business process development across the enterprise;
4) the design, development and management of applications in terms of business process requirements so that applications will match the business needs better;
5) the creation of consistent high-quality end-to-end process flows;
6) the identification of opportunities for overall cost and performance improvements in deployed services and systems.

The NGOSS described in [89] and [90] is based on the mentioned eTOM framework which, according to the authors, resolves the legacy issues with stovepipe management. It is said to provide a blueprint for all the processes within the enterprise starting from strategy and product management to operations. Each level in the eTOM model represents a more finely grained decomposition of the management processes, thus enabling a modular service oriented OSS. In addition to the eTOM framework, the TM Forum has adopted the OSS through Java (OSS/J) and the Multi Technology OSS Interface (MTOSI) initiatives which provide standards-based APIs for the communication of the enterprise-wide management systems.

Following SOA princples in the management system, firstly the network elements, local agents and provisioning systems must be equipped with service oriented interfaces and secondly the workflows have to be designed based on service oriented process schema. For this, [90] has elaborated on three guidelines:

1) Namely, to realize a greater degree of automation with plug and play integration for new services and resources, network management should be policy based. This means using policies to separate service logic from system run-time behavior and also providing subscriber centric service delivery. The fundamental components of a policy framework are described in [91], comprising of a policy management tool and a repository for policy storing. The repository is also the policy decision point (PDP). Similar to the scenario discussed in QoS management, the necessary and appropriate actions are retrieved from the PDP and forwarded to the policy enforcement point which carries out the action.
2) The second notion besides policy based management is the utilization of models in service and architecture creation. The authors claim that using models at service and architecture creation stage enables a more rapid development and

deployment process through the fact that the impact of the new service to the service enabler is already known.

3) The final guideline deals with autonomic control loops at the network element level which enable the use of self-regulating mechanisms, i.e. self-monitoring or self-healing. This is done to ultimately reduce the OPEX of an enterprise.

The notion of self-regulation is closely coupled with fault management. [91] states that contrary to legacy fault management solutions, the ones in NGNs must cover the full end-to-end service delivery in order to guarantee an assurance mechanism which is efficient enough to provide the user with an enhanced experience. This means that systems to actively and passively monitor NGN traffic and probe network nodes and functionalities must be put in place.

The experience of the current author has shown that similarly to self-regulation, the matter of autoconfiguration is an essential part of any next generation networks' general management principle. This includes updating the firmware and software of devices connected to the network or dynamically configuring their settings such as DNS or file transfer protocol (FTP) server addresses. Autoconfiguration as a core functionality in an NGN, however, entails risks which may cause downtime for the customers if done incorrectly or in a worst case scenario may cause serious security vulnerabilities. Updating nodes and devices through a server-client connection may also cause congestion and processing load for the distribution server, a matter which should be addressed in the analysis. For example, performing updates can be temporally distributed to avoid congestion during a certain time of the day. Also, as the SP or operator has no desire to visit the client after autoconfiguration, all the changes and their effects must be fully tested to avoid erroneous behavior.

Charging

Although charging has briefly been mentioned with regards to analysis, an additional detailed discussion will be provided in the following sections as this topic is essential to the survival of any SP or operator.

A differentiation can be made with regards to accounting, charging and billing. Accounting is the process of using metering data to aggregate resource usage from different network nodes while charging uses the accounting information to calculate the cost of service consumption. Billing refers to the process where charges have been collected and the payment procedures are initiated and managed towards the party that is responsible for consuming the service. In [92], the general charging requirements and principles are listed as follows:

1) services cannot be provided to the end users unless they are aware of the charges accompanying the services. This also means that the users will have to be able to accept or reject the services based on the calculated charge.
2) an ability must exist to charge each media component separately in a single session.
3) an ability must exist to charge the end user based on their location and presence.
4) a possibility must exist to use the same charging model for both the home environment and while roaming.

Starting from 3GPP Release 11, policy enforcement, which has been discussed in this thesis with regards to QoS, and charging have been combined within the policy and charging control (PCC) architecture since policy control is often needed to enforce charging decisions. This may happen for example when a user runs out of credit and thus the active session the user is involved with must be terminated. [93] and [94] clarify the IMS charging architecture which is shown, with the non-pertinent excess nodes removed by the author of the thesis, in Fig. 3.6 and should be the foundation for service providers and operators in implementing their charging systems.

Upon implementing the charging trigger function (CTF), a network node can collect accounting metrics. Both offline and online charging can be applied by the offline charging system (OFCS) or the online charging system (OCS) respectively.

With offline charging the CTF generates charging events and forwards these to the charging data function (CDF). The CDF generates CDRs based on this information and sends these to the charging gateway function (CGF) which acts as a gateway between the IMS and the billing realm. The CGF forwards the data to the billing domain.

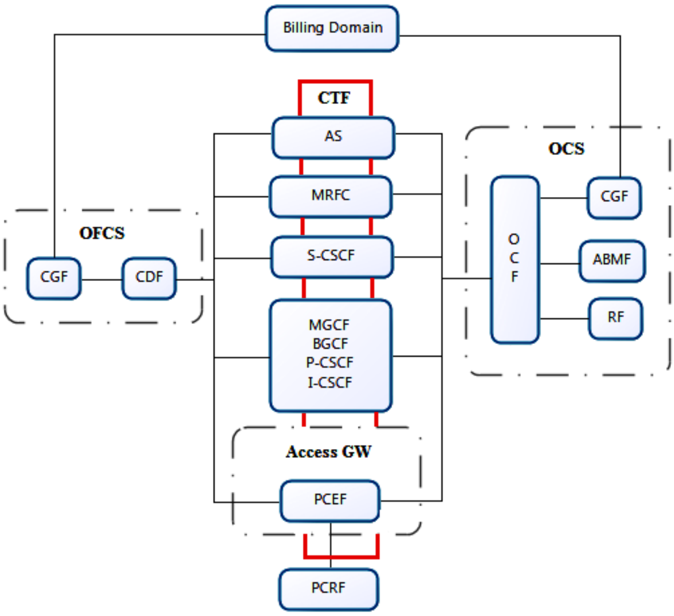

Figure 3.6. IMS charging architecture [93], adopted and modified by the author

Online charging is defined as credit based and supports both event-based and session-based charging. Charging events from the core IMS nodes are sent to the online charging function (OCF) which communicates with the rating function (RF) and the account balance management function (ABMF). Based on the input from the OCF, the RF assigns the value of the resource used and returns the rating output (monetary or non-moneraty units). The RF is capable of handling a number of instances such as the rating of data volume or the rating of session time. The ABMF manages user credits and comprises of the users' total, reserved and available balance.

The parties involved in service delivery and thus in charging in a general case include: the end user, the end user's home network, a visited network and a third party SP while the charging data contains information concerning identities, service units the end user has requested, requested QoS parameters, presence and location information. Table 3.1 lists the data provided by different parties according to [92].

Table 3.1. 3GPP specified data for charging from different parties involved in service delivery

Charging data from the end user	**Charging data from home or roaming network**	**Charging data from 3rd party SP**
User ID	Serving network ID	SP ID
Home network ID	Provided QoS to the user	Timestamp for charging session
Terminal ID	User location	Service type
Requested resources	Presence information	Service content
QoS parameters	Resources allocated to user	
Service ID	Timestamp for charging session	
	Data quantity transferred to and from the user	
	Charging data ID	

As mentioned, charging in NGNs can broadly be divided into two: online and offline. [95] and [96] define online charging as a method of charging where information regarding resource usage is collected concurrently with the resource usage and is then used to affect, in real-time, the resource rendered. Offline charging is described as a method of charging where information regarding resource usage is also gathered concurrently with the resource usage, however, it is then passed through a process where CDR files are generated and ultimately sent to the billing function and thus no real-time resource manipulation will take place.

Online charging systems use information regarding the user, network and services in their processes. Still, this is only a subset of the total amount of data available for example to the network management systems. This has been identified as a problem in [97] where a study has been conducted to determine whether the mentioned available information (e.g. user location, nearby users, service usage habits, etc) could be utilized more efficiently. According to the authors this is possible, although three open issues are named: lack of a general charging information specification and structure, the absence of a mechanism for charging data sharing among the parties in the service delivery process and finally, a lack of a framework for information sharing while maintaining user privacy.

The author of this thesis claims that in next generation networks, use of the information in charging data should be considered by the SP or operator at three architectural levels. Firstly, at the bearer level where this information can be used to control network resources for delivering a service. Secondly, at the subsystem level where sessions can be managed through the use of charging processes and finally, at the service level. In this case, services or their specific content can be controlled. According to [97], a similar division can be made with regards to key charging data as well: user profile related, charging model and accounting record related. Figure 3.7 illustrates this where the user profile contains a collection of user related information such as available credit and authorized services. This profile is updated during or after the charging event. The charging model contains all of the rules and tariffs used in calculating the service cost while the accounting record is, as already mentioned earlier, a collection of resource usage records, aggregated from elements across the network. In [97], the accounting record is further depicted to contain usage data which the current author has excluded as this is inferred by the explanation of what an accounting record contains.

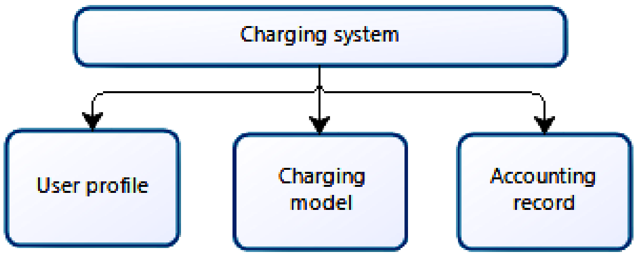

Figure 3.7. Division of data used in charging [97], adopted and modified by the author

According to [98] the costs and general resource utilization related to charging will have to be minimized for the SP or operator to remain competitive. As the charging for many services involves multiple aspects such as the duration of the session and traffic volume, a way to reduce resources is by conforming to the standards. In the case of IMS, the standards created by the IETF and 3GPP will have to be merged to produce a comprehensive charging system. As an example of the need for this comprehensiveness, VoIP can be billed based on session duration, a flat rate or media volume exchanged by the parties.

The author of this thesis claims that, in general, several charging schemes should be deployed in NGNs. Considering IP transport, volume based charging may be the most appropriate. The benefit of this scheme is the fact that it can be used to measure network usage and thus manage congestion. The most common scheme in IMS is however flat-rate charging. This metric can and is actively used for statistics to determine resource usage on a per session basis. Flat-rate charging also facilitates predictability of revenue and service usage for the SP or operator. Traditional duration based charging is also still used mainly for VoIP while QoS based charging should be used for services with different levels of quality. In this case it is important to note that whenever this kind of schema is enforced, the users should be able to request different quality levels. With regards to the complex task of charging for content, the content providers should outsource the charging and billing function to the SP or operator.

The SP or operator must also consider the NGN-external issue of interconnection and the integration of multiple access networks in service provisioning. The first notion is expanded upon in [99] where the regulatory and economic aspects of the bill-and-keep (BAK) principle are studied. The authors conclude that BAK has a key advantage over the initiating party's network pays (IPNP) principle as termination fees are eliminated and the regulators are saved from setting termination charges. The research additionally concludes that when shifting to an NGN, the interconnection charging models will become essential in achieving efficiency and that no single interconnection model suits all NGN contexsts. If at all commercially feasible, a range of interconnection charging models should be applied to maximize economic efficiency.

As next generation networks are access technology independent, this should be factored in to the charging logic. By integrating multiple access networks in service provisioning, the operator can save costs while offering enhanced quality of service to its customers. The authors in [100] have analyzed this by using cellular networks in conjunction with wireless local area networks (WLANs) and have detailed authentication, security, QoS support and mobility management as some of the issues to be solved with this setup. Despite the initial problems, the mentioned blend of access technologies was found to be suggestible to price manipulation in the sense that user behavior could be influenced by different charging policies depending on the access network. Pricing incentive was found to coax the users, who were more price sensitive, from the congested high-priced cellular network to the less congested WLAN. With the evolution of NGNs the described situation becomes increasingly frequent and ultimately demands adaptive charging management which has been expanded upon for example in [101]. The paper proposes a reconfigurable charging management platform which takes into consideration items such as service characteristics, network conditions, user categories and QoS assurance to provide the functionality of generating an adaptive charging rule. Specifically, each charging rule is deduced by integrating charging information from the subscription charging agreement and from the session related charging data. The subscription information is considered static and contains items such as user class, service identifier and QoS rate while session data is dynamic and may include the type of UE, access network type and resource usage. Based on the described information a charging rule is created for a specific user and service.

Security

3GPP has considered IMS security from the access and network standpoint. The current author asserts that this division is a reasonable starting point for analyzing security related issues for migration. According to [102] and [103], access security includes authenticating users and the network and additionally protecting the traffic between the UE and the network. Network security on the other hand deals with traffic protection between network nodes within the same or between separate operators. Based on this division, Fig. 3.8 illustrates the areas of analysis in the security chain.

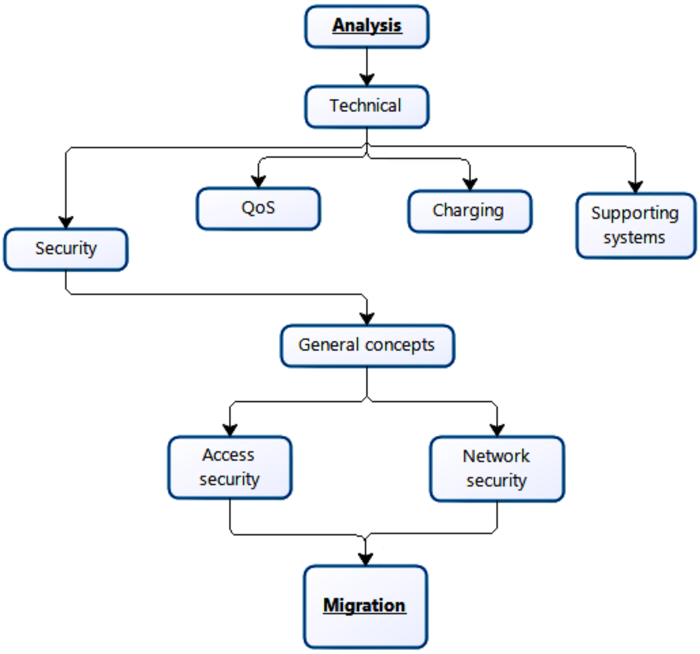

Figure 3.8. Security concepts analysis from 3GPP perspective [63], adopted and modified by the author

In [63], a similar illustration was created, however the author had centered his work specifically around IMS and thus the general concepts were followed by IMS specific concepts. In the context of this thesis, a broader, NGN based approach has been taken and IMS specific concepts have been removed and the focus has been directed at access and network security. The following sub-sections convey the contents in the security analysis chain.

The analysis should start by focusing on the general constraints and concepts that the SP or operator is subjected to. These include basic demands such as the list of protocols that are allowed within the network or whether external access to company internal IP networks is allowed and if so, then how. These general concepts lay the foundation for a more detailed discussion of NGN specific details.

After the general constraints and based on the security associations concerning IMS, depicted in Fig. 3.9, access and network security can be further elaborated upon. Additionally, as pointed out in [104], since the IMS core can be accessed from both the wired and wireless domains, the corresponding security approaches are also different. However, the five main associations are based on IMS security specifications and therefore should be the cornerstone of every deployed IMS solution:

1) A - the authentication between the UE and the IMS is done here using the recommended authentication and key agreement (AKA) security protocol;
2) B - using IPSec, this association should assure a secure link between the UE and P-CSCF to guarantee the authenticity of the originating data;
3) C - the Diameter based IMS internal link between the HSS and I/S-CSCF which needs to be secured due to the fact that during the UEs registration process challenges and keys will be transferred here;

4) D - the association between the home and visited network, used when the UE is roaming and which should use the Internet Key Exchange (IKE) protocol in IPSec;
5) E - whenever the UE is operating in the home network these links provide security between the core nodes within the security domain.

The IMS security services concept has been further elaborated upon in [51] where a layered IMS security model has been defined and this models' dependency on the operators' general preferences has been emphasized. Hence, if chosen, this trail of analysis should focus on clarifying the security model and choosing the appropriate authentication method. Contrary to the IMS security services analysis, dealing with issues which will remain constant after being decided, the operational security is considered to be dynamic. The analysis here should entail P-CSCF discovery, session termination and initialization, UE registration and protection against an array of attacks. Additionally, as the operators' network evolves in time, some of the mentioned keywords and the respective security principles will change and this will have to be factored into the analysis.

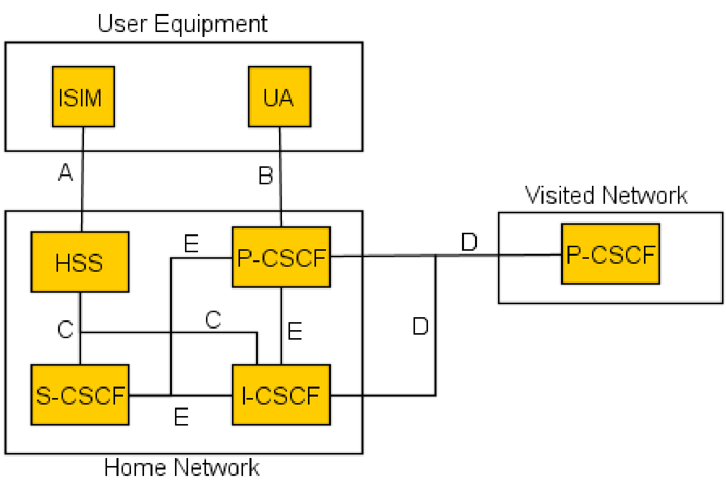

Figure 3.9. Security associations in the IMS architecture

Although security specifications define a complete mechanism for adequate protection in IMS, real deployments sometimes vary from the specified. [105] and [107] have listed some of these discrepancies based on the analysis of several real world IMS implementations:

1) As there is virtually no IP multimedia services identity module (ISIM) support in laptops, IP desktop phones nor in PSTN phones, the use of AKA is limited and the use of MD5 Digest Authentication permeates. This is in essence a security issue worth noting, however not much can be done to change this.
2) The issues with IPSec. Due to the limited use of IPv6, network address translation (NAT) is extensively in operation. This, however violates IPSec's principles of integrity since IP address translation means modifying the IP packet header.

Additionally, using IPSec tunneled SIP traffic, the IMS does not mandate the authentication of INVITE messages. Still, this authentication can be set operational.

3) The specifications for implementing IMS security are too complex and therefore SPs and operators have resulted to simplifications in their application which has lead to vulnerabilities.
4) Adding to the previous point, the complexity of the complete IMS deployment which causes network misconfigurations mainly due to human error and therefore makes the system receptive to security issues.

Based on the findings of [105] and the author of this thesis, a general list of the major threats, on a per IMS core node basis, can be specified and ways of dealing with these described. The listed keywords can be viewed as concrete reference points for service providers and operators to use while migrating their own solutions:

1) CSCFs
    a. toll fraud which will lead to revenue loss - in case the P-CSCF has been configured as a charging information collection point and the UE can bypass this and communicate directly to the S-CSCF. A similar situation can occur when the UE has the possibility to disguise itself as a different user.
    b. inability to hide network topology - the IMS security specifications state the capability of encrypting the data regarding the network addresses of entities including the Via, Route and Record-Route headers in SIP. If not applied, it is possible to gain insight into the operational details of a network.
    c. denial of service (DoS) attacks - flooding the P-CSCF, as the first contact point in the system, with REGISTER messages. Since a register procedure involves many IMS core nodes, a DoS attack can rapidly cause heavy loads on the network and thus reduce the QoS for the legitimate users.
    d. man-in-the-middle vulnerability - in case IPSec and AKA are not used and packets are transmitted using plain text, an adversary can station itself between the UE and the IMS thus compromising user privacy.

A way to reduce the effects of the listed issues is to follow the security specifications with as much detail as possible. To reduce errors stemming from the human factor, educational programmes concerning security must be in place to battle the ever evolving security threats.

2) HSS
    a. structured query language (SQL) injection attack - considering that the HSS is a database, the main threat concerns data integrity but it is also possible to permanently damage the data or delete it entirely.
    b. information leaks between the AS and the HSS - the Sh interface, based on Diameter, is used by the AS to request data from the HSS which includes, among other things, location information, IP multimedia public identity (IMPU) and the IFC. In case of a rogue AS it is therefore possible to collect unauthorized data and cause privacy loss to the users.

Mitigating the security issues regarding the HSS requires implementing an SQL injection detection system and validating user inputs before sending these as queries towards the HSS.

3) AS
    a. toll fraud - the threats regarding an AS can vary to a high degree, however the most common issue is still toll fraud which can cause loss of revenue to the SP or operator.
    b. false information provided by the user - in case of presence, users update their location, status etc to the AS and it should be the ASs responsibility to verify the sent information. If not, the false information will be sent to the users' watchers, causing confusion and disinformation.
    c. threats stemming from legitimate users - these issues can arise from the fact that users exhibit malicious behavior on purpose or by accident. Usually SPs and operators provide users with limited access to the AS to make simpler configurations, however this can eventually cause confusion if the customer does not know exactly what he or she is doing or in some cases, fraud. Ultimately this can lead to reduced QoS and loss of revenue.

Similar to the mitigations with the CSCFs, it is imperative to follow the security specifications provided by both the standardization organizations and the service providers themselves. Additionally, the restrictions set by the SP or operator must be checked on a regular basis and the customers informed and educated about these constraints.

Considering the decreasing communication costs in an NGN and the increase in usability, the threats to security in these networks will also increase. This trend was already formulated in [106] and further extended with research regarding fixed networks in [107]. Both works identified a number of security issues and also ways to mitigate these. The compiled list is similar to the one described in previous paragraphs with the exception of handling the security problems from an access side point of view. The threats mentioned that need countermeasure analysis by the SP or operator include:

1) the availability of the network infrastructure which can be compromised by sending a bulk amount of malformed messages.
2) session interception or modification which may result in the attackers learning privacy information (e.g. passwords).
3) unauthorized use of the networks' resources by impersonation attacks.
4) Spam over Internet Telephony (SPIT) which will essentially destroy user experience.
5) flooding attacks such as UDP flooding which will increase network traffic and load.
6) protocol parser attacks. Since IMS uses text-based protocols, there is a necessity to pay special attention to the operation of the parser in order to not overload it with malformed messages.
7) session hijacking in case an attacker manages to disguise himself or herself as a party of the session.
8) toll fraud. This type of issue has been mentioned earlier with regards to CSCFs but in case two UEs have already established a session and both of them are fraudulent,

they can send a BYE message to the S-CSCF without actually releasing the media connection and thus retaining the session for free.

The current author maintains that based on the listed issues, two separate directions towards a solution can be specified. Firstly, the creation of a system or algorithm and secondly, a solution based on hardware can be taken.

The initially mentioned approach has been elaborated upon in [106] with a five-stage algorithm:

1) SIP message inspection which is a non-intrusive method and includes for example black and white lists. In this stage messages are scored and based on these scores they can be either forwarded as normal, redirected for additional analysis or blocked.
2) Interaction with the caller to determine his or her trustworthiness. The audio Completely Automated Public Turing test to tell Computers and Humans Apart (CAPTCHA) method is applied here. Many companies which have created applications to IMS have produced similar solutions using multi stage dialing. Whenever a user dials an "unusual" number (e.g. expensive or international call) he or she is prompted to dial an additional special code before the actual session is initiated.
3) Consent oriented communication in which case the called party is asked for feedback regarding the callers identity before the session is connected.
4) Content analysis during the call when the session is scrutinized to detect unwanted calls.
5) Post-session feedback by the called party indicating that the ended session was out of the norm (e.g. SPIT).

The secondly mentioned approach of tackling the security issues with hardware means installing an entity between the UE and P-CSCF. This node may have many names depending on its exact function, such as a Session Border Controller (SBC) (can be integrated in the P-CSCF) or, like in the case of [107], Access Security Control Function (ASCF) but their ultimate aim is the same - to separate the UE from the IMS core. No matter the name, some of the functions of these edge nodes may include: NAT, firewall, topology hiding and signaling manipulation.

Another way of looking at security and its impacts on an NGN is by considering the quality of protection (QoP) of a set of security policies. [108] has elaborated on this by firstly stating that security in an NGN cannot be viewed as it has been done so far in traditional computer systems. The prevalent "secure-not secure" approach, where a complete system is either secure or it is not, is no longer valid since it does not reckon with the impacts of security on computing resources. For example, portable devices in IMS may not have the required computing power to comply with the set security profile and therefore need special consideration.

The authors of [108] elaborate further that the QoP not only considers the strength of the security mechanisms but also takes into account their effect on system performance. As an example, signaling delay and server utilization are monitored to assess the impact of applied security policies. This method enables the utilization of a multi-level configuration where security levels could be adjusted based on a specific application, the device used or the requirements of a particular user.

As stated in [109] and [110], the proliferation of next generation networks requires a multifaceted consideration of security aspects and simply employing the evolved specifications is not enough. Additional measures are needed, both proactive and reactive, to guarantee service availability and user authenticity. The preventive tools like authentication and integrity control lay the foundation for secure operation, however implementation errors, attacks and configuration issues can only be resolved after the fact.

3.3 Migration Task and Post-Migration Processes

A claim is made by the author that with the complexity of NGNs, monitoring of every node and procedure is the only way to ensure the continuity and quality of the services delivered to customers. This will be elaborated upon in the current sub-section, however, as mentioned earlier, the actual migration task will not be considered in detail in the thesis since this can be considered a series of trivial operations performed by man or machine. The reason why the migration task and post-migration processes have been gathered under a single sub-section is beacause these take place temporally very close to each other and the former is a direct introduction to the latter.

The final step in the complete migration process, post-migration processes, is divided by the current author in [63] into three general areas as seen in Fig. 3.10. These are verification, monitoring and management. Verification is the check to make sure that the final outcome of the migration process is successful. Verification can be further trisected based on the verification type. In case migration is done manually, the check, or parts of it, is usually also done manually. The same analogy can be applied to automatic migration with the verification performed without human interaction. The third option is a mixed case when some checks are performed manually and some automatically. The procedures during verification must contain information about the verifying entity, what exactly is verified and at what stage. Additionally, feedback must be given to earlier phases of the migration process to mitigate the effects of erroneous behavior.

Before starting the sub-step of monitoring, its task must be identified. Monitoring can be, firstly, viewed as input for fault management and hence for any proactive action taken by the SP or operator. Secondly, monitoring can be used as a verification tool. If monitoring indicates growing activity in an NGN, it means that a successful migration process is in operation. Lastly, monitoring is a source of information for future network planning since, for example, congestion problems will become visible is real-time and this data can be used for network scalability planning.

When monitoring tasks are identified, available resources should be considered. Telecom operators and service providers are working in a state of limited resources, meaning that it may not be possible to monitor every node within the NGN and in this case the core nodes usually get a priority. In IMS these nodes include the CSCFs, HSS, DNS and border nodes such as the SBC. This view is supported in [111] where specifically the UE registration procedure, concerning the CSCFs, has been identified as the foundation for service delivery since the lack of registration means no services can be delivered to the customer and hence the monitoring of registration data is assigned the highest priority.

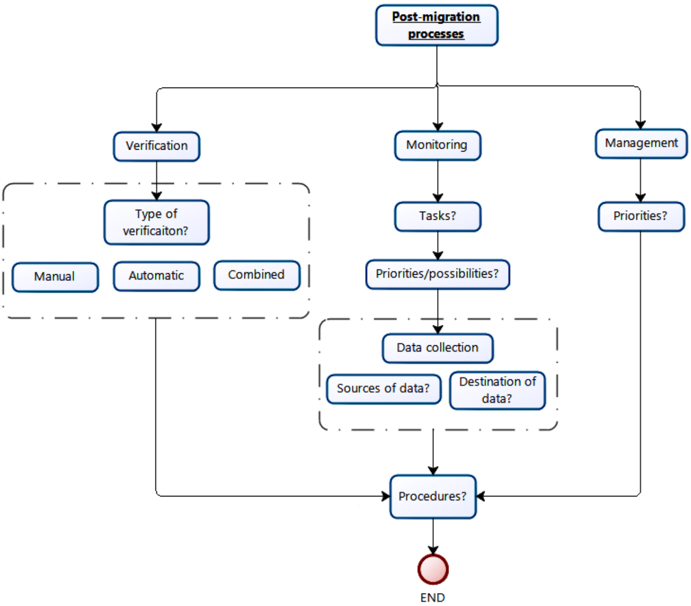

Figure 3.10. Schematic of operations during post-migration processes [63], adopted by the author

Data collection must also be addressed, meaning the aggregation of collected data into a single point where it can be manipulated to a desired human readable form. An example of this is depicted in Fig. 3.11 where a Cacti graph of the registration data and SIP response codes of an S-CSCF can be seen. This network information data, in general, consists of different alarms, events, operational notifications and network element counters. The alarms are generated when certain network metrics, called key performance indicators (KPI), exceed a defined threshold or when a link between elements is broken. Additional measurement graphs are illustrated in Appendix F in the form of a collection of key Cacti graphs within an operational telco company.

3GPP has defined counters in [112] for core IMS nodes such as the CSCFs, the HSS, MRFC, BGCF and the AS. These can be used as the basis for defining thresholds. Additionally, the thresholds should be based on QoS policies and need to guarantee that the problem is detected while the probability of false alarms is minimized.

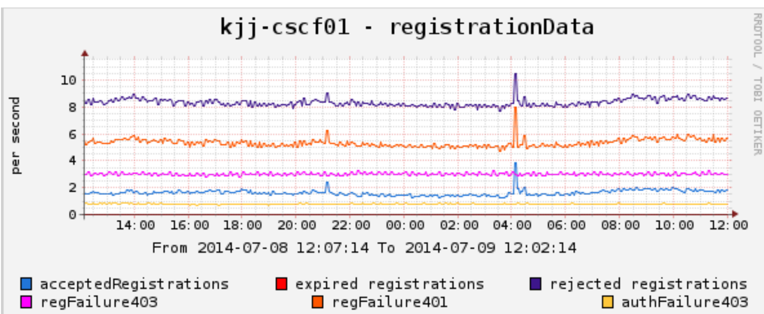

Figure 3.11. Monitored data of an S-CSCF

In Fig. 3.10, management in the post-migration phase comprises of initially describing priorities, similar to monitoring. While every user and service within the NGN must be managed, it is clear that some issues must be addressed first. Priorities should also define how and by whom management is done. Finally, as with other chains in post-migration, management relies on pre-established procedures regarding the division of labor between man and machine. In [63] the management chain also includes integration with OSS/BSS which has been removed from Fig. 3.10 since the author of the thesis did not deem it necessary to mention this specifically, since it is already implied in the analysis regarding management.

As to monitoring, although 3GPP has considered QoS provisioning through standardization, the matter of defining monitoring mechanisms, according to [113], is lacking. A claim is made that 3GPP specifications focus only on providing services such as reserving resources, without describing the behavior that should follow, hence effectively delegating the monitoring to the SP or operator. To solve this issue, the eTOM SLA verification procedure is considered and applied for monitoring services. The mentioned procedure identifies whether the current QoS level actually meets the level described in the SLA through the use of data collected from the network elements.

The verification process itself comprises of four stages:

1) the collection of performance indicators in the form of KPIs. Three classes of performance indicators are identified: network indicators (jitter, delay, bandwidth), configuration indicators (access technology, transport protocol, etc), service indicators (frame size, coding protocol, bitrate, etc).
2) mapping of quality indicators. Quality indicators are correlated to the service in order to identify the QoS in a more concrete way compared to the performance indicators. For this, using the performance data, a key quality indicator (KQI) is calculated to describe the quality perceived by the customer.
3) comparing the KQI and the SLA. The SLA must be compiled in a way that the quality clauses can be compared to the KQI.
4) reporting for further action. In the course of service delivery, KQIs are constantly calculated and compared to the SLAs and if contardictions are found, the issue is reported.

The author of the thesis is ensured that as a part of the automated fault management, which is an essential part of management in post-migration processes, the dynamically composed services in NGNs require mehcanisms for root cause analysis (RCA) as well as self-healing mechanisms. This in turn means that monitoring procedures for both the IMS signaling layer and the application layer must be put in place. By only monitoring the application layer may not provide enough data for proper RCA. In case there is a malfunction in a composite service and no errors are detected in the signaling plane, the management system can initiate a replacement of the erroneous component. Otherwise, restarts are initiated within the processes in the signaling layer. This method has been followed in [89], in which a fault management system for IMS processes and SOA-based composite services has been created which utilizes restarting mechanisms and re-composition mechanisms for dynamically substituting malfunctioning service components. However, the authors point out that while the self-healing mechanisms for the signaling layer can be initiated and completed within a second, the fault detection time in case of a complex service can be significantly higher.

A need to follow the mentioned notion of monitoring the network and services is also identified in [114] where a management system has been created, similar to the one illustrated in Fig. 3.4, which utilizes service managed objects (SMO) for error detection and fault recovery within services. Central to the management system is the, already mentioned, IMS-SDP Management Server, illustrated in Fig. 3.12. This monitors the states of the critical IMS/SDP components and comprises of different management functions which enable to collect and anlyze network traffic and performance data from the session control layer. Additionally, the ISMS gathers security, fault and configuration data using agents at different managed nodes that deliver the information.

As a roadmap for SPs or operators in fault management, the scenario using ISMS may occur as follows:

1) a service is disrupted and the client notices this (watching IPTV for example);
2) customer notifies the helpdesk of the issue;
3) helpdesk sends a notification of disruption to the ISMS;
4) a session service disruption SMO is created by the SMO Creator module;
5) the ISMS sends an on-demand for Managed Objects (MO) to the managed nodes;
6) MOs, which provide different measurements of the network, quality and services, are sent back by the IMS/SDP nodes;
7) the SMO Composer constructs an SMO from the collected MOs;
8) using the constructed SMO, the ISMS can identify the problem in the system by comparing the measured values with the threshold values;
9) the fault management node will detect and localize the problem and send an alarm to the configuration management module for reconfigurations;
10) maintenance parameters may also be sent to the maintenance personnel;
11) the nodes responsible for QoS, SLA and business processes are notified;
12) the parameters of those nodes are modified accordingly.

Adding to this, accoring to [115], specific information regarding RCA should be kept in the management servers' database and must contain a graph of inter-service dependencies and the health state of each monitored service. The policies used in fault management are tasked with connecting this information with the data received by actively testing a service which will eventually lead to a remote agent carrying out an error recovery procedure (e.g. restarting a service).

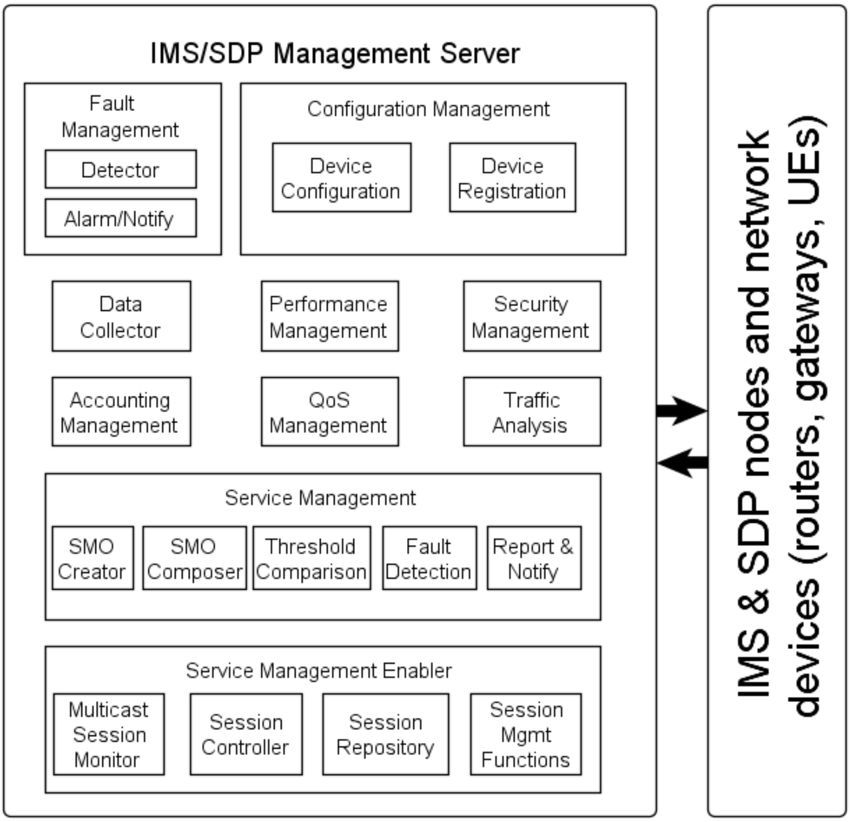

Figure 3.12. ISMS functional components

The same research also points to an issue of following chronological data in fault management. The experience of the authors refers to the matter of making erroneous service recovery decisions when timestamp information is discarded.

3.4 Summary and Assessment

A migration process, consisting of four phases, is proposed in the thesis. These phases include pre-analysis, analysis, the actual migration and post-migration activities. A claim is made that without proper analysis and preparation, the SP or telco operator will encounter issues in the final stages of migration which demand resource encompassing fixes or in a worst case scenario, the migration, or parts of it, may have to be restarted.

It is also clarified that a complete analysis can never be achieved by a single author as the myriad of issues to consider depends on a specific SP or operator and therefore cannot be identified. The analysis in this thesis is derived from studying best practices, standardization documents and the experience of the author in order to bring forth the main factors to consider when migrating users and services to a next generation network.

Both non-technical and technical issues are covered in the analysis section with the emphasis on the technical ones. While studying the materials published by telco companies and authors in the field worldwide, it becomes clear that the main effort is aimed at brushing up the little details instead of focusing on fundamental issues. This behavior can be viewed as a problem since the experience of the current author shows that neglecting core problems and concentrating immediately on details will eventually lead to a dysfunctioning network. On the other hand it is feasible that the core issues, which need solving, are taken for granted and thus disregarded from being published. Following the same logic, the analysis in general could have been more credible with additional data from companies. This specifically includes financial data which, with the exception of mandatory published data, is considered proprietary and thus not revealed to the general public.

Considering the initial aims, specified in the beginning of this chapter, the following statements can be made:

Firstly, looking at pre-analysis in conjunction with the applied strategies worldwide from Chapter 1, a statement can be made that exemplifying migration strategies is mostly successful. Initially, a set of possible migration strategies are brought forth by the author and to verify their use, telco companies in countries with differences in size and population are examined. The notion of abrupt PSTN replacement does not find assurance, most likely due to the necessity of considerable resources. The most common strategy is found to be an overlay solution with the legacy network and NGN operational at the same time which enables distributing resources over a longer period of time. A claim can be made that the best an operator or service provider can do abruptly is change a part of a legacy network.

The pre-analysis phase also considers the topic of migration from a broader viewpoint than just the SP or operator. This approach is important since large, and especially international, companies are becoming more socially aware. For this reason, the influence of migration to national GDP and dissemination of broadband are discussed with the latter being essential to a successful migration towards an NGN.

Secondly, creating a roadmap for SPs and operators to follow when migrating is partly successful. Initially, it is envisioned that producing such a roadmap is possible, however at this stage the author is convinced that due to the multifaceted nature and complexity of NGNs, success can only be partial. Although attempted, a concrete roadmap is achieved only with a high level on generalization for specific parts of the complete migration chain.

The thesis lists the technical core aspects to analyze as QoS, supporting systems, charging and security. With each keyword a foundation is placed through considering what standardization organizations have drawn up and then moving to a more detailed discussion to see what real-world applications have been provisioned. In conclusion, a relevant collection of ideas with examples are discussed and presented to the reader, leaving room for SP or operator specific interpretation.

Thirdly, with regards to post migration, monitoring and management are brought forth as the key issues. The reason why management is discussed here, when already considered in earlier parts of the thesis, is the aim of the author to emphasize the separation of network management in general and fault management which is neglected to a certain degree by most telco companies.

4 A Model Supporting System for Migration

The aim of this chapter is to further complement the analysis done in the previous chapter, especially in the realm of a concrete roadmap to follow. For this, the author of the thesis has described a part of a live supporting system, operational at Telia Estonia Ltd where the principles and notions discussed in Chapter 3 have been partially applied. Due to its vast size, considering the complete system will not be possible within the confines of this thesis, however, using the authors' own work in [116] as a basis, part of the system is described to illustrate how the mentioned issues in the analysis part of the thesis have been, if at all, solved and how the system can be enhanced. The key processes, nodes and interfaces have been brought forth where deemed reasonable and the data on them described.

4.1 Provisioning

The supporting systems used by telecom operators and service providers can be considered tailor made. This matter has been elaborated upon in detail in [116] where an operators' OSS/BSS is considered to be a crucial factor in migrating users and services to next generation networks. The systems in question include standardized interfaces and nodes but these only provide the core on top of which the complete system is built. The additions and extensions are built in-house and according to the needs and specifications of the operators or SPs themselves.

The same research shows how provisioning in NGNs has evolved from legacy networks. A general overview of this has been illustrated in Fig. 4.1.

Three key differences can be pointed out: firstly, pre-NGN provisioning was done predominantly manually, secondly the increase in the number of nodes and thirdly the need for a central component, a provisioning system (PS), to manage the provisioning process. The provisioning system indicated here is, as a general term, referring to a system capable of receiving provisioning orders, queuing and distributing these between several core and supporting nodes and monitoring the success and failure rate of provisioning operations.

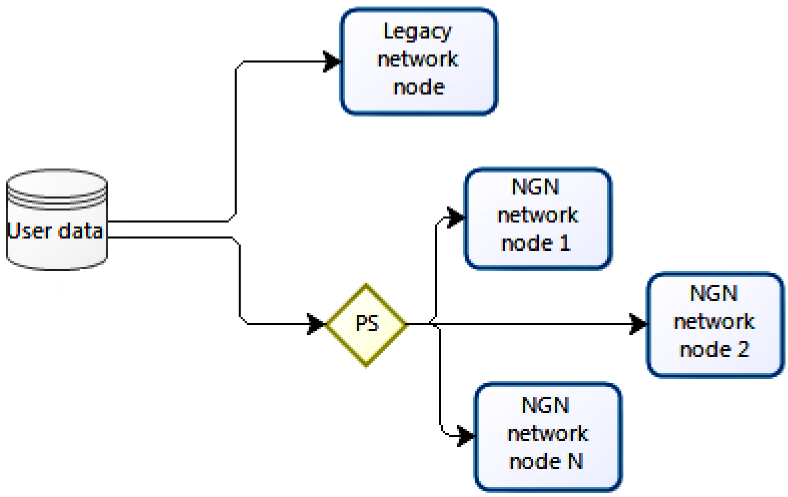

Figure 4.1. Change in provisioning from legacy networks to NGN [116]

Maximum automation has been considered a key factor in the transition to an NGN according to [117], however with legacy networks there was no urgent demand for this. First of all because the number of nodes in the network was small and secondly because the stovepipe nature of services made it difficult. Figure 4.2 shows a straightforward chain through which a user was provisioned.

The initial work order (WO) was inserted into the telco management front end (TMFE) and passed through the input mediation (IM) and provisioning tool (PT) to be terminated in the digital exchange (DE) by the command generator (CG). The task of the IM in pre-NGN scenarios was managing the work order queue and passing on the orders accordingly. The provisioning tool, consisting of a number of identical command generators, was used to access and modify the digital exchanges via a man-machine language (MML).

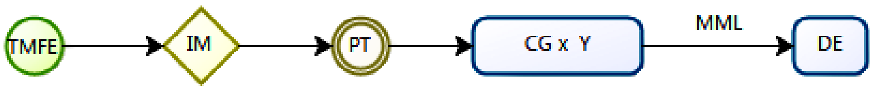

Figure 4.2. Pre-NGN system for provisioning [116]

The majority of the nodes considered in the current section are situated in the operations and maintenance (O&M) subnet as depicted in Fig. 4.3. This is due to company policy, keeping in mind the issues of security, management and access.

Figure 4.4 displays a general view of a model supporting system, in the context of IMS, operational at the telco operator. The figure is mainly compiled based on following the path of the initial migration WO, however it additionally includes the relations between adjacent nodes which are not directly roped in the migration task but are relevant to providing the post-migration end result to the customer.

The following paragraphs will consider all of the nodes and their relationships to other nodes in greater detail.

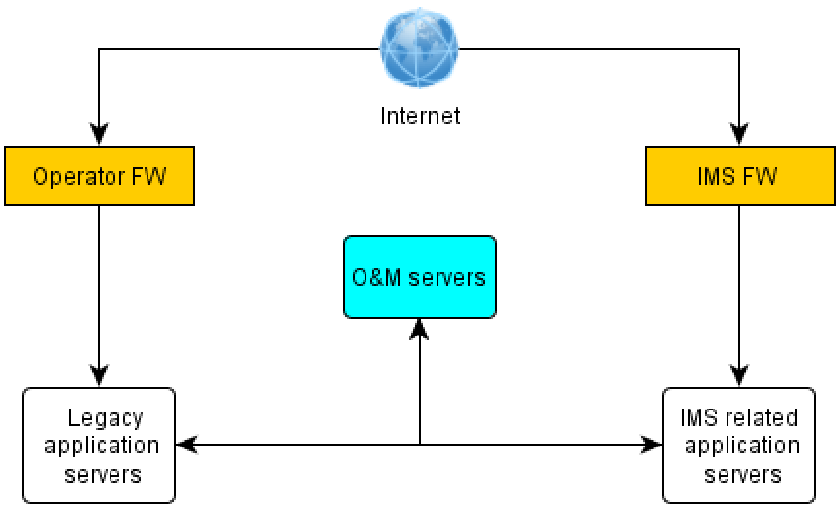

Figure 4.3. The operators' application server network

Telco management front end

As in Fig. 4.2, the work order enters the system via the TMFE which is a web based client management and invoicing system. The following areas are managed using the front end: operators' clients, services, client and product contracts. Additionally, the TMFE is used to carry out product sales and shipment.

The core of the telco management front end is comprised of a collection of modules, each with a specific task:

a. Product register (PREG) - the module deals with all of the products and additional products in the operators' selection. A product in this view is not a physical product such as an IP desktop phone or a 4G router but encompasses for example ISDN or IPTV affixes.
b. Services base (SRVB) - services sold to the customer are described and managed in this module.
c. Contract system (CONS) - deals with the contracts regarding the products listed in the PREG. Whenever a product is sold or built, a contract is formed. Additionally, the mentioned contracts may be stopped, terminated and modified according to the action taken with the product itself.

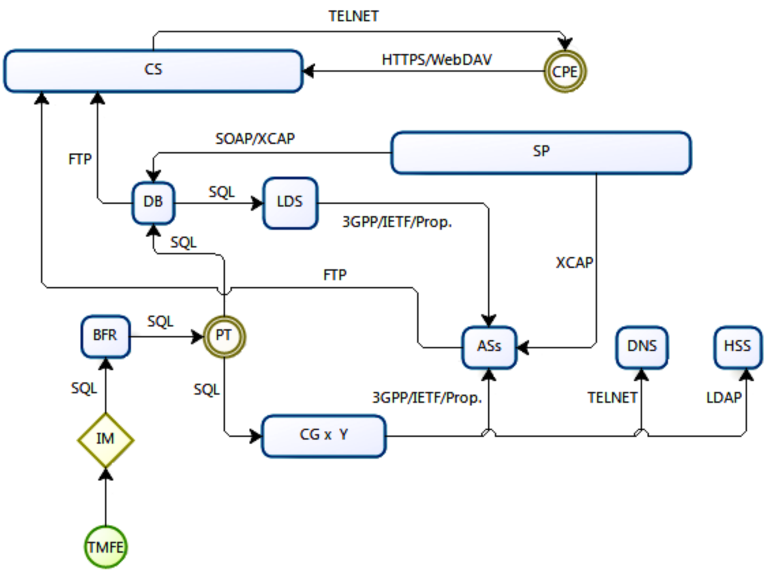

Figure 4.4. A partial high level schematic for a model supporting system of the operator [116]

d. Communication means (COMM) - a register of different communication means, whether it is a digital phone, business VoIP phone, business phone, analogue phone etc. The data in the COMM module is used by the operator in the sale and product supply processes.
e. Client management (CLIM) - the module operates with customer data. Every customer has a specific datasheet created for them and inserting and modifying information on the datasheet takes place using the CLIM module.

f. Credit control (CRCO) - the functionality concerning a customers' credit control is centered on the CRCO module. The functionality includes for example keeping records of client credit history and making inquiries into the saved data.
g. Client claim module (CLAIM) - client claims towards the operator are managed using this module.
h. Devices module (DEVM) - the module encompasses managing physical devices in the operators' assortment. The devices are listed in a modifiable register and used by other modules whenever needed.
i. Offerings register (OREG) - offerings made to the customers are listed and managed using this module.
j. Accounting module (ACCM) - invoices to the customer are managed in the ACCM. However, periodical invoices are created at the database level.
k. Accrual module (ACRM) - the funds accrued by the operator are visible and can be managed in this module.
l. Request module (REQM) - the REQM enables the operator to make requests towards different modules which may include financial, additional products or contracts requests. Additionally, the same module is used by law enforcement agencies in special cases.

Input mediation

The following node, input mediation, is one of the many outputs of the TMFE and is tasked with verifying each task before forwarding them to the appropriate module within the input mediation. The IM operates as the distributor of tasks and is connected to several network registers and adjacent systems. The operation of these systems is not only limited to migration tasks as they additionally make changes to several nodes in the operators' network and are therefore vital. The data enters the IM in the form of an eXtensible Markup Language (XML) document and is then further parsed and inserted into corresponding tables.

The modules of the IM are as follows:

a. Distribution module (DMOD) - the first contact point of a task upon entering the input mediation. The DMOD receives the task, verifies it by checking that all the parameters are valid and forwards it to the appropriate module for further processing.
b. Work order management (WOM) - encompasses a system for managing the work orders in the product and troubleshooting supply chain.
c. Mobile work order management (MWOM) - logic in this module is identical to the one created in the WOM, however, the user interface is optimized for certain smartphones.
d. Time planning module (TPLM) - since some tasks require a visit by a technician to the customer premises, their time must be planned. The TPLM module takes into account the possible tasks a technician may perform and the allotted times for those tasks to draft a schedule for optimal use of the operators' temporal resource.
e. Service management module (SMM) - the SMM is a central module in the input mediation in the sense that this is where the creation and termination of services is managed. Services belonging to both the phone and data communications realm are managed.

f. Number management (NMAN) - management of the operators' complete phone numeration. This includes creation, termination, modification and assignment of numbers to users and services.
g. Number portability (NPOR) - the given module is designed for managing local number portability (LNP) issues in cooperation with national agencies.

Although not planned intentionally, starting from IM, eTOM priciples can be identified in the form of attempting to create a high quality end-to-end process flow, adopting a standardized terminology within the company to simplify internal operations and identifying opportunities for performance improvements in deployed systems. The fact that the supporting system at the operators' premises has unintentionally matured to its current status in relative conformance with the eTOM framework is a testament to the latters' applicability and logical structure.

Buffer

The volume of the buffer (BFR) node has a defined limit - a maximum of a hundred tasks can be buffered per exchange or IMS node. The BFR is filled using an SQL query towards the IM after a predefined time. After receiving data from the IM, it is passed on to the next node and vice versa.

The buffer is also capable of handling data that does not only contain the fact of a task or its completion. In some cases, additional information is also forwarded by the BFR. This information may be passed on for instance when a task has failed and error codes or other reasons for failure are forwarded in conjunction with the data of task failure. The volume of the buffer does not have to be at maximum capacity in order for it to start forwarding tasks.

Provisioning tool

The central node of the supporting system, from a provisioning point of view, is the provisioning tool. It is used to deal with users, services and IP interfaces. Users can be created, deleted or modified, services can be linked to specific users and long distance configurations can be managed. The latter may be the case when, for example, a configuration change in the clients' router is needed. The PT can also be used as a source of information for fault management. For load distribution purposes the PT consists of a number of command generators. These are logical entities which make the actual changes in the required nodes. The CGs are configured to poll the PT after a predetermined interval for pending work orders. After a CG has acquired a job it marks it as "in operation" in the PT database so no other CG can fetch it. In addition to polling of new tasks the command generator also updates its own status after a predetermined time so the PT has knowledge of its operational ability.

The CGs are set to operate on a first come first served basis and independently to achieve redundancy. Each task polled by the command generator is assigned a command identifier (CID) by the provisioning tool and the CG uses this to determine a specific script to run. The complete process of any one script has separate steps and the completion of these steps are monitored. In case a step fails and an error condition is discovered the script will terminate or the following steps may be skipped. Upon successful completion of a step the next one will be initiated. After the script has run its course the CG will update the WO table in the provisioning tool and if any error conditions were met, these and the step at which they occurred will also be inserted. Depending on the severity of the error, a notification may be sent to an employee of the operator for detailed processing and possible enhancement of the system.

The AS, domain name system (DNS) and HSS, depicted in Fig. 4.4, are the key, but not the only, nodes accessed and modified by the PT in case of user migration to IMS. This is done using both proprietary and standardized protocols. An example output log (user creation) of the provisioning tool is added in Appendix C.

The command generator follows the given steps during user provisioning:

1) the application server is queried whether a group exists for the user. A group is a bundle of users usually belonging to a single company or private user. This system helps maintain order and find the user at any point in time.
2) the application server is queried whether a service provider has been created. The notion of a service provider here differs from that which has been mentioned throughout the thesis. Namely, it follows the same logic as with the group in the previous section, however the service provider is a collection of groups. The operator may have a need to distinguish users not only based on groups but on a larger scale. For example when operating in multiple countries, groups in a specific country may be collected under one service provider.
3) user data in inserted into multiple modules in the nodes belonging to the OSS/BSS realm. An example of this is the provisioning tool itself which can access the inserted data from its tables at a later point whenever needed. Additionally, user information may be inserted into tables of a number of supporting servers such as servers handling statistics, however this depends on the specific user and the services it is going to use.
   The data written into modules of the OSS/BSS nodes includes for example: the account, group identifier, service provider, personal identification number (PIN), user name etc.
4) the user is assigned a default set of services in the AS. This includes the ability to make calls, different call forwarding capabilities, call transfer, sequential ringing, etc capabilities. For ease of management, services have been bundled into service packs by the operator.
5) entry of the user is created into the HSS which includes: the user, subscriber information, PIN, user service profile, trigger information, phone context, SIP public ID, ENUM DNS data and TEL public ID.
6) user is created in the AS. Whenever a user is provisioned, one of the inputs is the group identifier mentioned earlier. In case the group exists the user is automatically provisioned in that group and if the group is non-existent, it will first have to be created.
7) user entry is created into the DNS to form an ENUM record for addressing the B-party in IMS.
8) data of the created user is entered into the service portal node which will be discussed at a later stage in the thesis.
9) all of the nodes and modules that have been accessed during user provisioning are accessed again to confirm the changes made.

The modules of the PT are as follows:

a. IMS application server management support tables (ISMST) - the tables contain data regarding, for example: IMS accounts (users names and types, extension numbers, E.164 numbers), proprietary application server information such as group memberships, service logic information, information about voice prompts and their locations, etc. There is a similar module in the database node, however the data there is structured differently. The data in ISMST is relocated into SQL databases of other IMS servers as with the database node this is not the case.

An example snippet list of the data in ISMST can be found in Appendix D.

b. IMS application server statistics (IASS) - this module deals with the collection of statistics information from different IMS application servers. The views to browse through the data are also situated in this module while the main task of the IASS is to translate the collected data into human readable form and send it to the customer. As an example the customer can receive information about what choices have been made using their IVR system.
c. Application server support tables (ASST) - a collection of tables containing both legacy and IMS application server supporting data about a multitude of services. This data is replicated into several application servers based on the service logic. An example of the information kept in this module is the IMS conference group data. This contains PIN codes and their relations to participants of the conference and also participants and their states.
d. Intelligent Network (IN) application server support tables (ISST) - the module houses IN application server supporting tables. For example number portability tables (both fix and mobile) and A-number modification service tables (initiating a call to a specific number will modify the caller ID of the originator).
e. IN services statistics import (ISSI) - statistics regarding IN services are imported using this module and inserted into specific data tables. The module also provides views to browse the data and facilitates exporting the information to customers.
f. Voicemail Management (VMM) - the module is used to manage the mobile voicemail service. This includes for example creating and deleting the mailbox, restricting the service due to debt and modifying the destination address (e-mail) to where the client is notified upon arrival of a new message.
g. Number provisioning module (NMP) - PSTN and VoIP numbers are provisioned in this module, i.e. every action in the creation of a number profile is conducted in the NMP. The number provisioning module also addresses other modules within the provisioning tool whenever required.
h. Number provisioning module 2 (NPM2) - the development module for the NMP. Currently situated in the live provisioning tool, however future plans see this module being moved to the backup provisioning tool which acts as a hot reserve.

Database

The provisioning tool additionally addresses the database (DB). As the PT needs to access different nodes and devices within the operators' network, it needs to know their location and access information. This has been saved in the DB. The DB also acts as the keeper of translation information, i.e. how to translate SQL commands into commands understood by the different nodes.

An example of the procedure logic when activating call restrictions for a user (the Simple Objects Access Protocol (SOAP)), messages involved and other relative data has been listed in Appendix E:

a. an SQL procedure is started in the provisioning tool to restrict a user from originating calls towards the mobile network;
b. after checking the input parameters the command is forwarded to the database;
c. the DB initiates a specific procedure where first of all the current settings of the user, in the form of an XML document, are requested from the AS;
d. upon receiving the document, the DB modifies it and sends it back to the AS through the load distribution server (LDS);
e. finally, the DB translates the answer coming from the AS into a form understood by the provisioning tool.

The database consists of the following modules:

a. Call center statistics module (CCSM) - this module handles the collection and processing of a proprietary IMS call center statistical information. After the data has been processed the customer can view it from the service portal which will be considered in a later section of the thesis.
b. Digital exchange CDR collection (DECC) - the CDRs of digital exchanges are collected and processed here and sent to the operator communication platform web (OCPW) which is an operator internal information system for viewing data.
c. IMS CDR collection (ICC) - similarly to the DECC module, IMS CDRs are collected and sent to the same internal information system for viewing. The data collected by the ICC can also be accessed by the customers through the service portal.
d. Mediation CDR collection (MCC) - the module is responsible for receiving CDR information from the operators' central mediation server. The operator uses different application servers within its IMS core, some of which are not capable of exporting formatted CDR data. Instead, call events are exported. For this reason the operator has created a central mediation server which collects events from a myriad of servers (not only from IMS) and translates these into formatted CDR data. The MCC is tasked with receiving the information from the mediation server and sending it to the OCPW for viewing.
e. IMS application server management support tables (ISMST) - essentially the same module as in the provisioning tool, however the data is structured differently.
f. Configuration log module (CLM) - the module gathers configuration log information. For example, if the configuration of a router is modified, the event is registered here and further sent to the OCPW for viewing. The mentioned information system is often used in troubleshooting by the helpdesk.

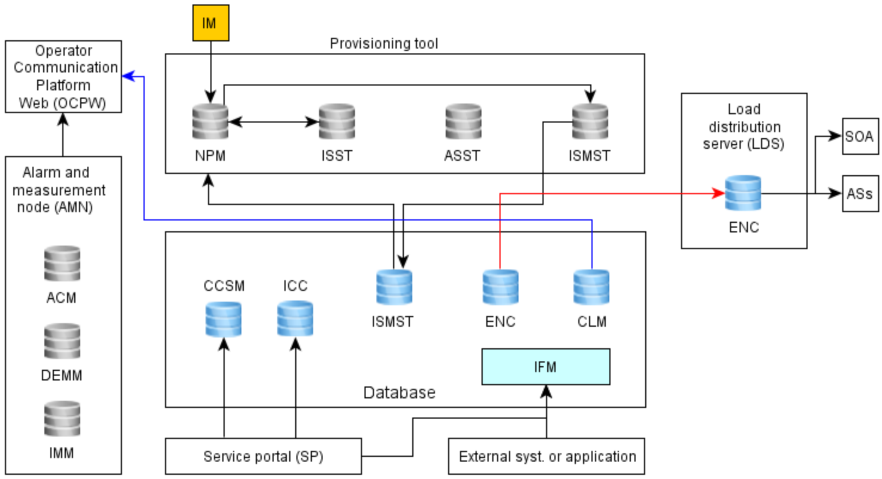

Figure 4.5. Extended view of the operators' provisioning system

g. External node communication (ENC) - whenever the provisioning tool uses the database node to access other network nodes it is done using the ENC module. As seen in Fig. 4.5 the database can access IMS internal nodes through the LDS. In this sense the ENC can be viewed as the distributor of outbound traffic from the DB.

h. Initial filtering module (IFM) - the first module accessed by any external system or application when making a request to the database. The IFM receives requests and filters them to be forwarded to a specific module.

Load distribution server

The LDS is an enhancement to the provisioning system, added at a later stage in the systems' development. The need for it became clear as the operator grew in size and complexity and currently it is used mainly to minimize lag while accessing the application servers during specific tasks which might cause overload conditions in the command generators. Figure 4.5 illustrates how the LDS, similar to the database node, contains an ENC for external communication and forwards the commands to the ASs.

Alarm and measurement node (AMN)

The alarm and measurement node in the operators' supporting system is vital since the information collected there is the input for the troubleshooting chain. Figure 4.5 depicts alarm data being collected in the AMN and forwarded to the OCPW where troubleshooting processes put in place can be further initiated. The OCPW is an environment for collecting, visualizing and forwarding fault and alarm data based on pre-established procedures.
Modules of the AMN are:

a. Alarm collection module (ACM) - all of the alarms from digital exchanges and IMS nodes are collected and processed here. As such, the AMN is in conformance with the main management principle of being tapped into multiple layers of the service delivery platform, discussed in Chapter 3. Different types of alarms are differentiated, i.e. initiated alarms and alarms end events. The information is sent to the OCPW from where it is monitored by helpdesk employees. The ACM also creates automated notifications based on the received alarms and sends these to predefined locations.

b. Digital exchange measurement module (DEMM1…n) - collects measurements from digital exchanges such as processor loads and momentary voice traffic.
c. IMS measurement module (IMM1…n) - has the same functionality as the DEMM but collects measurements from different IMS nodes.

Self-regulation

This sub-section collocates the service portal and configuration server (CS) nodes. The notion of adding these two under a single sub-section is the idea of the author, since they form a collection which, in the eyes of the operator, should not require any effort.

The service portal features, on the one hand, a number of service tutorials and instructional materials. However, when the VoIP group administrator logs in, he or she is presented with simple management features such as user name and number presentation or call recording activation, but can also be forwarded to the VoIP group management web, provided by the vendor of the application servers. In essence a client could modify their users and services to a large degree using the vendor provided web but as stated in the analysis part of the thesis, this can be considered a security risk and thus the management functions which pose a threat to the operation of the clients' users and services have been disabled by the operator.

To simplify the integration, provisioning and maintenance of access devices in the operators' network, a configuration server has been deployed in conjunction with the application servers. Telco industry best practice dictates that before a CPE can connect to the application layer of an IMS platform, a corresponding access profile must be defined for that device. This enables the operator or SP to tailor service delivery to match the specific capabilities of any given device operational in the network. As an example, one device can support multiple call appearances while another may support dynamic registration.

To tackle the issues arising from this exact reason the operator has deployed the configuration server which houses the mentioned access profiles for CPEs. Figure 4.4 indicates that the application servers can deposit their profiles to the CS using either FTP or web distributed authoring and versioning (WebDAV).

4.2 Assessment of Model System

Based on the presented supporting system the following statements can be made:

1) Nodes of the supporting system are placed in the O&M subnet which is logical and demonstrates basic compliance and understanding of network security. Only a limited number of people and processes can access the core nodes from a separated part of the network.
2) With the use of the TMFE parallels can be drawn to the management principles discussed in Chapter 3. As stated there, the aim of management in NGNs should be to unify service creation, business and management processes. Comparing the functions depicted in Fig. 3.5 and the TMFE description, a claim can be made that unification has been partly achieved. The TMFE contains a central CRM, a database

for products and services and a module for accounting, however it does not include for example fault management. This means that the management system is not tapped into every layer of service provisioning.

3) The LDS can be viewed to be in conformance with the main SOA principle of providing services to other nodes and services.
4) Fault management is, in principle, resolved in such a way as discussed in Chapter 3 by tapping into different layers of the NGN with the use of the AMN. However, the used AMN is a collector with the fault and measurement data only moving towards it. This means there are no active preventive measures to avoid problems in the network and nearly all issues can be detected after the fact.
5) As discussed in Chapter 3, to minimize contact between the client and the operator, business customers have been given access to manage their own user accounts and some of their most widely used services through a web interface called the service portal. Customers having a vast number of accounts, have usually authorized a single representative for this task.
6) In general, the supporting system is based on the notion of modularity. This can be observed with both the detailed construction of the discussed nodes and with the supporting system itself. This essentially complies with the eTOM model and guarantees that the telco can develop its processes and systems in an agile way while minimizing the possibilities of interrupted operation.

To the best knowledge of the author, the implemented supporting system has matured to its current state through operational experience. On a large scale no specific standards or frameworks have been followed which proves that a certain amount of standardization and adherence to best practices, discussed in Chapter 3, can be achieved by simple logical reasoning.

CONCLUSIONS AND OPEN ISSUES

The aim of this thesis was to create a roadmap for telecommunication operators and service providers to follow while migrating from legacy networks towards NGNs. The research done can be justified with four articles presented at international subject field conferences and published in corresponding journals. As the research focused briefly on the non-technical issues and more thoroughly on technical details of migration, items for further investigation can be brought forth from both realms.

The thesis contributes, firstly, to the compilation of a broad discussion on the best practices for migration. The most common strategy for migration was found to be using an overlay solution and keeping the legacy network in operation while implementing an NGN and moving services and users onto it. Still, the matter of a sudden transition from legacy to NGN remains uncharted. The author notes a similar initial investment for both cases as the required IMS core consists of the same nodes. However, due to the sensitive nature of any telco companies' financial records and strategical information, a comparison between the two approaches proved unachievable. Measuring the theoretical benefit of an abrupt transition from legacy to NGN may possess value with regards to future migration scenarios. An example of this, although not entirely accurate in the context of this thesis, may be a transition from any contemporary communications network to VoLTE or to a fifth generation mobile network.

The matter of migration to VoLTE can be considered an open issue throughout the thesis as most telco operators worldwide are striving towards this goal while at the same time operating PSTN for example. Considering that VoLTE is the next step in evolution, it is clear that migrating from PSTN to an NGN and VoLTE in conjunction places extra load on any telco company and it is the hypothesis of the author that some of this stress can be relieved by removing intermediate steps, regarding supporting systems for example, between PSTN and VoLTE.

The second contribution of the thesis is the creation of a migration process, consisting of four phases. The discussion in each phase is based on the authors' articles and further elaborated upon by studying similar published work and the work done by standardization organizations. It is stated that any telco operator or service provider should start the transition to a next generation network from a pre-analysis phase where the need for migration must be identified by the highest management of a company. Specific analysis regarding migration is done in the second, i.e. the analysis, phase. The third and fourth phase, the migration task and post-migration processes respectively, have been considered in conjunction as these are temporally close-set and form an intuitive unity. The most important phase of the complete migration process is identified as being analysis since it lays the foundation for all following activities.

The novelty of the thesis is revealed in Chapter 3 with a broad-based discussion of the mentioned migration process and specifically its technical details. Similar work has not been published thus far. The key technical issues identified for migration are QoS, supporting systems, security and charging.

Considering the quality of service, the notion of SLAs and policy based QoS provisioning is brought forth by the author. However concrete actions to alleviate any condition, which is out of the set norms, are not specified and can be considered an area of interest for future work. This means studying correcting mechanisms and the ways these can be applied with minimal resource consumption.

With supporting systems, the emphasis has been directed at central management and unification of management processes. For the latter, eTOM and SOA have been identified as keywords which merit attention in the analysis phase. The author believes that the real-world use of these principles is worth future investigation. As an example, the transformation of a model legacy supporting system into a next generation supporting system, which conforms to the eTOM principles, would be interesting. This would indicate the feasibility of such a task and if successful, could provide guidance for future attempts made by other companies.

As each evolutionary step in developing telco services, as a rule, requires additional nodes, the use of virtualization technologies will become inevitable. Although virtualization is not mentioned in the current thesis, it is an area of interest which will provide benefits to operators and service providers in the future in the form of reduced network complexity and management. This requires research on how the performance of NGNs and hence QoS can be guaranteed with virtual environments. This issue must also be studied from a non-technical point of view. For example, corresponding SLAs must be re-thought and amended.

The third contribution of the thesis is the discussion regarding a model supporting system in Chapter 4. Albeit only a portion, this much detail regarding an operational supporting system has not been published before. The model is considered to enhance the analysis done in the thesis and conformance is found between the theoretical work in Chapter 3 and the real-world application.

References

[1] Official website of Statista Inc., available at http://www.statista.com/statistics/271491/worldwide-shipments-of-smartphones-since-2009/, [Dec. 14 2015].

[2] Official website of Gartnec Inc., available at http://www.gartner.com/newsroom/id/2996817, [Dec. 14, 2015].

[3] J. Salina, L. Salina, P. Salina, *Next Generation Networks: perspectives and potentials*. John Wiley & Sons Ltd. ISBN: 978-0-470-51649-2. 2007.

[4] Cisco, C.V.N.I. (2013). *Global Mobile Data Traffic Forecast Update, 2012-2017*. Cisco Visual Networking Index (VNI) Forecast.

[5] J. Matthing, P. Kristensson, A. Gustavsson, A. Parasuraman, "Developing successful technology-based services: the issue of identifying and involving innovative users," *Journal of Services Marketing*, vol. 20(5), pp. 288-297, 2006.

[6] Y. Jeong, I. Park, B. Yoon, "Forecasting technology substitution of disruptive technology through transformed survival analysis," in *Proc. Internation Conference on Advances in Science and Technology*, Pattaya, 2014, pp. 93-98.

[7] J.-P. Joseph, "PSTN Services Migration to IMS. "Are SPs finally reaching the tipping point for large scale migrations?" *in IEEE Proc. Telecommunications Network Strategy and Planning Symposium (NETWORKS)*, Warsaw, 2010, pp. 1-6.

[8] B. Jacobs, "Economics of NGN deployment scenarios: discussion of migrations strategies for voice carriers," in *IEEE Proc. 12th International Telecommunications Network Strategy and Planning Symposium*, New Delhi, 2006, pp. 1-6.

[9] H.-B. Chiou, D. Morrison, W. Liao, "Experience with an IP Multimedia System Trial for PSTN Migration," *IEEE Communications Magazine*, vol. 45, pp. 127-133, July 2007.

[10] H. Goestl, "Using NGOSS Principles in todays OSS/BSS Projects NGOSS meets IMS/SDP," in *IEEE Proc. 12th Telecommunications Network Startegy and Planning Symposium,* New Delhi, 2006, pp. 1-8.

[11] L. Hanhua, W. Yashi, M. Lijuan, H. Zhenqi, "OSS/BSS Framework Based on NGOSS," in *IEEE Proc. International Forum on Computer Science-Technology and Applications*, Chongqing, 2009, pp.466-471.

[12] J.Wittgreffe, C.Trollope, T.Midwinter, "The next generation of systems to support corporate grade ICT products and solutions," *BT Technology Journal*, vol. 24, Issue 4, pp. 93-112, Oct. 2006.

[13] Y.-H. Choi, S.-H. Park, S.-D. Kim, D.-M. Kang, C. K., T.-M. Chung, "NGOSS Based OSS/BSS Architecture for Hosting Common Platform for Convergence Services, " in *IEEE Proc. Second International Conference on Ubiquitous and Future Networks*, Jeju Island, Korea, 2010, pp. 199-204.

[14] T. Plevyak, V. Sahin, *Next generation telecommunications networks, services and management*. John Wiley & Sons Ltd. ISBN: 978-0-470-57528-4. 2010.

[15] F. Piedad, M. Hawkins, *High Availability: Design, Techniques and Processes*. Prentice Hall. ISBN 0-13-096288-0. 2001.

[16] P. Podhradský, J. Dúha, P. Trúchly, J. Blichár, *NGN (Next Generation Networks) – Selected Topics, 1st Edition*. Czech Technical University in Prague, ISBN: 978-80-01-05294-5.

[17] J. Dúha, P. Galajda, I. Kotuliak, D. Levický, S. Marchevský, E. Mikóczy, P. Podhradský et al., *Multimedia ICT technologies network platforms and multimedia services*. Published by STU Bratislava. ISBN 80-227-2310-X. 2005.

[18] ITU-T NGN FG Proceedings, Part II, 2005.

[19] ITU-T NGN FG Proceedings, Part I, 2005.

[20] *Series Y: Global Information Infrastructure, Internet Protocol Aspects and Next-Generation Networks,* ITU-T Recommendation Y.2001, 2004.

[21] *Telecommunications and Internet Converged Services and Protocols for Advanced Networks (TISPAN), NGN Terminology,* ETSI TR 180 000, 2006.

[22] *Telecommunications and Internet Converged Services and Protocols for Advanced Networks (TISPAN), NGN Release 1; Release definition,* ETSI TR 180 001, 2006.

[23] *Telecommunications and Internet Converged Services and Protocols for Advanced Networks (TISPAN), IPTV Architecture; Dedicated subsystem for IPTV functions,* ETSI TR 180 028, 2008.

[24] *Telecommunications and Internet Converged Services and Protocols for Advanced Networks (TISPAN), IPTV Architecture; IPTV functions supported by the IMS subsystem,* ETSI TR 180 027, 2008.

[25] R. Münch, „Defining the Next Generation Network," presented at the 2008 TISPAN Workshop, Bejing, China.

[26] 3GPP. Presence service using the IP Multimedia (IM) Core Network (CN) subsystem; Stage 3. TS 24.141, 3rd Generation Partnership Project (3GPP), March 2008.

[27] Open Mobile Alliance. Presence Simple Specification. Candidate Version 2.0. Open Mobile Alliance, December 2010.

[28] 3GPP. Internet Protocol (IP) multimedia call control based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP) Stage 3; TS 24.229, 3rd Generation Partnership Project (3GPP), March 2008.

[29] S. Pärand, "Migration towards NGN: common applied strategies," *International Journal of Computer and Communication Engineering*, vol. 2, no. 5, pp. 584-589, September 2013.

[30] T. Aljaž, U. Mrak, B. Imperl, "Migration towards IMS – CIS perspective," presented at the International Conference on Intelligence in Service Delivery Networks, Bordeaux, November 2007.

[31] W. Michalski, “Survey of NGN migration profiles deployed by selected carriers in Europe, North America and Asia,” *Journal of Telecommunications & Information Technology,* vol. 3, pp. 60-64, Sept. 2008.

[32] Official website of a leading UK IT managed services provider, available at http://www.redcentricplc.com/resources/articles/top-10-things-to-know-about-21cn/, [Dec. 22, 2014].

[33] Official website of the British Telecom wholesale section, vailable at, https://www.btwholesale.com/pages/static/Library/Network_Information/21CN_Broadband_Availibility/index.htm, [Dec. 22, 2014].

[34] Official website of Verizon Wireless, available at http://www.verizonwireless.com/news/article/2014/11/verizon-and-att-move-toward-voice-over-lte-volte-interoperability.html, [Dec. 23, 2014].

[35] Official website of the telecom news and analysis provider Telecom.com, available at http://www.telecoms.com/292992/china-mobile-kpn-ibasis-claim-first-volte-roaming-implementation/, [Dec. 23, 2014].

[36] Official website of TeliaSonera, available at http://www.teliasonera.com/en/about-us/markets-and-brands/, [Jan. 05, 2015].

[37] T. Magedanz, K. Knüttel, D. Witszek: “The IMS Playground @ Fokus – an Open Testbed for Next Generation Network Multimedia Services,” in *IEEE Proc. 1st Int. IFIP Conference on Testbeds and Research Infrastructures for the Development of Networks and Communities (Tridentcom)*, Trento, 2005, pp. 2–11.

[38] T. Kovačik, “IMS service provisioning improvement,” *Information Sciences and Technologies Bulletin of the ACM Slovakia*, vol. 4, no. 3, pp. 12-22, Sept. 2012.

[39] 3GPP. Overview of 3GPP Release 5 V0.1.1. 3rd Generation Partnership Project (3GPP), February 2010.

[40] 3GPP. Technical Specification Group Services and System Aspects; Packet Switched Conversational Multimedia Applications; Default Codecs (Release 5); TS 26.235, 3rd Generation Partnership Project (3GPP), March 2002.

[41] 3GPP. Overview of 3GPP Release 6 V0.1.1. 3rd Generation Partnership Project (3GPP), February 2010.

[42] 3GPP. Work Item Description (WID). IMS Messaging. SP-020065. February 2002.

[43] 3GPP. 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; 3GPP enablers for Open Mobile Appliance (OMS); Push-to-talk over Cellular (PoC) services Stage 2 (Release 6); TR 23.979 V6.2.0, 3rd Generation Partnership Project (3GPP), June 2005.

[44] 3GPP. Overview of 3GPP Release 7 V0.9.16. 3rd Generation Partnership Project (3GPP), January 2012.

[45] 3GPP. Overview of 3GPP Release 8 V0.3.1. 3rd Generation Partnership Project (3GPP), March 2014.

[46] 3GPP. 3rd Generation Partnership Project; Technical Specification Group Services and Architecture; Feasibility Study on Multimedia Session Continuity Stage 2 (Release 8); TR 23.893 V8.0.0, 3rd Generation Partnership Project (3GPP), June 2008.

[47] 3GPP. 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; IP Multimedia Subsystem (IMS) centralized services (Release 8); TR 23.892 V8.0.0, 3rd Generation Partnership Project (3GPP), March 2008.

[48] 3GPP. 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA) Radio Resource Control (RRC); Protocol specification (Release 8); TS 36.331 V8.0.0, 3rd Generation Partnership Project (3GPP), December 2007.

[49] 3GPP. 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 Application Protocol (S1AP) (Release 8); TS 36.413 V8.1.0, 3rd Generation Partnership Project (3GPP), March 2008.

[50] G. Camarillo, M. A. Garcia-Martin, *The 3G IP multimedia subsystem (IMS): Merging the Internet and the cellular worlds, 3rd edition*. John Wiley & Sons Ltd. ISBN: 978-0470516621. 2008.

[51] M. Poikselkä, G. Mayer "The IMS, IP Multimedia Concepts and Services, Third Edition" ISBN 978-0-470-72196-4, John Wiley & Sons Ltd. West Sussex, England, 2009.

[52] J. Rosenberg, H. Schulzrinne, G. Camarillo, A. Johnston, J. Peterson, R. Sparks, M. Handley, E. Schooler, "SIP: Session Initiation Protocol", IETF RFC 3261, June 2002.

[53] E. Rescorla, "HTTP over TLS, IEFT RFC 2818", May 2000.

[54] J. Klensin, "Simple Mail Transfer Protocol, IETF RFC 2821", April 2001.

[55] J. Rosenberg, H. Schulzrinne, "An Offer/Answer Model with the Session Description Protocol (SDP)", IETF RFC 3264, June 2002.

[56] C. Rigney, S. Willens, A. Rubens, W. Simpson, "Remote Authentication Dial In User Service (RADIUS), IETF RFC 2865, June 2000.

[57] J. Loughney - "Diameter Command Codes for Third Generation Partnership Project (3GPP) Release 5", IETF RFC 3589, September 2003.

[58] P. Calhoun, J. Loughney, E. Guttman, G. Zorn, J. Arkko, "Diameter BaseProtocol", IETF RFC 3588, September 2003.

[59] H. Schulzrinne, S. Casner, R. Frederick, V. Jacobson, "RFC 3550 RTP A Transport Protocol for Real-Time Applications", July 2003.

[60] 3GPP. 3rd Generation Partnership Project; Technical Specification Group Technical Specification Group Services and System Aspects; Protocols for Advanced Networking (TISPAN); IP Multimedia Subsystem (IMS); Functional architecture (Release 8), December 2007.

[61] 3GPP. 3rd Generation Partnership Project; Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); LTE; Network architecture (3GPP T 23.002 version 11.6.0 Release 11), June 2013.

[62] 3GPP. 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; IP Multimedia Subsystem (IMS); Stage 2 (Release 9), March 2010.

[63] S. Pärand, "A Migration Decision for Users and Services Towards and Within the IMS," *International Journal of Advances in Computer Science and Its Applications*, vol. 5, no. 1, pp. 125-130, April 2015.

[64] V. P. K. Tanguturi, „Strategic investement decisions in telecommunications," PhD dissertation, Faculty of Stevens Institute of Technology, Hoboken, NJ, 2007.

[65] J. Scott-Joynt, „The Secret of NTT i-mode success," press release February 22, 2002, available at http://news.bbc.co.Uk/2/hi/business/1835821.stm, [June 5, 2015]

[66] D. L. Waring, „Regulation of telecommunications in the broadband age," PhD dissertation, Rutgers University Graduate School, New Brunswick, 2012.

[67] H. Kum, „Global broadband diffusion: identifying the factors affecting a country's broadband deployment and a government's role in it," PhD dissertation, Florida State University, FL, 2008.

[68] F. Miralles. „Efficiency of public promotions policies in the diffusion of broadband networks: An exploratory analysis." 34th Research conference on Communication, Information, and Internet Policy, Arlington, Virginia, USA. September 29, 2006.

[69] Dr. M. Shakir, „Challenging Issues in NGN Implementation and Regulation," in *IEEE Proc. 6th International Conference on Wireless Communications Networking and Mobile Computing (WiCOM)*, Chengdu, 2010, pp. 1-4.

[70] R. W. Crandall, H. J. Singer. "The Economic Impact of Broadband Investment", Broadband for America study, available at http://www.hrp.org/Site/docs/ResourceLibrary/broadbandforamerica_crandall_singer_final.pdf, [June 25, 2015].

[71] 3GPP. 3rd Generation Partnership Project; Technical Specification Group Core Network and Terminals; Open Service Access (OSA); Application Programming Interface (API); Part 1: Overview (Release 9) TS 29.198-1 V9.0.0, 3rd Generation Partnership Project (3GPP), December 2009.

[72] 3GPP. 3rd Generation Partnership Project; Technical Specification Group Core Network; Customized Applications for Mobile network Enhanced Logic (CAMEL) Phase 4; CAMEL Application Part (CAP) specification for IP Multimedia Subsystems (IMS) (Release 9) TS 29.278 V9.0.0, 3rd Generation Partnership Project (3GPP), December 2009.

[73] Impact of Broadband on the Economy, April 2012, ITU internal document, available at https://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_Impact-of-Broadband-on-the-Economy.pdf [June 25, 2015].

[74] K. Rikitake, K. Nakao, “NGN and internet: From coexistence to integration,” in *IEEE Proc. First ITU-T Kaleidoscope Academic Conference Innovations in NGN: Future and Services*, Geneva, 2008, pp. 315-322.

[75] G. Elkhodari. „Mobile broadband - bridging the gaps for successful deployment and implementation,“ PhD dissertation, Bobby B. Lyle School of Engineering, Southern Methodist University, Texas, 2014.

[76] J-P. Joseph, W. J. Barnett Jr, „Leveraging Broadband Access Exspansion for PSTN Migration: A Case Study for Converged Fixed Access,“ Bell Labs Technical Journal, vol. 17, pp. 141-162, June 2012.

[77] M. Jamoussi, „A „Customer Satisfaction“ Based Migration Approach toward NGN,“ in *IEEE Proc. 8th International Conference on Advanced Communication Technology*, Phoenix Park, 2006, pp. 97-101.

[78] S.-W. Yu, C.-S. Tang, K-S. Lo, „Transformation of PSTN to Next Generation Networks,“ in *IEEE Proc. 15th Asia-Pacific Network Operation and Management Symposium (APNOMS)*, Hiroshima, 2013, pp. 1-6.

[79] ITU-T, „Network Performance Objectives for IP-Based Services“, *ITU-T RECY.1541*, 2006.

[80] M. A. Callejo-Rodríguez, J. Enríquez-Gabeiras, W. Burakowski, A. Beben, J. Sliwinski , O. Dugeon, E. Mingozzi, G. Stea, M. Diaz, L. Baresse, “EuQoS: End-to-End QoS over Heterogeneous Networks,” in *IEEE Proc. First ITU-T Kaleidoscope Academic Conference on Innovations in NGN: Future Network and Services*, Geneva, 2008, pp. 177-184.

[81] B. Raouyane, M. Bellafkih, D. Ranc, “QoS Management in IMS: DiffServ Model,” in *Proc. Third International Conference on Next Generation Mobile Applications, Services and Technologies*, Cardiff, 2009, pp. 39-43.

[82] C. Yun, H. Perros, “QoS Control for NGN: A Survey of Techniques,” *Journal of Network and Systems Management*, vol. 18, no. 4, pp. 447-461, Dec. 2010.

[83] R. Good, F. Carvallo de Gouveia, S. Chen, N. Ventura, T. Magedanz, “Critical Issues for QoS Management and Provisioning in the IP Multimedia Subsystem,” *Journal of Network Systems and Management*, vol. 16, no. 2, pp. 129-144, June 2008.

[84] 3GPP. 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; End-to-end Quality of Service (QoS) concepts and architecture (3GPP 23.207 version 9.0.0 Release 9), December 2009.

[85] M. S. Siddiqui, R. A. Shaikh, C. S. Hong, “QoS Control in Service Delivery in IMS,” in *IEEE Proc. 11th International Conference on Advanced Communication Technology (ICACT)*, Phoenix Park, 2009, pp. 157-160.

[86] A. Ponnappan, L. Yang, R. Pillai, P. Braun, “A policy based QoS management system for the IntServ/DiffServ based Internet,“ in *IEEE Proc. 3rd International Workshop on Policies for Distributed Systems and Networks*, 2002, pp. 159-168.

[87] B. Malila, N. Ventura, "Performance evaluation of a Next Generation Network prototype using WiMax as an access network," in *IEEE Proc. EUROCON*, Zagreb, 2013, pp. 407-414.

[88] T. Nakajima, H. Kawata, K. Ito, S. Fujita, "Next-Generation Management System," *NEC Technical Journal*, vol. 1, no. 2, pp. 46-50, Feb. 2006.

[89] N. Blum, T. Magedanz, F. Schreiner, "Management of SOA based NGN service exposure, service discovery and service composition," in *Proc IFIP/IEEE International Symposium on Integrated Network Management*, Long Island, 2009, pp. 430-437.

[90] N. Blum, T. Magedanz, F. Schreiner, S. Wahle, "From IMS Management to SOA Based NGN Management," *Journal of Network and Systems Management*, vol. 17, no. 1, pp. 33-52, Feb. 2009.

[91] N. Blum, P. Jacak, F. Schreiner, D. Vingarzan, P. Weik, "Towards Standardized and Automated Fault Management and Service Provisioning for NGNs," *Journal of Network and Systems Management*, vol. 16, no. 1, pp. 63-91, March 2008.

[92] 3GPP. 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Service aspects; Charging and billing (3GPP TS 22.115 version 9.2.0 Release 9), March 2010.

[93] S. Islam, J.-C. Grégoire, "Policy and Charging Control for Virtual IMS Client," *Journal of Network and Systems Management*, vol. 22, no. 4, pp. 609-628, Oct. 2014.

[94] 3GPP. 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Policy and charging control architecture (3GPP TS 23.203 version 11.6.0 Release 11), June 2012.

[95] 3GPP. 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Telecommunication management; Charging management; Charging architecture and principles (3GPP TS 32.240 version 8.6.0 Release 8), June 2010.

[96] 3GPP. 3rd Generation Partnership Project; Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); LTE; Telecommunication management; Charging management; Diameter charging applications (3GPP TS 32.299 version 12.6.0 Release 12), Oct. 2014.

[97] T. Grgic, M. Matijasevic, "An overview of online charging in 3GPP networks: new ways of utilizing user, network, and service-related information," *Intenational Journal of Network Management*, vol. 23, no. 2, pp. 81-100, March 2013.

[98] V. G. Ozianyi, N. Ventura, "Design and Implementation of Scalable IMS Charging Systems," in *IEEE Proc. 34th Conference on Local Computer Networks*, Zürich, 2009, pp. 800-806.

[99] M. Dodd, A. Jung, B. Mitchell, P. Peterson, P. Reynolds, "Bill-and-keep and the economics of interconnection in next-generation networks," *Telecommunications Policy*, vol. 33, no. 5-6, pp. 324-337, July 2009.

[100] J. Wang, M. Chen, V. C. M. Leung, "A price-based approach to optimize resource sharing between cellular data networks and WLANs," *Telecommunication Systems*, vol. 52, no. 2, pp. 485-496, May 2011.

[101] Z. Hao, M. Zhengkun, P. Rongqun, "A Reconfigurable Charging Management Platform within the Adaptive Service Provisioning Architecture of NGN," in *IEEE Proc. Fourth International Conference on Networking and Services*, Gosier, 2008, pp. 272-276.

[102] 3GPP. 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; 3G security; Access security for IP-based services (3GPP TS 33.203 version 9.3.0 Release 9), December 2009.

[103] 3GPP. 3rd Generation Partnership Project; Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); LTE; 3G security; Network Domain Security (NDS); IP network layer security (3GPP TS 33.210 version 12.2.0 Release 12), October 2014.

[104] C-Y. Chen, T-Y. Wu, Y-M. Huang, H-C. Chao, "An Efficient End-to-End Security Mechanism for IP Multimedia Subsystem," *Computer Communications*, vol. 31, no. 18, pp. 4259-4268, Dec. 2008.

[105] F. S. Park, D. Patnaik, C. Amrutkar, M. T. Hunter, "A Sucurity Evaluation of IMS Deployments," in *IEEE Proc. 2nd International Conference on Internet Multimedia Services Architecture and Applications (IMSAA)*, Bangalore, 2008, pp. 1-6.

[106] N. d'Heureuse, J. Seedorf, S. Niccolini, T. Ewald, "Protecting SIP-based Networks and Services from Unwanted Communications," in *Proc. IEEE Global Telecommunciations Conference*, New Orleans, 2008, pp. 1-5.

[107] C. Liu, D. Wang, "Improving the Fixed-Line Access Security for IMS," in *IEEE Proc. 5th International Conference on Wireless Communications, Networking and Mobile Computing*, Bejing, 2009, pp. 1-4.

[108] K. Wang, C. Ling, F. Liu, "Quality of Protection with Performance Analysis in IP Multimedia Subsystem," in *Proc. 8th IEEE/ACIS International Conference on Computer and Information Science*, Shanghai, 2009, pp. 234-239.

[109] S. Wahl, K. Rieck, P. Laskov, P. Domschitz, K-R. Müller, "Securing IMS Against Novel Threats," *Bell Labs Technical Journal*, vol. 14, no. 1, pp. 243-257, Apr. 2009.

[110] N. Vrakas, D. Geneiatakis,C. Lambrinoudakis, "Evaluating the Security and Privacy Protection Level of IP Multimedia Subsystem Environments," *IEEE Communications Surveys & Tutorials*, vol. 15, no. 2, pp. 803-819, Aug. 2012.

[111] J. Balcerzak, G. Tyszka, S. Senecal, "QoS monitoring model of registration procedure for IMS platform," in *IEEE Proc. 16th International Telecommunications Network Strategy and Planning Symposium (Networks)*, Funchal, 2014, pp. 1-6.

[112] 3GPP. 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Telecommunication management; Performance Management (PM); Performance measurements; IP Multimedia Subsystem (IMS) (3GPP TS 32.409 version 9.2.0 Release 9), March 2011.

[113] B. Raouyane, M. Bellafkin, M. Errais, D. Leghroudi, D. Ranc, M. Ramdani, "eTOM Business Processes Conception in NGN Monitoring," in *Proc. Advanced Research on Computer Education, Simulation and Modeling*, Wuhan, 2011, pp. 133-143.

[114] M. S. Siddiqui, S. O. Amin, C. S. Hong, "A Management Framework for IMS Using Service Managed Objects," in *Challenges for Next Generation Network Operations and Service Management*, vol. 5297, Y. Ma, D. Choi, S. Ata, Ed. New York: Springer, 2008, pp. 483-486.

[115] B. V. Harjoc, T. Magedanz, F. Schreiner, "Automated Root Cause Analysis for IMS and SDP," in *IEEE Proc. Third International Conference on Next Generation Mobile Applications, Services and Technologies*, Cardiff, 2009, pp. 27-32.

[116] S. Pärand, A. Kirikal, „A Scalable and Reliable OSS/BSS for User Migration in IMS,“ *International Journal of Applied Mathematics, Electronics and Computers*, Volume 3, Issue 3, pp. 211-214.

[117] H. Goestl, "Using NGOSS Principles in todays OSS/BSS Projects NGOSS meets IMS/SDP," in *IEEE Proc.12th Telecommunications Network Strategy and Planning Symposium,* New Delhi, 2006, pp. 1-8.

[118] A. Vallejo, A. Zaballos, X. Canaleta, J. Dalmau, "End-to-End QoS Management Proposal for the ITU-T IMS/NGN Architecture," in *IEE Proc. 16th International Conference on Software, Telecommunications and Computer Networks*, Split, 2008, pp. 147-151.

[119] Official website of Telemanagement Forum, available at https://www.tmforum.org/business-process-framework/, [Nov. 04, 2015].

ABSTRACT

Globally, telecommunication service providers (SP) and operators are in the course of migrating away from legacy networks such as the public switched telephone networks (PSTN) towards next generation networks (NGN). This process has been going on for the past half-decade with different applied approaches which have resulted in varied outcomes thus far.

Previous published work in the area has focused on, firstly, the non-technical issues of migration for specific telecom operators and secondly on technical nuances of migration. With non-technical aspects, the tip of the focus has been directed at different migration strategies, discarding additional relevant keywords such as the impact on society, financial implications or legislation. On the other hand, the technical discussion has been limited to concrete operator or service provider specific issues which have needed solving. Stemming from the previous, the author of this thesis defines a problem of not having a comprehensive discussion of migration towards NGNs.

The current work is aimed at gathering the core aspects of migration and analyzing these, with the emphasis on technical issues, in order to compile a framework or roadmap for SPs or operators to follow while migrating to an NGN. As the author of the thesis is associated with Telia Estonia Ltd, the topics discussed in the thesis have, in addition to the aquired knowhow, also factored in the real-life applications of operational systems needed for migration. These systems have been developed in conjunction with the writing of this thesis.

The aim is achieved by firstly considering the state of the art at migration and next generation networks. This is done by looking at the strides made so far by SPs and telco operators worldwide and also work done by standardization organizations with regards to NGNs. Different migration strategies and their specifics are brought forth and discussed. Additionally, next generation networks with their core services and proliferation enabling aspects are considered and used as a basis for dwelling into IP Multimedia Subsystem (IMS) which is the service delivery platform of choice for most telco companies.

The core of the thesis is formed by the analysis. Initially, a four-phase complete migration process is proposed by the author, followed by a detailed consideration. The analysis done considers both non-technical and technical issues with the emphasis on the latter and each phase starts with the authors' own work and is then additionally elaborated by studying published papers and standardization documents as these lay the foundation for each topic.

The most common migration strategy, discussed in the pre-analysis phase of the migration process, is found to be an overlay solution with the legacy and next generation network operational at the same time. This enables a transition in technology where resource consumption can be divided over a longer period of time, thus making it more manageable for the SPs and operators.

The second, analysis phase, is considered to be the most crucial. In this phase, four essential notions to consider are identified for migration: quality of service (QoS), supporting systems, security and charging. With each keyword, different approaches taken by telco companies and standardization organizations, where applicable, are presented.

Considering the high degree of complexity of NGNs, the principle ideas throughout the discussion can be considered consolidation and standardization. Be it offering quality of service based on policies or a management solution with probes in each layer of the network, discussed in the post-migration phase, there is a demand for a central entity which performs its tasks based on standardized procedures while utilizing as much pertinent information as possible. To further complement the technical analysis, a model operational supporting system has been discussed.

Ultimately, a conclusion is made that the initial statement of creating a complete roadmap to follow for SPs and telco operators is successful, although it is highly dependent on the specific company. The complexity of the migration is, as a rule, defined by the history of the company - a longer history means more intertwined systems which are difficult to break apart and attune to a new service delivery platform. It is also concluded that not having a broad based consideration of migration and initially focusing excessively on details will ultimately lead to a dysfunctioning network. It is crucial that the migration be based on the principle of “from broader to narrower”.

KOKKUVÕTE

Telekommunikatsiooni valdkonna teenusepakkujad ning operaatorid on kogu maailmas migreerumas senistest tavavõrkudest järgmise põlvkonna sidevõrkudele (inglise keeles *next generation networks*, NGN). Antud protsess on kestnud ligikaudu viimased viis aastat. Üleminekuks kasutatakse erinevaid strateegiaid, mis on andnud erinevaid tulemusi.

NGN ja sellele ülemineku protsessi käsitlevad varasemad publikatsioonid on keskendunud peamiselt kas migratsiooni mittetehnilistele aspektidele või migratsiooniga seotud tehnilistele nüanssidele konkreetsete firmade puhul. Mittetehniliste küsimuste käsitlemisel on peamine rõhk olnud erinevatel migreerimise strateegiatel, samas on arvestamata jäetud teised olulised märksõnad nagu migratsiooniga kaasnev mõju ühiskonnale ning majanduslikud ja seadusandlikud mõjud. Tehnilistes käsitlustes on piirdutud vaid operaatori või teenusepakkuja spetsiifiliste probleemidega. Eelnevast lähtuvalt on käesoleva töö autor probleemina esile tõstnud laialdasema migratsioonikäsitluse puudumise.

Antud doktoritöö eesmärk on välja tuua migratsiooniga seotud peamised faktorid ja märksõnad ning analüüsida neid eelkõige tehnilistest aspektidest lähtuvalt selleks, et koostada teenusepakkujatele ja operaatoritele sobiv üldine raamistik järgmise põlvkonna sidevõrkudele migreerimise läbiviimiseks. Kuna doktoritöö autor on seotud Telia Eesti AS-ga, siis on selles käsitletavate teemade puhul arvestatud, lisaks omandatud oskusteabele, ka mainitud ettevõttes reaalselt toimivate migreerimiseks vajalike süsteemidega, millede arendustegevus on toimunud paralleelselt käesoleva töö kirjutamisega.

Töö eesmärk saavutatakse käsitledes esmalt globaalseid parimaid praktikaid nii migreerimise kui ka NGN vallas. Seejärel uuritakse, kuidas standardiseerimisorganisatsioonid on antud teemat reguleerinud. Järgmise põlvkonna sidevõrkude puhul vaadeldakse ka selle tuumikteenuseid ning nende levikut soodustavaid aspekte kuni jõutakse *IP Multimedia Subsytem* (IMS) platvormi põhjalikuma käsitlemiseni. IMS on teenuse osutamise platvormina enamiku telekommunikatsiooni ettevõtete esimene valik NGN sidevõrkude puhul.

Doktoritöö tuumiku moodustab NGN-le migreerimise protsessi analüüs. Kõigepealt esitatakse autori poolt koostatud neljaetapiline täieliku migratsiooni protsess, mida siis käsitletakse detailsemalt. Analüüs koosneb nii mittetehnilistest kui ka tehnilistest aspektidest ning iga etapi kirjeldus algab autori enda käsitlusega, mida seejärel täiendatakse publikatsioonidele ja standardiseerimisdokumentidele toetudes.

Leitakse, et migratsiooni protsessi eelanalüüsi etapis välja toodud ülekattega lahendus (inglise keeles *overaly solution*) on kõige levinum migratsiooni strateegia. Sellisel juhul hoitakse senine sidevõrk ning järgmise põlvkonna sidevõrk esialgu töös paralleelselt, mis võimaldab teenusepakkujatel ja sideoperaatoritel jagada migratsiooniks vajalikke ressursse pikemale ajavahemikule ning seeläbi saavutada sujuvam üleminek uuele tehnoloogiale.

Esitatud täieliku migratsiooni protsessi teine etapp, analüüs, tuuakse välja kui kõige olulisem antud töös. Selles etapis käsitletakse migratsiooniga seotud peamisi võtmesõnu: teenuste kvaliteet, tugisüsteemid, turvalisus ning maksustus. Iga võtmesõna puhul käsitletakse erinevaid lähenemisviise, mida telekommunikatsiooni ettevõtted ning standardiseerimisorganistatsioonid on kasutanud.

Pidades silmas NGN sidevõrkude komplekssust, võib analüüsi läbivateks märksõnadeks tuua konsolideerimise ning standardiseerimise. Kasutades teenuse kvaliteedi tagamiseks erinevaid poliitikaid (inglise keeles *policy*) või käsitledes halduse tugisüsteemi, mis on ühendatud sidevõrgu kõigi kihtidega (käsitletakse migratsioonile järgnevas etapis), eksisteerib nõudlus keskse entiteedi järele, mis teeb oma tööd lähtuvalt standardiseeritud protseduuridest ning kasutab selleks ära võimalikult palju kogutud asjakohast informatsiooni. Analüüsi paremaks sisustamiseks kirjeldatakse ja käsitletakse ka ühte toimivat näidis-tugisüsteemi.

Töö lõpptulemusena jõutakse järelduseni, et teenusepakkujatele ning operaatoritele võrkude migreerimiseks sobiva üldise raamistiku loomine on võimalik, ent see on siiski küllaltki organisatsioonispetsiifiline. Migratsiooni raskusaste on, enamikel juhtudest, sõltuv ettevõtte elueast. Pikem ajalugu tähendab suuremat hulka omavahel põimunud süsteeme, mida on keeruline lagundada ning sobitada järgmise põlvkonna sidevõrkudele. Jõutakse ka mõistmisele, et keskendudes migratsiooni algfaasis liialt detailidele ning mitte mõeldes üldistele põhimõtetele, päädib migratsioon mittetoimiva sidevõrguga. Peetakse oluliseks, et migratsiooni protsess lähtuks põhimõttest „laiemalt kitsamale“.

APPENDICES

Appendix A

PUBLICATIONS

PUBLICATION 1

Pärand, Sven. Migration towards NGN: common applied strategies. International Journal of Computer and Communication Engineering, 2(5), pp. 584-589.

Migration towards NGN: Common Applied Strategies

Sven Pärand

***Abstract*—Telecommunication service providers (SP) around the world are still in the process of migrating away from legacy networks towards next generation networks (NGN). The strategies for this have been and are different depending on the size of the market, historical background or financial resources of the SP just to name a few. This paper addresses these strategies mainly from a non-technical point of view aiming at seeking commonalities amongst different SPs. The migration processes of two smaller European countries have been looked at more closely to complement the dominant research done towards similar processes in larger countries to see if there are equally compatible strategies for different SPs irrespective of their background and properties. The work concludes that above all the size of the operator is a key factor in the transition to NGN.**

***Index Terms*—IMS, migration strategies, next generation networks, PSTN.**

I. Introduction

Telecommunication operators have been making great strides in recent years to migrate their legacy networks, users and services towards next generation networks (NGN) [1]. Although the concept of NGN and the need for its adoption is well known, discussions on different strategies for migration are still pertinent. Due to the complicated nature of this issue the number of approaches nearly equals the number of operators, at least from a technical point of view. However, there are aspects and keywords most agree upon - for example the use of IP Multimedia Subsystem (IMS) [2] as the basis for future multimedia services.

The primary aim of this paper is to identify the common steps that different telecommunication service providers (SP) have taken migrating their business towards NGN. Previously published papers have been taken as the basis for the research and also two operators have been studied in more detail. The SPs, Elion Enterprises Ltd (EE) and TeliaSonera Sweden (TSS), are both part of TeliaSonera group but are based in different countries (EE in Estonia, TSS in Sweden) and also differ substantially in size, albeit they operate in small countries compared to central European countries for example. The choice of TeliaSonera also comes from it being the biggest telecom operator in North-Europe (Scandinavian countries and the Baltic region), a region comprising mainly of small to medium size countries. The size of the country is important in the sense that it often determines the size of the operator. Even with international operators, its size mostly depends on the size of the native country. The secondary aim of this paper is to clarify which migration strategies have proven successful and does the size of the operator play any role in this part. So far the published material on this matter has many gaps and usually only considers countries and more specifically operators with a very large customer base, like British Telecom for instance.

The structure of this paper is as follows: Section II expands upon the main considerations when migrating from legacy networks to NGN. The concept of migration to next generation networks is discussed briefly and the section continues to open up the main technical and non-technical aspects of migration. Concrete actions taken by chosen SPs are studied in Section III. The topic is concluded in the final section of the paper.

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II. Different Aspects for Migration

Migration to NGN became a hot topic among major service providers worldwide around 2005 [3] when the drive from the market for new and innovative services became extremely apparent. The fast developing telecommunications sector empowered the client to ask more from the SPs in terms of services and therefore protection against customer churn required a transition to a new paradigm, namely NGN. With a new direction in the way services were offered a need for new access technologies arose and having said that, keeping up with the times became a must. Aging equipment was, and still is, an issue for many SPs, so migrating to NGN facilitated the long overdue replacement of legacy technology as well.

In the broadest sense of the phrase, when talking about migration to NGN, a move away from public switched telephone network (PSTN) is meant. It is also often not specified whether the legacy network in question is a fixed or a mobile network or will the services be migrated as well in conjunction with the users. There are a few possibilities regarding the choice of platforms to which the migration is planned as well, IMS or a softswitch solution [4] for example. The main emphasis in the current paper, not excluding others completely, is on migration from legacy fixed networks to IMS mainly from a non-technical point of view.

Before definite steps were to be taken by the SPs, a myriad of issues had to be considered, starting from the question of exactly what needs to be migrated to NGN and to what extent. On a high level those questions could be divided into two main categories: technical and non-technical.

A. Non-Technical Issues

The most important issues for any SP wanting to migrate away from legacy networks encompass choosing the right strategy, starting from the motivation [5] and ending up with a specific model of execution [3], and the financial aspects.

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1) Migration cost

It is safe to say that PSTN has paid off for nearly all the incumbent operators. So the question arises whether it is financially viable to keep offering services to customers using the already existing networks with the only cost being the operating cost (OPEX) or to make a substantial one-time capital expenditure (CAPEX) towards NGN and essentially transform the company's model of operation. An important issue here is also the time at which to make the investment if this path is chosen because at some point it will be more expensive to provide services on legacy networks compared to IMS for example. According to [5] the savings generated over the period of 5 years from power consumption, personnel and equipment maintenance is 24%. This data is of course specific to a certain SP but it gives an idea of the magnitude of OPEX that can be saved. Similar research [6] concluded that the start time plays a significant role: the possibilities of not losing money during the migration process increased with the earlier start of the process.

The issue of migration cost is in a sense an inevitable problem to tackle simply because it is a matter of survival. An operator not willing to consider NGN will undoubtedly eventually wither.

Another consideration is the extent of migration with regards to cost. An SP should assess if it is a financial necessity to eliminate the legacy networks at once or to use an overlay approach and migrate step by step. It may also be feasible to keep offering some services using the existing network – this is the case when the migration of a service is more expensive than offering it as is.

2) Migration strategies

When it comes to migrating away from PSTN there are a few general approaches that have been accepted among service providers: firstly complete PSTN replacement, secondly an overlay solution with PSTN and an NGN operating simultaneously, fading the PSTN out slowly while keeping it in operation for services close to their end of life and thirdly a softswitch solution. Many service providers have also chosen to develop their broadband (BB) networks in correlation with migration from PSTN to NGN. This seems logical as there is a definite need for a broadband connection towards the customer to provide modern multimedia services. Complete PSTN replacement is suitable for service providers that are either operating on a small scale or have very little historical background with PSTN. In the case of the SP operating on a small scale, the main issue is the cost. The CAPEX for migration is simply a lot smaller than it is with big SPs. Also the youth of such a service provider is a benefit in this case due to the lack of a large number of services, users and support systems. Looking at the telecommunications market realistically, SPs that have not engaged themselves deeply with PSTN networks are usually very young and therefore at least theoretically capable of complete PSTN replacement.

The most common approach to migration towards NGN seems to be the overlay solution. Keeping PSTN alive in parallel while going forward and developing an NGN is reasonable for many reasons. First of all, as mentioned before, the CAPEX for immediate PSTN replacement is enormous and this is the case even with a step-by-step migration where the initial resources needed for the core of the NGN are still considerable. The biggest obstacle is however the size of the service provider. One cannot imagine a fast transition from PSTN to IMS in a short timeframe [3]. Legacy network in such cases will eventually be closed, but this may take several years if not decades. Looking at [7], the sheer size of the geographical location, the multitude of technologies in use and the market itself forces the SPs to pass through many smaller steps before reaching the desired end goal of a migration to IMS.

With the overlay solution there is also a question of the amount of PSTN services that should be migrated. It might not be reasonable to start migrating a service if the process for it is too complex or expensive. In this case creating a similar, if not an enhanced service on the new platform should be considered. Fig. 1 illustrates a high level overview of an overlay solution with the breakout gateway control function (BGCF) used as the node to connect the packet switched (PS) and circuit switched (CS) domains.

A softswitch solution is often not considered a carrier grade solution with limitations in redundancy and scalability. However, since the CAPEX for such solutions is more to the liking of smaller SPs it will appeal to starting or fairly young companies.

B. Technical Issues

After an operator has made the decision or perhaps is forced to migrate form legacy networks to NGN the technical process can begin. The actions taken are based on the choice of the migration strategy and can therefore be quite straightforward, in the case of a complete PSTN replacement, or much more complicated when moving to an overlay solution.

With an overlay solution a PSTN emulation subsystem (PES) is needed to support a wide range of PSTN services on NGN.

For IMS, interactions between the access gateway control function (AGCF, similar to BGCF in Fig. 1) and PES application server (AS) was first published in May 2006 in the telecommunications and internet converged services and protocols for advanced networks (TISPAN) standard TS 183 043 [8]. A similar setup for IMS is well described in [3].

The biggest technical issue with any migration strategy is however not the core of the NGN but rather how to incorporate the old into the new, meaning business support systems/operations support systems (BSS/OSS). An issue that has been expanded on in [9], where not only the OSS was found to be a problem but also the fact that the development of technology imposes a similar need for the personnel. A complicating factor here is the nature of IMS in its attribute to merge the classical telecommunications domain with Internet technologies hence requiring hybrid competence from the workforce.

With BSS/OSS the problem lies in the tailor made nature of such systems. If the interfaces between core IMS nodes are standardized and well documented then with BSS/OSS this is usually not the case. The fact that an operator has many support systems is nothing out of the ordinary, but often times than not these systems duplicate each other. For example bigger operators, doing business both in mobile and fixed networks may have a billing or provisioning system for both of them. The stovepipe nature of services running on legacy network has led to this situation and creating a single BSS/OSS system, or even reducing their number, is difficult, time consuming and costly.

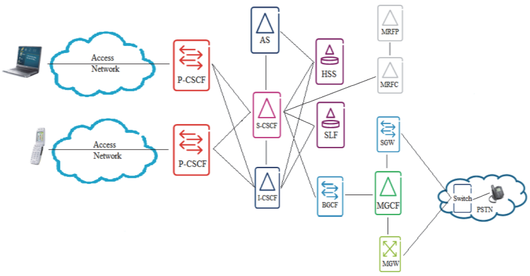

Fig. 1. High level view of an overlay solution [2], adopted by the author

III. Applied Strategies

A. Elion Enterprises Ltd

According to [10], the basis for the following section,

90% of the operators' profit came from the PSTN in 2001. In 2011 the same number had dropped down to 20% of the total profit. The fading business from PSTN, clearly visible after the turn of the millennium, forced EE towards broadband. It was very unclear how or to what extent broadband would develop but the key matter was the recognition of BB as the way to the future. It was not until 2005 before concrete steps were taken towards migration to NGN. The direction taken was IP Multimedia Subsystem.

The decision was naturally preceded by quite a substantial period of time spent on analyzing the telecommunications market and the different technologies for PSTN migration. It was clear from the beginning that there were two considerable ways to move forward: a softswitch solution or the IMS. The softswitch solution, however, was not considered suitable for large operators looking for a carrier grade solution. At that time Elion had 300 000 clients that needed to be moved to NGN.

In addition to the end of the lifespan of the PSTN network in operation a more alarming problem had arisen – support for the PSTN network was ending or had already ended to some extent. One of the two major switching nodes in the network was also working under constant overload condition. Still, it was clear that PSTN was not going to fade away quickly. Estimation at that time for complete PSTN migration was the year 2020 whereby it was thought clients would migrate before the operator had to face problems with major equipment deterioration.

A partner for procuring and setting up the IMS core was found in Ericsson - a strong brand with high technical capability. By 2006 the IMS core network was up and running. All that was missing were services to attract users away from legacy networks. With the now rapid growth of broadband and the fact that Elion was the market leader with 60% in offering private branch exchange (PBX) services for business clients, a similar service was worked out using session initiation protocol (SIP) trunks.

After SIP trunking was operational BroadSoft Inc. was chosen as a partner for providing services to business clients in the form of hosted PBX. Cloud services were seen as the way forward, especially when considering convergence with the cellular world.

1) Current developments and future outlook

Today, 175 000 business and private customers have migrated to IMS which is seen as the fastest and simplest platform for generating revenue in the area of voice over internet protocol (VoIP) communication. Some services are created in-house and applications created by BroadSoft and Ericsson are used.

By the end of 2012, 40% of business clients and 30% of private clients have been migrated to IMS and by the end of 2015 an estimated 70-80% of voice customers have been migrated. Today there is no forceful tactics to migrate users from the legacy networks through a service pack change although it is highly recommended and suggested by the operator. The only time when customers are facing a certain upgrade form legacy networks to NGN is when old equipment is being decommissioned. In other times the decision is up to the customer. All new voice customers are naturally automatically provisioned in IMS. A major contributor here is internet protocol television (IPTV), which is seen as a good aspect for selling voice affiliations since IPTV is part of triple play alongside a telephone connection.

It is also planned that in 2015 there will be more direct campaigns towards users to migrate them from the legacy networks and to close PSTN by 2017. The reason for the expedited schedule is the already mentioned lack of support for old technologies.

2) Obstructions in the migration process

The biggest obstacles came from inside the operator. It took a long time to arrive at the understanding that cloud based services such as hosted PBX was the only viable future strategy. The break in this matter came in 2008 when the SP came around to the fact that selling integrated services digital network (ISDN) connections to customers will not provide future revenue and client loyalty.

Another issue to tackle was IP network monitoring and management. The keyword here was and still is quality of service (QoS). It was speculated, based on the early trials with VoIP, that problems would arise with IP network quality and the only way of mitigating them was to put in place an extensive monitoring system. There are some QoS issues today but these are mostly caused by the clients own IP infrastructure. Currently, the monitoring is working as a proactive system with the goal of identifying problems before they appear to the customer.

Since the signaling protocol for IMS is SIP, there was a need to monitor it for better management and troubleshooting. The same can be said for signaling system no. 7 (SS7) since IMS and PSTN were to be working as an overlay solution for a period of time.

The provisioning of services along with customer premises equipment (CPE) had to be made automatic. It was a clear demand from the operator that the client did not have to make any complicated operations when migrating to NGN. All that he or she had to do was plug in the CPE and start using the service.

B. TeliaSonera Sweden

Based on [11], similarly with Elion Enterprises Ltd in Estonia, TeliaSonera Sweden started putting a lot of effort into NGN in 2005. The biggest pressure for the move coming from the fast expanding and developing technology of IP networks. The age of the PSTN network and specifically some of its components was also considered a problem, given the fact that at the time nearly 900 000 customers were still connected to Ericsson automatic cross-connection equipment (AXE) telephone exchanges.

Due to the aforementioned reasons a strong enough business case was created to get the migration process towards IMS underway. Although alternatives in the form of a softswitch solution were considered, financial calculations indicated the advantage of IMS compared to replacing nodes of the PSTN network.

The contract for the procurement of the IMS core was done in the spring of 2007 and the actual setup of the nodes began in the second half of the same year. Integration work took place in 2008. The provider for the IMS core, surprisingly Nokia Siemens Networks and not Ericsson, cleared up after a procurement process.

1) Current situation

The migration process is still ongoing. Currently there are approximately 500 000 users in IMS and roughly 1, 9 million still in legacy networks. Despite the initial predictions of migration lasting only a few years, it is now said that the Swedish PSTN network will remain for at least another decade. Although the plan initially included a fast migration of services and users, which seems logical considering the timeframe, this has not come to be. Before the project started, the biggest problems were seen to arise from IT integration and processes. More specifically it was the multitude of different systems and processes that now had to be combined to work together – an unfortunate yet inevitable legacy of an operator with a long history. This issue has been a pervading one throughout the history of migration to IMS in TSS.

The first clients were provisioned to IMS in 2009. Today, migration is purely voluntary progressing at a rate of roughly 100 000 users per year. Virtually the only service offered using IMS is plain old telephone service (POTS) replacement and all new customers are automatically offered this service from IMS. Therefore a way of coaxing users away from PSTN was needed to speed up migration. Today this lure is triple play. Since the majority of the clients in IMS are residential, with only a marginal amount of business clients, this seems a solid strategy.

2) Future outlook

PSTN migration will be an ongoing process for years to come with many obstacles to overcome of which the biggest at this point is the matter of TSS broadband. Namely, services on IMS can today only be offered to users that are connected to TSS broadband. Currently TSS fixed broadband market share is close to 40%, narrowing the field of potential NGN customers significantly.

Migration from legacy networks so far has mainly been the responsibility of the TSS broadband section. However, future plans include a tighter cooperation with the TSS mobility section in terms of fixed-mobile convergence (FMC) and voice over long-term evolution (VoLTE). There are many issues to solve here but the biggest hurdles are seen in the area of BSS/OSS and more specifically ways to integrate mobility into the already established systems used by the broadband section.

IV. Conclusion

Despite the fact that EE and TSS are both part of the same concern, they have taken independent paths towards NGN. Both saw the need for NGN before 2005 and since then have made strides to migrate legacy networks at the maximum pace possible. Looking at the services and clients it is clear that EE has managed the move to IMS more efficiently. A simple testament to this is the multitude of services ranging from basic VoIP to IPTV integration whereas TSS currently uses IMS virtually only as a POTS replacement. There is a major difference in served client groups as well. Although TSS has nearly 500 000 customers, compared to the 175 000 in EE, these are nearly all residential VoIP clients. The 175 000 at EE is divided between residential (75 000), business (75 000) and other (international, mobile and PBX) clients.

Looking at the data studied and the examples presented for this paper it becomes clear that there is no single path to follow during migration which is suitable for every operator. Still, despite the size or geographical location of the operator there are common strategies that have been applied: complete PSTN replacement, a relatively quick PSTN fadeout or an overlay solution combining legacy networks with NGN during which replacing old equipment and infrastructure over a longer period of time. Comparing experiences of operators differing in size shows us that migration strategies and the success of these strategies is not so much dependent on the strategy itself as the size of the market and legacy of the operator. Legacy in the sense that the more history a service provider has the more equipment there is and the more technologies are in use, making a move towards a new paradigm more difficult. Migration to NGN will be an ongoing process for at least another decade and the simple truth is, the smaller the operator the faster it is to implement any of the mentioned approaches.

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References

[1] Y. Series, "Global Information Infrastructure, Internet Protocol Aspects and Next-Generation Networks," ITU-T Recommendation, Y. 2001, 2004.

[2] G. Camarillo and M. A. Garcia-Martin, *The 3G IP Multimedia Subsystem: merging the Internet and the cellular worlds*, 3rd edition. Chichester, West Sussex, United Kingdom, 2008, pp. 25-48.

[3] W. Michalski, "Survey of NGN migration profiles deployed by selected carriers in Europe, North America and Asia," *Journal of Telecommunications & Information Technology,* vol. 3, pp. 60-64, Sept. 2008.

[4] A. Goldstein and B. Goldstein, “Softswitch,” BHV-St. Petersburg, 2006, pp. 13-38.

[5] J. P. Joseph, “PSTN Services Migration to IMS, Are SPs finally reaching the tipping point for large scale migrations?” in *Telecommunications Network Strategy and Planning Symposium (NETWORKS)*, Warsaw, 2010, pp. 1-6.

[6] B. Jacobs, “Economics of NGN deployment scenarios: discussion of migrations strategies for voice carriers,” in *Proc. 12th International Telecommunications Network Strategy and Planning Symposium*, New Delhi, 2006, pp. 1-6.

[7] T. Aljaž, U. Mrak, and B. Imperl, “Migration towards IMS–CIS perspective,” presented at the International Conference on Intelligence in Service Delivery Networks, Bordeaux, November, 2007.

[8] *Telecommunications and Internet Converged Services and Protocols for Advanced Networks (TISPAN), IMS-Based PSTN/ISDN Emulation Stage 3 Specification*, ETSI TS 183 043, 2006.

[9] H. B. Chiou, D. Morrison, and W. Liao, “Experience with an IP Multimedia System Trial for PSTN Migration,” *IEEE Communications Magazine*, vol. 45, pp. 127-133, July 2007.

[10] J. Kraft, Elion Ettevõtted Ltd, Head of Division, Network Business Development, *Private Communication*, January 2013

[11] J. Romo and T. Sonera AB, Head of Development, Voice Communication, *Private Communication*, January 2013

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PUBLICATION 2

Pärand, Sven. Analysis of migration strategies towards NGN based on technical and non-technical issues and support systems. International Journal of Advances in Science and Technology (IJAST), pp. 23-28.

Analysis of Migration Strategies Towards NGN Based on Technical and Non-technical Issues and Support Systems

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Abstract - Next generation networks (NGN) are the destination of choice for most incumbent telecommunication service providers (SP) around the world. The migration away from legacy networks has been a difficult one and is still ongoing. The strategies used for these processes differ substantially depending on the historical background of the operator, size of the market and available financial resources. The current article aims at addressing these strategies with the end goal of seeking commonalities with regards to different service providers. The analysis mainly focuses on non-technical issues while including operator support systems/business support systems (OSS/BSS) as well to emphasize the importance of not only the NGN itself but the inseparable supporting realm needed for the SP to be successful in the changing market. To enhance the research done towards migration processes in larger countries, similar processes of two smaller European countries have been examined more closely. The reason for this is to see if, irrespective of the SPs background, there are equally compatible strategies. The key factor in the effectiveness of the transition to NGN is concluded to be the size of the operator.

Index Terms-IMS, migration strategies, NGN, NGOSS, OSS/BSS, PSTN.

INTRODUCTION

Next generation networks (NGN) [1] is the direction that telecommunication operators have been moving towards in recent years. The migration process towards NGN has included networks, users and services. Having said that one must admit that although the notion of NGN is well known and the need for it is a certainty, the discussion over different migration strategies has not yet subsided. Looking at the operators from a technical point of view there are nearly as many approaches as there are operators, a fact that could be attributed to the complicated nature of the matter. Still, there are keywords most SPs have accepted – as an example the use of IP multimedia subsystem (IMS) [2] in their strategies, as the service delivery platform (SDP) for future multimedia services, could be mentioned.

This paper has two primary aims. Firstly, to analyze and point out the common steps in the migration towards NGN that different telecommunications service providers (SP) have taken. For this, research based on previously publish papers has been taken as the main source of data and also two operators have been studied in detail. The mentioned companies, Elion Ettevõtted Ltd (EE) and TeliaSonera Sweden (TSS), are both part of TeliaSonera Group but operate out of different countries (EE in Estonia and TSS in Sweden). Compared to central Europe for example they operate in relatively small countries and are also profoundly different compared to each other when it comes to size. Another reason for choosing these companies comes from the fact that TeliaSonera is the largest telecommunications operator in North-Europe (Scandinavian countries and the Baltic Region). The given region mainly comprises of medium or small size countries and this is important in a sense that the country often alludes to the size of the operator. Looking at different operators, even with the international ones, the native country usually determines their size. The secondary aim of this paper is to study and clarify which migration strategies have proven to be successful for operators. It is studied what role the size of the operator plays in the success or failure of any given strategy. To this day there has been research published on this matter but it has many gaps and tends only to consider countries and more specifically operators with a very large customer base, like British Telecom for instance.

This paper follows the consequent structure: the main considerations when migrating from legacy networks to NGN have been considered in detail in Section II. A brief overview of the concept of next generation networks has been brought forth and the section continues to open up on the main technical and non-technical aspects of migration. Operating support systems/business support systems (OSS/BSS) have been considered here as well in more detail since they encompass a significant part of the transition to NGN.

Specific actions taken by Elion Ettevõtted Ltd and TeliaSonera Sweden on their road towards NGN have been studied in detail in Section III. The topic concludes in section IV of the paper.

ASPECTS TO CONSIDER FOR MIGRATION

Major service providers around the world were compelled to start dealing with the issue of migration to NGN around 2005 [3]. This was due to the drive from the market and from the realization that the prevalence of new and innovative services could no longer be disregarded.

The pace at which the telecommunications sector was changing enabled the client to ask more from the SPs in terms of services. So the question of protecting oneself against customer churn required a transition to a new paradigm, namely NGN. This transition brought up a few nuances. Firstly, the way that new services were offered also demanded that new access technologies would develop accordingly which in turns meant that operators had to be willing to keep up with the latest technical evolutions. Secondly there was, and for many still is to this day, the problem of aging equipment. In this sense the migration process facilitated the long overdue replacement of legacy technology.

The phrase migration to NGN, in the broadest sense, refers to a move away from public switched telephone network (PSTN). In most times it is left unspecified whether the legacy network in question is a fixed or a mobile network. The same vague approach applies to services as well - will these be migrated in conjunction with the users often remains unclear. However, SDP wise there are a few general possibilities to choose from: IMS or a softswitch solution [4]. In the current paper the focus is on migration away from legacy fixed networks to IMS mainly from a non-technical point of view. This does not denote the exclusion of any other possibility.

Preceding the concrete steps in the migration process taken by the SPs, an analytical period has to be transitioned where a number of issues were to be considered. This phase must not be underestimated because it is used to determine the following actions, starting from the question of exactly what is to be migrated to NGN and ending up with the matter of support systems. With regards to these questions, on a high level, two main categories could be distinguished: technical and non-technical.

Non-technical Considerations

A service provider wanting to migrate away from legacy networks must start with finding the suitable strategy. The nature of this issue is threefold. At first the motivation has to be clarified [5] followed by a more specific model of execution [3] and finally the financial aspects have to be analyzed and decided upon.

1) *The Cost of Migration:* Today, offering services to customers is relatively cheap for the incumbent operators. The reason for this is that PSTN has paid off for most of them and now they are faced with the question of whether it is viable to keep offering services as is, using the already existing networks. With the situation planted the only cost to consider is the operating cost (OPEX) while moving towards NGN and therefore transforming the company's operational model requires a substantial capital expenditure (CAPEX) on their behalf. A key factor here is also the time at which to make the transition. It is clear that at some point providing services on legacy networks will become more expensive than using IMS for example as a service delivery platform. The research done in [5] shows that over a period of 5 years 24% of savings could be generated from equipment maintenance, power consumption and personnel alone. Although this data is specific to a certain SP it is a clear indication of the possible amount of OPEX that could be saved. The beforehand mentioned start time of the migration process has been found to play a crucial role in similar research done in [6] which concluded that the overall possibilities of losing money during the migration process decreased with the earlier start of the transition.

When it comes to cost a service provider should also take into account the duration of the migration. It might not be financially necessary to eliminate the legacy networks at once but to use an overlay solution instead. This means using the existing networks to keep offering some services while at the same time going forward with the migration process step by step. It may also come to be that migrating a service away from legacy networks is more expensive than offering it as is. This situation requires analysis on the viability of the given service and a decision on the appropriate action to be taken.

2) *Strategies for Migration:* There are general approaches accepted by most service providers when it comes to migrating away from PSTN: firstly, complete PSTN replacement, secondly, an overlay solution with PSTN and NGN operating simultaneously and thirdly a softswitch solution. With the overlay solution PSTN is faded out slowly, usually used only to provide services close to their end of life. A logical course of action for the service providers is also to develop their broadband (BB) networks in conjunction with the migration process towards NGN. It is clear that modern multimedia services require a lot more bandwidth than previously offered services and hence establishing a BB network becomes a must.

Replacing the PSTN completely seems to suit service providers that have not profoundly bound themselves to PSTN historically or are operating on a small scale. In the latter case the cost becomes the main issue. Simply put, the CAPEX for migration in this case is relatively small compared to bigger SPs. Another facilitating matter with complete PSTN replacement is the youth of the operator. This is beneficial since it usually means there are not so many active services, users and support systems. Realistically, service providers not deeply engaged with PSTN are in most cases relatively young and should therefore, at least in theory, be capable of complete PSTN replacement.

The overlay solution seems to appeal to operators for many reasons, making it the most common approach to migrating away from legacy networks. Developing NGN and keeping PSTN alive at the same time is first of all reasonable due to the fact that CAPEX can be distributed over a longer period of time. As mentioned, the immediate replacement of PSTN is costly. This is the case even with a step-by-step situation since the initial resources needed for the core of the NGN are still noteworthy. Secondly, the size of the service provider sets many limits and obstacles. A fast transition from PSTN to IMS is according to [3] not feasible. The closing of legacy networks in such cases will eventually happen but this may take up to decades to complete. Research done in [7] also clearly implies that the sheer size of the geographical location, the market and the plurality of technologies in use forces the SPs to pass through many small sub-goals before reaching the desired end goal of a complete migration to IMS.

The amount of PSTN services to be migrated with the overlay solution will have to be considered as well. As mentioned previously this process might be too expensive or complex. If the lastly mentioned situation becomes a reality, the creation of a similar if not an enhanced service on the new service delivery platform should be considered. Connecting the packet switched and circuit switched domains in case of an overlay solution can be achieved through the use of a breakout gateway control function (BGCF) as illustrated in Fig. 1.

Due to limitations in scalability and redundancy, using a softswitch is often not considered a carrier grade solution by service providers but since the CAPEX for such solutions is smaller, it makes this more appealing to starting or fairly young companies.

Technical Considerations

The actual technical process of migration can begin after the operator has made the necessary analysis and ultimately the decision to move towards NGN. The steps taken in the technical phase of the transition are based on the strategy chosen and can therefore be straightforward, in the case of complete PSTN replacement, or they can be substantially more complex when it has been concluded to use the overlay solution.

A PSTN emulation subsystem (PES) is needed for the overlay solution to interconnect systems and support PSTN services on next generation networks.

Telecommunications and internet converged services and protocols for advanced networks (TISPAN) standard TS 183 043 [8], first published in May 2006, specifies the interactions between the access gateway control function (AGCF which is similar to BGCF in Fig. 1) and the PES application server (AS) for IMS. A description of a similar setup can also be found in [3].

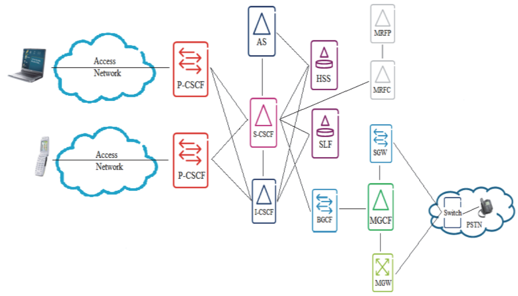

Fig. 1 A high level view of an overlay solution (based on[2]), modified and adopted by the author

The biggest technical issue with any migration strategy is however not the core of the NGN but rather how to incorporate the old into the new, meaning operations support systems/ business support systems.

There are many fundamental problems to consider with regards to OSS/BSS. Firstly, the vertical structure of the pre NGN support systems which have a lot of isolated components [9]. Since technology and services are evolving rapidly and there is a need for a fast time-to-market for services, these systems can no longer be applied by the operators to support their activities in the current market situation.

Another concern for the operators is the consistency of the OSS/BSS [10]. The system cannot have any gaps in its operation and therefore the architecture needs to remain stable in the long run. This is however difficult to achieve when the system is basically designed for a single technology and that technology is constantly changing.

The issue of human resources has been expanded on in [11], where not only the OSS was found to be a problem but also the fact that the development of technology imposes a similar need for the personnel. A complicating factor here is the nature of NGN, and more precisely IMS, in its attribute to merge the classical telecommunications domain with Internet technologies hence requiring hybrid competence from the workforce.

Looking at future directions in the domain of OSS/BSS a few key factors have been identified. The ability to support both existing services and the ones being developed [9, 12] has been seen to help the transition from legacy networks to NGN and to save resources. Additionally, since a lot of business today in the telecommunications sector is being done in co-operation by several operators, there is a definite need for the support systems to work seamlessly together [10, 12].

Regardless of the different issues described previously in this paragraph, there seems to be a remedy. The use of frameworx, formerly known as next generation operational systems and software (NGOSS) [9, 10, 12, 13], will provide a future proof solution for the operators and service providers. It will describe a methodology for the design, architecture and life cycle of the OSS/BSS for the changing market conditions.

The main reasons why NGOSS in considered to suit the NGN is the fact that it is independent technology wise, it promotes end to end automation of processes and data sharing and a modular structure of the OSS/BSS. This way a maximum possible amount of the same components will be used and there is no constant need to customize the support system, hence saving costs and speeding up processes.

The problem with OSS/BSS today seems to be the lack of standardization. Most of the support systems that operators are running are tailor made which usually means weak documentation and a disregard for the proper standards. Looking at the other end of the spectrum the interfaces between IMS core nodes for example, are well documented and standardized. Moreover, an operator often uses many duplicating support systems in parallel. Bigger operators, doing business in both mobile and fixed domains may have a billing or provisioning system for both of them, therefore unnecessarily losing recourses on two supporting instances instead of one. However, this situation has been created over time due to the stovepipe nature of services running on legacy networks and it is difficult and resource consuming to reverse.

STUDIED STRATEGIES APPLIED BY SELECTED OPERATORS

Realization to Migrate

Elion Enterprises Ltd and TeliaSonera Sweden are both part of TeliaSonera Group and similarly started to realize the necessity for NGN right after the change of the millennium. There were many reasons for this. For EE, 90% of its profit in 2001 originated from the PSTN. By 2011 this number had decreased to 20%. This trend of the fading PSTN business model was already clearly visible at the beginning of the 21^{st} century and forced the operator towards broadband. At the time it was unclear how and to what extent broadband was to develop but the main issue was the shift in thinking and focusing on NGN, BB and more specifically IP Multimedia Subsystem. Still, it was not until 2005 before the first actual steps were taken to start implementing NGN. For TSS the main concern was the age of their PSTN network and specifically some of its components, especially when there were approximately 900 000 customers still connected to Ericsson automatic cross-connection equipment (AXE) telephone exchanges.

A similar alarming problem had arisen in EE as well. Adding to the already critical issue of the end of the PSTN lifespan was the matter of ending support. For some nodes it had already ended. Despite the aforementioned reasons and the fact that one of the two major switching nodes in the network was under constant overload condition it was clear that PSTN was to remain active for some time. Estimation for complete migration away from legacy networks was the year 2020. It was also thought that clients would migrate themselves before the operator had to face problems with major equipment deterioration.

For both operators the decision to migrate away from legacy networks was naturally preceded by a substantial period of analysis. Different business conditions, developments in the telecommunications market and technological possibilities were all taken into consideration. Of the latter mentioned a softswitch solution and the IMS were seen as the two possible SDPs. EE, who at the time had 300 000 clients that needed to be moved to NGN, did not see the softswitch solution as a viable approach. TSS however went about to create a strong enough business case to get the migration process underway. Financial calculations done at TSS indicated the advantage of IMS compared to start replacing nodes of the PSTN network and therefore the procurement process for the IMS core was able to start. The contract for the core was signed in 2007 and the actual setup of the system began in the second half of the same year. Integration work for the newly installed service delivery platform took place in 2008. Interestingly, the winner of the procurement process was not Ericsson but Nokia Siemens Networks.

Elion Ettevõtted Ltd found a partner for procuring and setting up the IMS core in Ericsson. The installation work of the IMS core was finished by 2006 after which a search began for services to attract users away from legacy networks. Since broadband was now growing rapidly and EE was the market leader with 60% in offering private branch exchange (PBX) services for business clients, it seemed reasonable to develop a similar service. This was done using session initiation protocol (SIP) trunks.

Still, SIP trunking was to be the first step. Since cloud services and convergence with the cellular world were seen as the basis for a new business model, BroadSoft Inc. was chosen as a partner to provide a wide range of services to business clients in the form of hosted PBX.

The Current Situation

Today, the progress of migration is somewhat different for the studied operators. EE has migrated 175 000 business and private customers to IMS which has proved to be the fastest and easiest service delivery platform to offer voice over internet protocol (VoIP) services to customers. Most of the services are created by BroadSoft

Inc. and Ericsson while some in-house applications are used as well.

The end of 2012 saw 40% of business clients and 30% of private clients migrated to IMS and it is estimated that by the end of 2015 some 70-80% of voice customers have been migrated. The operator has so far not taken any forceful tactics to make users migrate from legacy networks to NGN through a service pack change although it is recommended and suggested. However, since old equipment from legacy networks is constantly being decommissioned the customers may be compelled to migrate and this is the only case when they are faced with a definite transition towards NGN. New voice customers are naturally automatically provisioned in IMS. Internet protocol television (IPTV) is also seen as a contributor for selling voice affiliations since it is part of triple play alongside a telephone connection.

Current predictions put the close of PSTN at 2017. To facilitate this process the operator has planned to use more direct campaigns towards users starting from 2015 to migrate them away from legacy networks. The main reason for this schedule is the before mentioned lack of support for the currently working technologies.

For TeliaSonera Sweden the amount of users migrated is approximately 500 000 and roughly 1,9 million still in legacy networks. The initial predictions estimated a fast migration, lasting only a few years, however now it is said the PSTN network in Sweden will be active for another decade.

2009 saw the first customers provisioned to IMS and today this process is ongoing at a rate of roughly 100 000 users per year. Like Elion Ettevõtted Ltd, TSS does not use forceful measures to migrate users.

IMS is currently only used as a plain old telephone system (POTS) replacement and all new clients are provisioned to this SDP. Since the majority of customers in TSS IMS are residential, with a marginal amount of business clients, the logical approach was to offer triple play to coax users away from legacy networks and hence speed up the migration process.

Hurdles in the Migration Process

The biggest obstacles for EE originated from the operator itself. To arrive at the understanding that selling integrated services digital network (ISDN) connections was not the way to secure future customer loyalty and revenue, took time. In 2008 it became clear for the operator that hosted PBX was the strategy to move forward with and this view has remained to this day.

Another key issue seen was the IP network and more specifically its monitoring and management. Early trials with VoIP indicated there might be problems with the quality of service (QoS) and the way to mitigate them was applying an extensive monitoring system. The matter of QoS is still receiving a lot of emphasis today and there are some issues with it but these are mostly caused by the clients own IP infrastructure. The initial idea of the monitoring system was to operate as a proactive system with the goal of identifying problems before they appear to the customer and this has been achieved.

A need for a monitoring system for SIP and signaling system no. 7 (SS7) was also seen as a necessary tool since IMS and PSTN were initially to be working as an overlay solution. Before the actual migration of users and services were to begin the operator also had a definite demand to make the process as easy as possible to the client. A part of this requirement meant that the provisioning of customer premises equipment (CPE) had to be made automatic. This way the transition to NGN does not involve any complicated procedures and all the customer has to do is plug in the CPE and the service is automatically ready to be used.

TeliaSonera Sweden encountered the biggest problems in the technical domain. Firstly, issues in the area of IT integration and processes were faced. The abundance of different systems that had to be merged together proved to be a challenge that has pervaded throughout the migration process towards NGN. Still, this can be seen as an inevitable result of an operator with a long history.

Secondly, TSS broadband is considered an issue to tackle to facilitate the migration process. In detail, the problem lies in the fact that services on IMS can only be offered to users that are connected to TSS broadband but currently the TSS fixed broadband market share is close to 40%, which tightens the potential NGN market share substantially.

The non-technical issues included the inner workings of TSS. So far migration from legacy networks has been the responsibility of the TSS broadband section but future plans with regards to fixed-mobile convergence (FMC) and voice over long-term evolution (VoLTE) require a closer cooperation with the TSS mobility section. This will naturally eventually translate into more technical problems, for example in the area of OSS/BSS and the ways to integrate the respective systems of the mobility and broadband sections.

CONCLUSION

EE and TSS, both belonging to the same TeliaSonera Group, saw the need for NGN at the beginning of the 21st century and have since taken independent paths towards migrating away from legacy networks. Elion Enterprises Ltd has managed to make the transition more effectively in the sense that more services have been migrated to IMS. Services including basic VoIP and IPTV among others are used whereas TSS currently uses IMS virtually only as a POTS replacement. Since the size of the market is different in their native countries, there is a major difference in the amount of served clients. TSS currently has nearly 500 000 customers, compared to the 175 000 in EE but an important distinction can be made with regards to the served client groups. For TSS nearly 100 % residential VoIP clients while the 175 000IMS customers at EE are divided between residential (75 000), business (75 000) and other (international, mobile and PBX).

It is clear that there is no single correct path for any given operator to follow on their way towards NGN. The data covered in Section II and the later examples of EE and TSS clearly clarify this statement. Nevertheless, some common applied strategies can be brought forth: complete PSTN replacement, an overlay solution combining legacy networks with NGN during which the replacement of old equipment and infrastructure will take place over a longer period of time. The experience of operators differing in size, market penetration and geographical location indicates that the success of migration strategies is much more dependent on the legacy of the operator rather than the strategy itself. This means, the more history a service provider has the more active equipment and technologies there are, hence the move towards a new paradigm will inevitably be more difficult.

It is also apparent that in order to offer services based on NGN an operator or service provides will need the appropriate support systems as well, as the ones used today are no longer up for the task.

Briefly, the process of migration to NGN will last worldwide for many years to come if not decades and operators smaller in size and not burdened with a long history will have the advantage to apply whatever the strategy chosen.

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REFERENCES

[1] *Series Y: Global Information Infrastructure, Internet Protocol Aspects and Next-Generation Networks,* ITU-T Recommendation Y.2001, 2004.

[2] G. Camarillo, M. A. Garcia-Martin, *The 3G IP Multimedia Subsystem: merging the Internet and the cellular worlds*, 3rd edition. Chichester, West Sussex, United Kingdom, 2008, pp. 25-48.

[3] Wojciech Michalski, "Survey of NGN migration profiles deployed by selected carriers in Europe, North America and Asia," *Journal of Telecommunications & Information Technology,* vol. 3, pp. 60-64, Sept. 2008.

[4] A. Goldstein, B. Goldstein, *Softswitch*. BHV-St. Petersburg, 2006, pp. 13-38.

[5] J.-P. Joseph, "PSTN Services Migration to IMS. "Are SPs finally reaching the tipping point for large scale migrations?" in *Telecommunications Network Strategy and Planning Symposium (NETWORKS)*, Warsaw, 2010, pp. 1-6.

[6] Bodo Jacobs, "Economics of NGN deployment scenarios: discussion of migrations strategies for voice carriers," in *Proc. 12th International Telecommunications Network Strategy and Planning Symposium*, New Delhi, 2006, pp. 1-6.

[7] Tomaž Aljaž, Urban Mrak, Bojan Imperl, "Migration towards IMS – CIS perspective," presented at the International Conference on Intelligence in Service Delivery Networks, Bordeaux, November, 2007.

[8] *Telecommunications and Internet Converged Services and Protocols for Advanced Networks (TISPAN), IMS-Based PSTN/ISDN Emulation Stage 3 Specification*, ETSI TS 183 043, 2006.

[9] Herbert Goestl, "Using NGOSS Principles in todays OSS/BSS Projects NGOSS meets IMS/SDP," in *Proc.12th Telecommunications Network Startegy and Planning Symposium,* New Delhi, 2006, pp. 1-8.

[10] Lu Hanhua, Wang Yashi, Min Lijuan, Huang Zhenqi, "OSS/BSS Framework Based on NGOSS," in *Proc. International Forum on Computer Science-Technology and Applications*, Chongqing, 2009, pp.466-471.

[11] Hong-Bin Chiou, David Morrison, Wanjiun Liao, "Experience with an IP Multimedia System Trial for PSTN Migration," *IEEE Communications Magazine*, vol. 45, pp. 127-133, July 2007.

[12] J.Wittgreffe, C.Trollope, T.Midwinter, "The next generation of systems to support corporate grade ICT products and solutions," *BT Technology Journal*, vol. 24, Issue 4, pp. 93-112, Oct. 2006.

[13] Young-Hyun Choi, Seon-Ho Park, Soo-Deuk Kim, Dong-Min Kang, Changsup Keum, Tai-Myoung Chung, "NGOSS Based OSS/BSS Architecture for Hosting Common Platform for Convergence Services, " in *Proc. Second International Conference on Ubiquitous and Future Networks*, Jeju Island, Korea, 2010, pp. 199-204.

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A Migration Decision for Users and Services Towards and Within the IMS

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Abstract— **Making the decision to migrate a user or service from a legacy network to a next generation network (NGN) requires thorough analysis. Despite the will and a clear necessity of telecom operators and service providers (SP) worldwide, many are still struggling with the migration process even after nearly five years and this can be attributed largely to the mentioned analysis aspect. New service delivery platforms (SDP) have necessitated the need to modernize or in some cases rebuild completely new operations support systems/business support systems (OSS/BSS). Mistakes have also been made in choosing an appropriate strategy for migration due to miscalculation in several key areas prior to migrating. Based on a task of moving users and services from legacy networks to IP multimedia subsystem (IMS) as well as inside the IMS, the current paper addresses the issue of making a solid migration decision, based on facts and proper analysis, concentrating mainly on the technical side of it. A high level migration process is presented to give an understanding of what a complete migration task entails. This is followed by a series of more detailed descriptions of specific steps and their sub-steps that contain key questions and issues that need addressing. The aim of this paper is to produce a generic guide or protocol for SPs and telecom operators to follow when making a migration decision.**

Keywords— analysis, IMS, migration process, migration phases, NGN.

I. Introduction

The decision to migrate a user or service to or within a next generation network (NGN) [1] service delivery platform (SDP) should be based on detailed analysis. This means that every conceivable issue of the migration process must be broken down into smaller sub-processes and looked at from different angles to identify possible sources for failures during the actual migration itself. This paper makes a distinction between the overall migration process and the actual migration of users and services, the latter being a sub-step of the former.

As both short- and long term problems may arise in the migration process due to poor analysis and the fact that telecom operators and service providers (SPs) worldwide are still struggling with this matter, the current article is focused on two main goals. Firstly, to elaborate on the migration process and make a distinction between the, already mentioned, complete process and one of its sub-steps which is migrating concrete users or services.

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A four step process is described in the paper. The aim of this paper is also to further specify the phases mentioned in the initial migration process with the ultimate goal of essentially creating a roadmap, in the form of flowcharts, for operators and service providers to follow while doing the analysis for migration. All of the issues raised are based on the notion that the SDP of choice for NGN is IP multimedia subsystem (IMS) [2]. Since the migration process can occur from legacy networks to IMS and also within the IMS, the latter option is disserted as well. A complete list of matters that need attention is, however, nearly impossible to create as this is highly dependent on the specific SP or operator.

For reaching the aims of the paper, the second and fourth step of the suggested process are presented in more detail. The first and third steps are omitted from the detailed description as the first phase, the pre-analysis, has already been considered in earlier literature. The third phase, the actual migrating of users and services, consists simply of acting upon the results achieved during analysis, i.e. computers running pre-determined scripts or humans following certain procedures to migrate the selected users or services. In addition, the introduced process takes into consideration the actions that need to be performed after the actual migration has taken place and which are not emphasized enough – the verification of results and monitoring for possible fault management.

The structure of this paper is as follows: the general four step migration process is described in Section II. This is followed by a discussion of all of the phases of the process in more detail: Section III sees the analysis phase being emphasized and Section IV concentrates on the activities after the migration has taken place, i.e. on the fourth phase of the suggested process. Section V concludes the paper.

II. The Migration Process

The process a telecom operator or service provider has to pass through, to migrate its users and services to an NGN platform, can ultimately be defined. Naturally, this collection of phases cannot be standardized, as each company is different in a vast number of aspects, and nor should it be - there are only ideas and proposed solutions to make the transition to NGN as smooth and seamless as possible. The current section of this paper describes one possible general view of the mentioned process which will lay the foundation for successive sections where the presented flow chart will be further disentangled.

Fig. 1 illustrates a generalized four step process for migration. Before expanding on these phases in more detail, again, it must be emphasized that the focus of this paper is mainly on the second and fourth phase. The reason for this being the fact that the migration process is ongoing for most telecom companies worldwide, so the pre-analysis phase has already been passed through and needs no further elaborated discussion while the migration itself in the third phase is a trivial set of actions based on the analysis phase.

The first pre-analysis phase is where the operator or SP recognizes the need to migrate. This is usually caused by signals coming from the market or due to declining revenue and profit numbers. Whatever the reason, a clear shift in the business model of the company is realized and the second phase may be entered.

The analysis phase is the most important one since this is where the actual success or failure of the migration will be defined. Poor analysis may cause hard to fix or unrepairable damage in later phases. The different types of analysis done in this phase has been described and analyzed in [3].

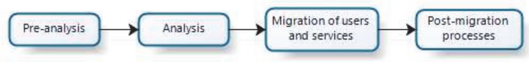

Figure 1. A general view of the migration process to NGN.

The third phase is where the actual migration takes place. This phase is a direct consequence of the analysis phase and as mentioned depends on its thoroughness. The next generation service delivery platform is set up here, tested and eventually users and services will be transferred to it. It is imperative that throughout this stage the negative effects on customers should be as minimal as possible. This means the quality of service (QoS) must remain, at minimum, on the pre-migration level and the transition itself should be as seamless as possible.

The final phase in the migration chain is called post-migration processes. This is when the work done thus far has to be assessed and if need be, changes made. Also, constant quality measurement systems have to be put in place for proactive fault management and further QoS enhancement.

III. The Analysis Phase

The activities undertaken in the analysis phase are essential and critical in the sense that any changes that need to be done after the completion of this phase can be attributed to poor analysis and considered highly resource encompassing.

Fig. 2 depicts, on a large scale, the different aspects that need attention in the analysis phase. Let it be noted that the figure is simplified and only the key factors are brought forth, in accordance with the initial aim of this paper.

The analysis can be divided into technical and non-technical. The latter part will not be elaborated on in detail here since the scope of this paper is more technical. Still, to mention a few keywords on the non-technical side – these would be resources and strategies. It is clear that any effort made by a service provider or telecom operator requires resources, both financial and non-financial (e.g. manpower, knowledge, cooperation with other companies). The relevant implementation choices for migration are described in more detail in [4].

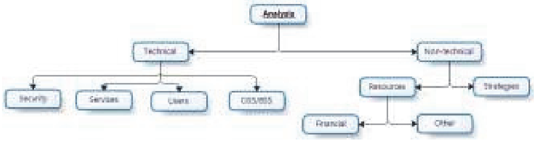

Figure 2. Top level overview of the analysis phase.

The technical side of the analysis is broken up into the following sub-steps: security, services, users and operating support system/business support system (OSS/BSS). Although the central idea of any NGN is to provide innovative and quality services to users, this cannot be done without appropriate security measures and functional supporting systems. Hence the mentioned items should be considered during the analysis. The following sections will describe all of the previously mentioned sub-steps in more detail.

A. *Security*

Security in any system or network is a complicated matter that needs thorough consideration. Stemming from this and from the aim of the paper, the current article will not be able to describe an all-encompassing guide to analyzing all the possible security issues in IMS. A broad-based discussion on this topic has been published in [5], where threats to IMS implementations are examined. This paper will, instead, list the key factors that should be considered before migration which will in turn give hints to further research if and when the SP or operator deems it necessary.

The main considerations for a service provider regarding security can be classified into the following areas:

1) authentication and authorization for users and services;
2) access control for users and services;
3) information integrity and confidentiality;
4) use of proper communication protocols;
5) keeping track of activities in logs in a secure manner.

Based on the listed principles, Fig. 3 illustrates the analysis involved in the sub-steps of the security step.

Before addressing the actual IMS specific security matters in the analysis flow, the service providers' or operators' general constraints and concepts must be studied. These might for example include basic demands to areas such as outside access to company internal IP networks or support for specific protocols. The passing of this step in the analysis process lays the foundation for further, more detailed, security related nuances.

The following step, IMS specific concepts, can be divided into two major categories: IMS security services and operational security. The former is expanded upon in detail in [6] where a layered IMS security model is defined and the dependency of IMS security on the operators' general preferences is emphasized. Hence, in this step the analysis should mainly focus on clarifying the mentioned security model and choosing the suitable authentication method. In addition, since IMS is a network capable of cooperation with other networks, network domain security (NDS) will also have to be addressed. NDS comes into play when the users' first point of contact, the proxy-call session control function (P-CSCF), is located in the visited network.

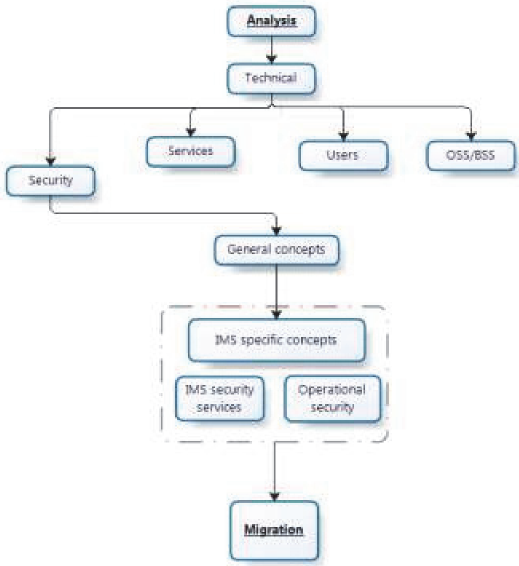

Figure 3. Analysis for security concepts.

As the IMS security services sub-step concentrates on major security aspects that will remain permanent after these have been decided, the operational security step might not be so static. The analysis here focuses on keywords such as P-CSCF discovery, user equipment (UE) registration, session initialization and termination, protection against different types of attacks and security management. As mentioned, some of these principles may change over time as for example attacks against the SPs or operators' network may become more evolved in nature.

The marked security management aspect is noteworthy and parallels may be drawn with any other system which, after initial startup, needs management. Security procedures and rules are no exception. This topic is dissected in [7] where it is concluded that the operational security of any NGN needs to have a strong security compliance program with the, not only support, but involvement of senior management. The security step analysis will eventually flow into the migration phase.

B. ***Services and Users***

The reason services and user analysis has been collocated under a single paragraph lies in their near identical analysis flow chart. The minor differences will be mentioned separately in the following description.

Figure 4 illustrates that the analysis starts with the notion of whether the user or service is IMS internal or external. In the external case, it is suggested that these will be migrated from legacy networks such as the PSTN. If this is the case, the matter of prudence should arise – is it worth wile for the operator or SP to start migrating the service or user? There is a possibility that the existing service based on PSTN is no longer supported in IMS or has changed to a large degree. A similar trail of thought applies to users. It might be more reasonable for the operator or SP to renounce the client as opposed to making substantial resource allocations to keep him or her. This is naturally only the case when the client absolutely has to be, for whatever reason, moved away from PSTN.

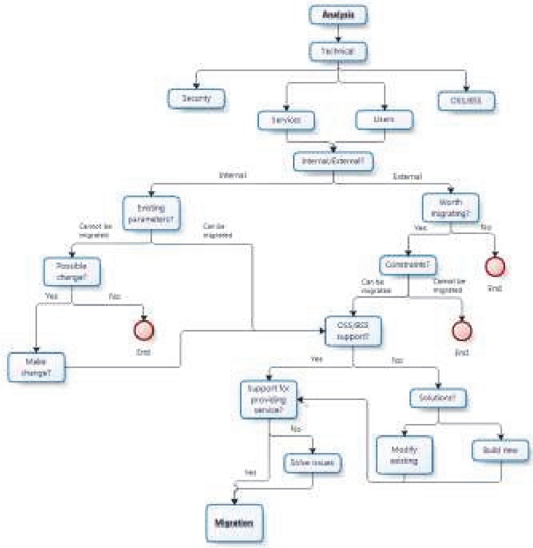

Figure 4. Analysis for migrating services and users.

In the event that the company, making the analysis, finds the user or service worthy of migration, all of the constraints attached to this user or service have to be determined. For example, these can be the issues regarding number portability or even missing copper wire or optical cable running to the customers' premises. Services usually have a myriad of nuances as well, which all have to be addressed separately.

Advancing further with the analysis in the external case, the support systems check has to be completed next. Neither the user nor any of the services can be moved without proper support from the OSS/BSS. If the analysis so far has resulted in a positive outcome as far as the migration decision is concerned, there are only two possible scenarios regarding the OSS/BSS: firstly, it might come to be that the existing support systems are already in a state of readiness to handle the new user or service and secondly, the opposite is true, in which case solutions are needed. The first scenario is however highly unlikely which means the operational support systems either need modifying or in the worst case scenario have to be built from the start. In any case, one or the other task will have to be completed to make the whole migration process eventually possible.

> However, the mistakes made could have been avoided and more importantly, can be avoided in the future if the SP or operator approaches the migration process analytically and in a detailed manner.

Lastly, upon completion of all of the previous steps, a final large scale readiness check has to be made. This might include the human resource and training, checking of all adjacent systems that do not fall under the OSS/BSS category, but also have to be in place for providing a service to a certain customer. The sub-step in question also entails looking at what happens after the service or user has been migrated - how or who takes care of the management, how are the client complaints handled etc. To be brief, this step of the analysis should mainly take a thorough look at the companies' internal processes and how these are equipped to handle operating in an NGN environment.

The left branch in Fig. 4 denotes the questions that should be addressed in case the migration task is IMS internal. This might happen when, for specific reasons depending on the SP or operator, the user or service must change application servers. Most of the logic here is similar to the situation where the user or service is external to the IMS. Still, there are differences in the initial part of the phase. Since the user or service is already in IMS, there is no need to consider if the migration is worth wile. Instead, it is of utmost importance to chalk down the existing parameters of the user or service with a high degree of precision. This mapping determines if and how the rest of the migration process will run its course.

When the details of the user or service reveal no obstacles for migration, the analysis can proceed straight to the supporting systems sub-step. However, upon discovering issues that prevent migration, changes have to be made. It is possible to modify either the users' or services' parameters or adjust the platform to house the migrated user or service. Only when it is clear that the modifications are feasible and possible in reality, can the analysis proceed again to the supporting systems sub-step.

C. *OSS/BSS*

Similar to the security analysis, this paper will not be able to provide an all-encompassing description of every possible issue worth mentioning. Still, major components in the OSS/BSS analysis chain are highlighted based on Fig. 5.

Firstly, let it be mentioned that the support systems analysis is centered on two main notions: the central customer relationship management (CRM) and the task management, which are the backbone of the whole supporting realm. To differentiate the two, the CRM is considered to be the main tool for everyday use by the SP or operator and acts as an interface between a human being and the technical systems while the task management is essentially a system or a collection of systems which works in the background and either interprets the human input and acts accordingly or gathers data and translates it to a human readable form.

The product/services database is regarded as a collection of services descriptions and it should not be forgotten during the analysis. This threat exists as it is often not considered a part of the actual value chain, meaning it does not make real money. However, these descriptions are used whenever a service is initially built for a customer and also when a need arises to further develop the existing service in which case a solid start point, in the form of a detailed description, is in order. Hence, all the metadata about any given service must be considered carefully and saved in a corresponding data table. The main input for this database comes from the CRM.

The assurance sub-step analysis should focus on how the customer can approach the operator or service provider in case of need and how that request is processed. Different service levels have to be described and the corresponding tasks confirmed. An example first level point of contact for the customer may be a basic helpdesk, the second, a low level specialist and so on. As part of this analysis branch the interconnections of all of these levels must be described in parallel with specifying the systems and tools that are to be used for the management of the customer request. The flow should terminate with feedback. Its method and destinations are to be specified. As a default solution, both the client and the company providing the service need to know that the issue has been resolved. However, this may not always be the case.

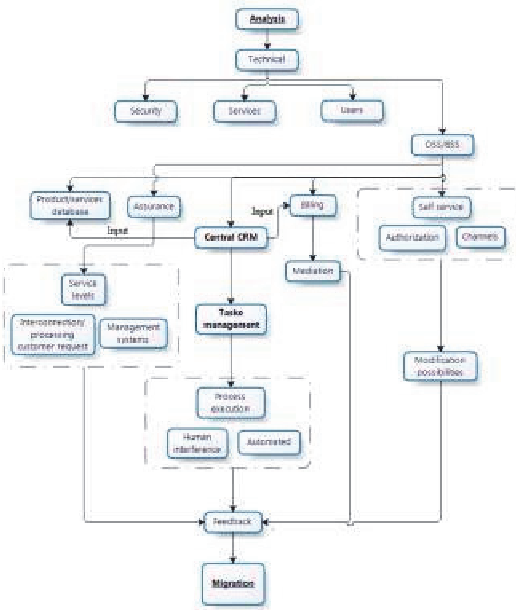

Figure 5. The OSS/BSS analysis flow.

As mentioned, the task management is responsible for performing a bulk of the concrete assignments in the

OSS/BSS, ranging from provisioning new users to changing the configuration in a specific customer premises equipment (CPE). The main focus of analysis is directed towards elaborating the courses of action, i.e. how the process is executed, taken by the technical systems in achieving the end goal. This applies also in the case where human intervention in necessary. The last part of the chain considers, similarly to assurance, the issues of feedback.

The analysis process in the billing branch should focus on the mediation layer. Mediation in this case is a generic term and stands for an entity which collects and processes call detail records (CDR) data from various applications and sends it to a predefined location. The processing task is critical as the service provider or operator would eventually like to have all the CDR information in a similar form, however the CDR form in the application output may be proprietary and therefore vary from the desired outcome. A feedback or monitoring sub-step should also be regulated in billing as there may arise a need to troubleshoot the matter. In fact, feedback here could be considered extremely important since the billing system is the basis for writing invoices to customers.

Any modern telecom operator or SP today should strive to make as little contact with their customers as possible regarding day-to-day operations. This is not to say that contact with customers is bad but that simple requests made by the clients do not always need the interference of human resources. The self-service analysis in Fig. 5 concentrates on a way for the clients to make changes in their services by themselves. There are two main issues here to consider: first, the matter of authorizing the users and second, the channels through which customers can make their requests. The latter may include for example a web page or an interactive voice response (IVR) system.

After the authorization and request channels have been chosen, the actual modification possibilities must be analyzed. Clearly, a client may not be permitted to delete user accounts but simpler tasks, such as activating call recording for instance, are conceivable. Again, the flow ends with feedback in order to assure the customer that the desired changes have really been successful.

IV. Post-Migration Processes

The post-migration phase is the final step in the general process of migration, depicted in Fig. 1. This can be, on a high level, divided into three major categories – verification, monitoring and management. Verification in this stage is considered to be a check to see whether the end result of the whole migration process towards NGN is successful. It must be noted, however, that process verification, which should be done in the, earlier, analysis phase, will also have to entail a verification sub-step. This area has been studied in more detail in [8], [9] and [10] where the need for process verification, both theoretically and empirically, has been clearly highlighted and several approaches for verification have been brought forth. However, as mentioned, in the context of the current stage of migration only the final outcome will be verified.

Depending on the migration, verification can be divided even further based on the type of verification as seen from Fig. 6. For example, if the migration process from PSTN to IMS is completed manually, the end result, or a major part of it, may also be verified manually. If the migration process is done automatically, the final check is also usually done without human interference. The type then ultimately dictates the procedures that have to be in place. The procedures contain information about who verifies, what and when. Additionally, an important procedure is giving feedback about possible issues to earlier stages of the migration process. This entails information regarding who or what systems are informed about the migration process having ended.

Monitoring may have many tasks which need to be identified when starting that sub-step. Firstly, it can be viewed as a source of information for fault management and therefore for any possible pro-active action done by the SP or operator. Secondly, it can act as a verification tool simply by indicating increasing activity in the NGN which refers to a constant successful migration process, assuming the migration process is not only IMS internal. Thirdly, monitoring provides vital information for future network planning in the sense that for example congestion issues will become visible in real time and this information will help in future network scalability planning.

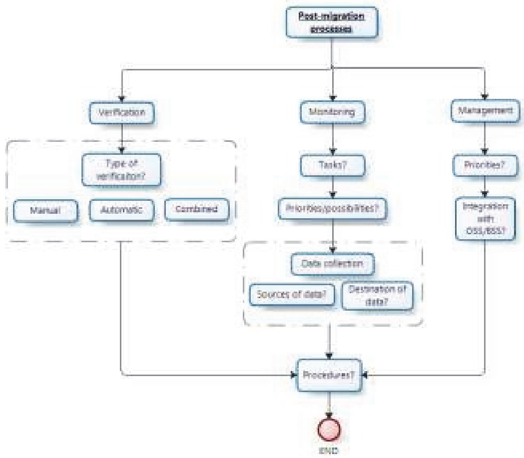

Figure 6. Post-migration processes flow.

Once the tasks of monitoring have been put in place, the SP or operator must consider the amount of nodes that can be monitored. Since a telecom company is usually working in a situation where recourses are limited, certain priorities have to be assigned to monitoring. In IMS the highest priorities should be assigned to the core nodes which make the operation of the NGN essentially possible. These are the call session control function (CSCF), home subscriber server (HSS), domain name system (DNS) and the border elements such as the session border controller (SBC). Naturally, provided there are ample amounts of resources, other nodes and systems can be added to this list.

Next, the matter of data collection should be addressed, meaning the collected information from different sources will most likely have to be collected in a single point and processed to a human readable form. An example of this can be seen in Fig. 7 where the most important registration data of a CSCF is illustrated, i.e. accepted and rejected registrations and the response codes in the latter case.

The management branch in Fig. 6 comprises of initially describing priorities, just like in the case of monitoring. While it is clear that all the users and services will have to be managed to the full range of their properties, it is a question of priorities what will be done first, how and by whom. The management chain should ideally be integrated with the OSS/BSS, so this will have to be checked as well and any problems addressed. Finally, as with verification and monitoring, specific procedures will need to be put in place regarding the division of labor between both people and systems as well.

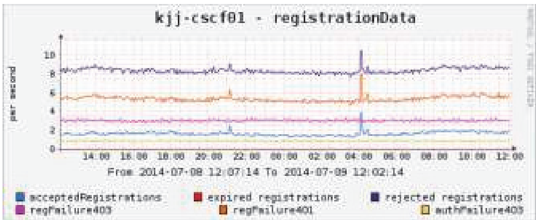

Figure 7. Registration data of a CSCF.

V. Conclusion

Although service providers and telecom operators worldwide have been migrating users and services towards next generation networks for nearly five years they are still struggling with the process. This can be attributed to poor initial planning and analysis which has led some companies to a point where they need to start the process all over again.

However, the mistakes made could have been avoided and more importantly, can be avoided in the future if the SP or operator approaches the migration process analytically and in a detailed manner. The complete migration process can essentially be broken down into smaller phases, each one containing a collection of notions that need to be addressed and analyzed thoroughly. Clearly, a complete general list of problems can never be identified as these are dependent on an individual SP or operator.

Looking at the migration process and its phases, proposed in the current paper, it is clear that the most important phase is the analysis phase. The core questions to address there from a technical perspective are security, users, services and OSS/BSS. Each one has a different level of complexity and volume but none can be discarded as being unimportant. An issue worth mentioning is the fact that the analysis can not only be contained in the realm of legacy networks vs NGN, but all of the adjacent systems must be roped in as well. A good example of this is the OSS/BSS which does not offer a service to the customer per se but is still a crucial link in the complete chain of migration.

Emphasis must also be put into the actions which take place after the actual migration process has been completed. The results have to be verified, monitored for possible troubleshooting and finally, the users and services in NGN need management. All of the lastly mentioned keywords, if thought through and implemented properly, can help make the life of the SP or operator much easier and help keep client loyalty.

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References

[1] *Series Y: Global Information Infrastructure, Internet Protocol Aspects and Next-Generation Networks,* ITU-T Recommendation Y.2001, 2004.

[2] G. Camarillo, M. A. Garcia-Martin, *The 3G IP Multimedia Subsystem: merging the Internet and the cellular worlds*, 3rd edition. Chichester, West Sussex, United Kingdom, 2008, pp. 25-48.

[3] Sven Pärand, "Migration towards NGN: common applied strategies," *International Journal of Computer and Communication Engineering*, vol. 2, no. 5, pp. 584-589, Sept. 2013.

[4] S. A. White, M. M. Clougherty, "PSTN migration using IMS," *Bell Labs Technical Journal*, vol. 13, Issue 1, pp. 199-219, May 2008.

[5] E. E. Anderlind, D. W. Faucher, E. H. Grosse, D. N. Heer, A. R. McGee, D. P. Strand, R. J. Thornberry Jr, "IMS security," *Bell Labs Technical Journal*, vol. 11, Issue 1, pp. 37-58, May 2006.

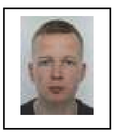
[6] M.Poikselkä, G.Mayer, *The IMS: IP multimedia concepts and services*, 3rd edition. Chichester, West Sussex, United Kingdom, 2009, pp. 113-126.

[7] S. Jacobs, *Security management of next generation telecommunications networks and services*, Hoboken, New Jersey, 2014, pp. 277-309.

[8] S. Patig, M. Stolz, "A pattern-based approach for the verification of business process descriptions," *Information and Software Technology*, vol. 55, Issue 1, pp. 58-87, Jan. 2013.

[9] M. Kaner, P. Soffer, "Complementing Business Process Verification by Validity Analysis: A Theoretical and Empirical Evaluation," *Journal of Database Management*, vol. 22, Issue 3, pp. 1-23, Jul. 2011.

[10] Nien-Lin Hsueh, Wen-Hsiang Shen, Zhi-Wei Yang, Don-Lin Yang, "Applying UML and software simulation for process definition, verification, and validation," *Information and Software Technology*, vol. 50, Issue 9-10, pp. 897-911, Aug. 2008.



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A Scalable and Reliable OSS/BSS for User Migration in IMS

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Abstract: Telecommunications operators moving away from legacy networks towards next generation networks (NGN) are faced with the complex task of migrating not only users and services but modifying or designing and rebuilding supporting systems as well. New service delivery platforms (SDP) like IP multimedia subsystem (IMS) are fundamentally different compared to the old ones and require a novel approach from both the business and technology point of view. The main emphasis in the latter case is namely on operations support systems/business support systems (OSS/BSS) and the way these have to change in conjunction with the development of SDPs. The current paper addresses just this matter and is focused mainly on technical aspects and more specifically user migration. Different migration cases have been brought forth, clearly defining their differences while keeping in mind the issues of reliability and scalability since migration towards NGN for most operators will happen with great volumes. The migration process and its relation to supporting systems has been expanded upon to specify how and what has changed during the path towards NGN, especially with regards to users. Also a novel system for provisioning and migration has been discussed to illustrate a possible way for large scale user migration.

Keywords: *IMS, NGN, OSS/BSS, provisioning, user migration.*

1. Introduction

Telecommunications operators in their path towards next generation networks (NGN) [1] are faced with the inevitable task of migrating services and users away from legacy networks such as public switched telephone network (PSTN) or public land mobile network (PLMN). This is aggravated by a small number of general, yet major reasons common to all operators. These are: (1) financial, (2) the overall development and direction taken by the operator and (3) technical support systems. The latter however comprises of a large volume of nuances to be solved before migration can be performed successfully. Keeping in mind the lastly made statement the current paper is focused specifically on technical issues from a user migration point of view.

The paper has three main aims. Firstly, to elaborate on different user migration cases. The need for user migration and the way it is done depends on a specific service provider (SP) and the level of its commitment to voice over internet protocol (VoIP) solutions and next generation networks in general. There may be cases when users are migrated away from PSTN or for companies with longer experience in NGN the need to move users from one application server (AS) to another may be pertinent for example. Emanating from the fact that the dominant service delivery platform (SDP) in NGN for multimedia services is IP multimedia subsystem (IMS) [2], the migration cases will be considered keeping this in mind. The secondary aim of this paper is to outline operations support systems/business support systems (OSS/BSS) and analyze the role these systems play in user migration. OSS/BSS-s are complex and mostly tailor made systems that enable much more than simply managing users. A definitive list of OSS/BSS nodes and functions is impossible to enumerate and can only be confined to the need and imagination of the operator. Still, there are on a high level some general functions that a support system must fulfill which include monitoring, authentication, authorization and accounting (AAA), customer hardware management and management of supporting data. However, stemming from the focus of this paper the main emphasis has been directed towards user migration and provisioning related issues of OSS/BSS-s, hence only focusing on a small part of an entirety. Lastly, a possible system for user migration will be described in detail to show how large scale migration tasks could be successfully completed keeping in mind the matters of scalability, redundancy and load balancing.

The structure of this paper is as follows: different user migration cases are expanded upon in Section II, followed by a discussion of related OSS/BSS issues in Section III. A detailed overview of a feasible system for user provisioning and migration is given in Section IV. The topic is concluded in the last section of the paper.

2. User Migration Cases

Migration, on a high level, suggests the transferring of users, data or services from one computer system or platform to another. Keeping this in mind and for the sake of clarity two main and one minor sub case for migration have been distinguished dwelling from the focus of this paper. Naturally more cases can be isolated depending on necessity. The following paragraphs will expand on these cases in more detail.

Firstly, the most widespread and controversial case today which is the migration from legacy networks to IMS. SPs around the world are in the middle of this process and making progress at different rates. This type of clear-cut migration is in essence a change of paradigm for the clients in the way services are delivered. The transition to NGN and the strategies that different operators are using has been focused on in more detail in [3]. From a logical standpoint the process seems simple. The user must be deleted from a legacy network and created again in NGN. However, the technical aspects of this delete-create scenario are far more complicated. Service delivery to customers on a new platform will require the replacement of most, if not all, network elements which in terms means a completely new way of provisioning users. This will be discussed in detail in Section III. In the context of this section it is crucial to stress the importance of continuity in the sense that the customer must be migrated with a minimum amount of disruption, with the accompanying processes and services left unchanged or enhanced after the

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transition to NGN. To be brief, the migration process has to be as seamless as possible.
The second case for migration is within the IMS. An example of this might be moving users from one application server to another. This scenario in fundamentally different from the previous. The preparations for the first migration case demand large amounts of resources from the operators, whilst preparing to migrate within the IMS, by rule of thumb, does not require ample amounts of resources. No major changes to the SDP have to be made or nothing completely new has to be designed, built or implemented. Given that the operator already has systems in place to provision users, the emphasis here is then directed to minor modifications of already working processes, software and/or hardware. The mentioned task is theoretically made easier taking into consideration that IMS is a standardized platform. However, even though this case might seem simpler than the first, real life applications often require making complex changes to a large number of intertwined nodes and systems of the SDP.
Another nuance which separates preparing the support systems for migration in the second case from the first one is the fact that the migration process does not need to be based on the earlier mentioned delete-create method. There may be cases when migration could be achieved by a few or even a single modification, for example to the home subscriber server (HSS) trigger [4].
In addition to the two scenarios for migration already described in this section there is a third which cannot be referred to as migration per se, namely, this is affiliation of new clients for the operator. The matter of new affiliations could be considered a subset of migrating users from legacy networks to NGN due to the need for user provisioning and this fact makes it pertinent in light of the current paper.

3. Evolution of the OSS/BSS With the Transition to Next Generation Networks

Support systems for telecommunications operators and service providers are computer systems that deal with the networks themselves that are used to provide services to customers. OSS/BSS-s are constantly evolving with the development of technology and the service provider. This area has been researched in [5, 6, 7, 8].
Due to the dissimilar and complex nature of communications networks deployed over time by different service providers the OSS/BSS becomes a crucial factor in migrating users to IMS. Although the interfaces towards IMS are well standardized, they are considered merely a means to an end, used by the tailor made migration system to exchange data through.
SPs each interpret support systems in their own way depending on their individual needs and properties. Considering that in order for users and services to be provisioned in a new SDP all of the OSS/BSS nodes and functions mentioned in Section I must be operational. As mentioned earlier the current paper focuses only on a specific area of an OSS/BSS. This has to do with user provisioning and in no way does this refer to diminish the importance of any other part of a complete support system.
Fig. 1 illustrates a high level overview of the difference between provisioning a user in a legacy network and in NGN. Three distinctions can be denoted: mainly manual provisioning, increased number of nodes in NGN and the need for a central component in next generation networks to manage the provisioning process, indicated as the provisioning system (PS).
Maximum automation of the SPs processes has been considered a key factor in the transition to NGN [6]. Service providers operating in a pre-NGN environment had some major deficiencies in this area. First of all there was simply no need for full automation since the amount of nodes in the network was small and secondly the stovepipe nature of services made it extremely difficult. Fig. 1 and Fig. 2 illustrate this matter.

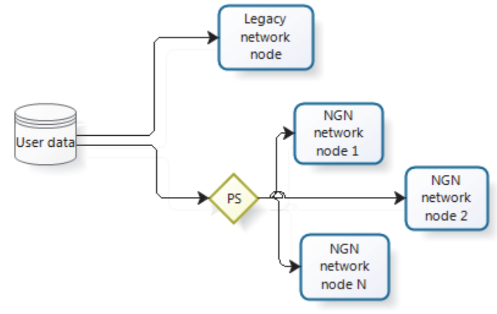

Figure 1. A change in user provisioning from legacy networks to next generation networks.

The user provisioning system in PSTN, depicted in Fig. 2 shows the digital exchange (DE) to be virtually the only node to provision a user in. In comparison, Fig. 1 indicates an increase in the number of nodes within the SPs next generation network, therefore multiplying the operations of single users' provisioning and hence creating the demand for automation.

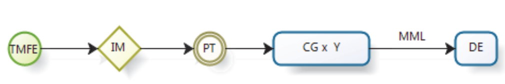

Figure 2. A simplified schematic of a pre-NGN user provisioning system.

Fig. 2 also illustrates the issue that there are nodes and functions from previous OSS/BSS-s that can be reused in NGN. The telco management front end (TMFE) which is in essence an operators' master database with an input/output layer built on top of it. It comprises of several functional blocks, for example accounting, customer relationship management (CRM) and product, client database. User access to this front end is defined by rights. In the context of user provisioning we consider this entity to be the input and no distinction shall be made whether the initial provisioning data is entered manually or is taken from a different connected technical system.
The input mediation (IM) receives work orders from the TMFE and verifies each specific task. Its main responsibility in pre-NGN scenarios was to keep track of the order queue and forward the orders accordingly. However, there have been significant modifications to the IM with the migration to next generation networks. It is now connected to a multitude of network registers and adjacent systems which make the actual changes in the SPs network. The data arrives to the IM mainly in the form of an extensible markup language (XML) document and is further parsed and inserted into multiple data tables.
The provisioning tool (PT) and its Y number of identical and individual sub-blocks called command generators (CG) were used to access and modify the digital exchanges. A detailed description of the PT and CGs is disclosed in Section IV.

4. A Novel System for User Provisioning and Migration

4.1. Nodes and Interfaces

Fig. 3 illustrates a system for user provisioning in IP multimedia subsystem with the TMFE and IM already explained in Section III. The buffer (BFR) block creates a structured query language (SQL) query after a constant predetermined time towards the IM to fill up the buffer with up to date information. The volume of the buffer is limited. Another task of the BFR is to exchange data between the previous and next step of the provisioning flow. Meaning, if the provisioning tool has completed a task the BFR will know about this and update the preceding block which is the input mediation. It is also possible that depending on the task the update may contain not only the fact of a task completion but specific relevant data as well.

The provisioning tool is the central component of user provisioning. In addition to users, it can also be used to manage services and internet protocol (IP) interfaces. To be more specific it is used to create and delete users, attach services to users (changing the user profile), manage long distance configurations (for example in the case of adding a client account to a router) and lastly it can be used as a source of relevant information for fault management. The current paper addresses the PT only from a user provisioning point of view.

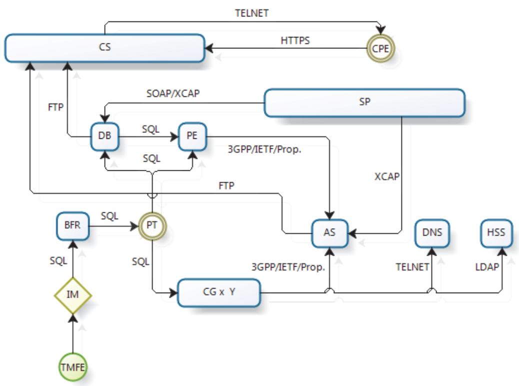

Figure 3. A schematic of a system for user provisioning in IMS.

As mentioned, the PT consists of several command generators. The reason for there being more than one CG lies in load distribution. Each CG polls a table within PT for pending work orders after a predetermined interval. All pending operations are initially placed in a single table and after a command generator obtains a task it marks this as "in operation" so no other CG can acquire it. During the fetching of tasks the CG also updates its own status. This ensures knowledge of the command generators' operational ability. In addition the CG updates its status every 10 seconds, thus indicating it is not out of order.

The CGs work on a first come first served basis and if one of them stops working it will not affect the others. The tasks are executed based on a command identifier (ID). Each command ID is attributed a specific script to run and monitor the outcome. If a step in the script is completed and the results are as expected the following step will start. In case there is an error condition the script will stop or future steps might be skipped.

After the CG has completed the script, the work order table in PT is updated accordingly and in if an error condition was met, detailed information about the problem and the step at which it was encountered is also added. It is also worth noting that depending on the nature of the error, a notification is sent to an employee for further processing and enhancement of the system.

The command generator operates as the main entity making relevant changes and queries to multiple IMS nodes. With regard to user provisioning the CGs access the ASs using either proprietary protocols or protocols based on the 3rd generation partnership project (3GPP) or internet engineering task force (IETF) specifications, the domain name system (DNS) server using TELNET and the HSS using lightweight directory access protocol (LDAP).

PT can also address the database (DB) or the process execution (PE) block using SQL. The DB houses data regarding the nodes in the SPs network. This includes for example data about the location of the nodes with access information. Translation information on how to translate SQL commands into commands understood by different nodes is also held in the DB. PE is used as an extension of the PT to access the application servers in order to minimize lag during specific tasks that might otherwise cause overload in the CG-s.

The application servers, one of the main components of the service delivery platform, house specific data regarding services delivered to customers and are described in [2, 9]. As illustrated in Fig. 3, the ASs can be accessed for modifications from the CG, PE and the service portal (SP).

The service portal is an operator created web portal that clients can use to manage their own users and services in the ASs. Naturally, not every possible modification within the ASs can be done using the SP but simpler and frequently used operations have been made accessible here. For example changing the account name or omitting a single service from a user are operations that do not necessarily need the interference of the operator. With respect to user migration the customers' administrator can create, delete or modify a user. The SP uses simple object access protocol (SOAP) or XML configuration access protocol (XCAP) to communicate with the DB and through that with the application servers. Direct access from the service portal to an AS can also be possible using XCAP if such a requirement is posed by the operator. In case the database server is used, at first the IP address and the existence of the clients' administrator is checked to rule out any false use. Another check is made regarding user rights to certify that the administrator has proper authorization to make changes. After necessary verification an SQL procedure is initiated to make the actual changes. In case there is a failure in any of the procedures a rollback is made to ensure there will be no accounts with partial configuration.

The configuration server (CS) holds the data of customer premises equipment (CPE) for download. For the sake of clarity it must be noted that CPE in this case encompass desktop phones and routers. The equipment configuration data is pushed to the CS either through the DB or directly from the AS every time the configuration file is modified. File transfer protocol (FTP) is used in both cases. The DB is used in cases where the application server cannot create a configuration file that is directly understood by the CPE and therefore needs extra modifying.

Customer premises equipment configuration data is sent to the CPEs by the CS after they have rebooted or as mentioned previously, modifications to the configuration data is made. To update router data, the CS initiates a TELNET session into the specified router and makes the changes. For desktop phones first a session initiation protocol (SIP) notify is sent to the phone indicating that the configuration data has been changed after which the phone uses hypertext transfer protocol secure (HTTPS) to get the latest configuration.

4.2. Modifications and Possibilities for Enhancement

The provisioning system will undergo minor changes every time the operator decides to modify user provisioning. These modifications are mostly derived from executive decisions such as to provision all new users with a different set of properties compared to an earlier set. A similar situation might also occur when an interface, be it standardized or proprietary, changes. In both mentioned cases most modifications will have to be made to the provisioning tool since this is the central part of the system.

The issue of technically enhancing the system for user provisioning is currently seen as two-fold. Firstly, the system is subject to ordinary hardware related constraints like the lack of disk space or memory on the servers. Hence, this is the least resource demanding way to improve the system.

The second alternative for overall system enhancement is from within the PT. There is a possibility to add new command generators. In addition to simply adding new CGs, there is valid reason to believe that modifying the algorithm how the tasks are allocated within the PT to the, currently identical and individual, CGs will provide an increase in system performance. However, this has not yet been analyzed in more detail. According to the current design if the command generator is free and is polling for a new task it updates its status in the PTs database to “looking for a task” and also checks if any of the other CGs are doing the same. If not and there are available tasks to complete it will take the first one. After this, the status of the CG in the database is again changed to “in operation”. In case there are several idling CGs and these are all looking for new tasks, the next task will be given to the first CG (the CGs are numbered from 1…Y with the lowest number having the highest priority). The deficiency with this kind of logic is the complexity of it and the constant operation with the PTs database.

5. Conclusion

There are a few common hurdles all incumbent telecommunications operators must overcome to migrate successfully to next generation networks. First of all the operator needs to have sufficient recourses for the transition, secondly the migration is closely tied to the way the company is run on an executive level and how the development of it is seen. Finally, from a technical aspect, the support systems used, meaning the OSS/BSS must also make the transition from legacy to NGN.

The support systems that an operator is using have to enable user migration cases with different levels of complexity. Users may be migrated away from legacy networks such as the PSTN just as they can be migrated within an already running NGN service delivery platform like the IMS. The current paper establishes that a user migration and provisioning system to fit all of the above mentioned demands that is also scalable and reliable, is feasible and such a suitable solution is described. It must be noted however that, depending on their background, different operators have differing views of what an OSS/BSS for NGN should be comprised of and how it should function. These are all arguments for the creation of an all-encompassing and flexible provisioning system.

To be brief, the incumbent systems that facilitate user provisioning to next generation networks have retained some functionality from the pre-NGN environment but have thrived in complexity due to the increased number of nodes and functionalities in modern SDPs. Previously, provisioning a user did not require an entry to be made for example in HSS or DNS as it does today with IMS.

The overall performance of the provisioning systems is difficult to assess before actual usage. Naturally, some test migration scenarios or user provisioning can be run on the system before going live but these are usually on a small scale and often without the presence of adjacent systems. So in essence the PS must have qualities like scalability and adaptability to be able to remain in operation for a longer period of time. The evolution of technology and ideas demand that the PS does the same.

Acknowledgements

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References

[1] Series Y: Global Information Infrastructure, Internet Protocol Aspects and Next-Generation Networks, ITU-T Recommendation Y.2001, 2004.

[2] G. Camarillo, M. A. Garcia-Martin, The 3G IP Multimedia Subsystem: merging the Internet and the cellular worlds, 3rd edition. Chichester, West Sussex, United Kingdom, 2008, pp. 25-48.

[3] Sven Pärand, “Migration towards NGN: common applied strategies,” International Journal of Computer and Communication Engineering, vol. 2, no. 5, pp. 584-589, Sept. 2013.

[4] G. Camarillo, M. A. Garcia-Martin, The 3G IP Multimedia Subsystem: merging the Internet and the cellular worlds, 3rd edition. Chichester, West Sussex, United Kingdom, 2008, pp. 181-184.

[5] Lu Hanhua, Wang Yashi, Min Lijuan, Huang Zhenqi, “OSS/BSS Framework Based on NGOSS,” in Proc. International Forum on Computer Science-Technology and Applications, Chongqing, 2009, pp.466-471.

[6] Herbert Goestl, “Using NGOSS Principles in todays OSS/BSS Projects NGOSS meets IMS/SDP,” in Proc.12th Telecommunications Network Strategy and Planning Symposium, New Delhi, 2006, pp. 1-8.

[7] Young-Hyun Choi, Seon-Ho Park, Soo-Deuk Kim, Dong-Min Kang, Changsup Keum, Tai-Myoung Chung, “NGOSS Based OSS/BSS Architecture for Hosting Common Platform for Convergence Services, “ in Proc. Second International Conference on Ubiquitous and Future Networks, Jeju Island, Korea, 2010, pp. 199-204.

[8] J.Wittgreffe, C.Trollope, T.Midwinter, “The next generation of systems to support corporate grade ICT products and solutions,” BT Technology Journal, vol. 24, Issue 4, pp. 93-112, Oct. 2006.

[9] M.Poikselkä, G.Mayer, The IMS: IP multimedia concepts and services, 3rd edition. Chichester, West Sussex, United Kingdom, 2009, pp. 27-29.

Appendix B

SUPPLEMENTARY SERVICES IN LEGACY NETWORKS AND NGNs

The following is a sample list of widely used supplementary services in legacy networks and NGNs.

Abbr.	Service in NGN (simulation)	Service in PSTN/ISDN
CDIV	Communication Diversion	Call Diversion
CFU	Communication Forwarding Unconditional	Call Forwarding Unconditional
CFB	Communication Forwarding Busy user	Call Forwarding Busy
CFNR	Communication Forwarding No Reply	Call Forwarding No Reply
CFS	Communication Forwarding Selective	-
CONF	Conference	Conference Calling
OIP	Originating Identification Presentation	Calling Line Identification Presentation
OIR	Originating Identification Restriction	Calling Line Identification Restriction
TIP	Terminating Identification Presentation	Connected Line Identification Presentation
TIR	Terminating Identification Restriction	Connected Line Identification Restriction
CW	Communication Waiting	Call Waiting
HOLD	Communication Hold	Call Hold
CB	Communication Barring	Call Barring
ECT	Explicit Communication Transfer	Explicit Call Trasfer
AC	Automatic Callback	Automatic Callback
BLF	Busy Lamp Field	Busy Lamp Field
DCP	Directed Call Pickup	Call Pickup
DND	Do Not Disturb	Do Not Disturb
ED	Extension Dialing	Extension Dialing
LNR	Last Number Redial	Last Number Redial
PaA	Pre-alerting Announcement	-
SCA	Selective Call Acceptance	-
SCR	Selective Call Rejection	-
SR	Simultaneous Ringing	-

Appendix C

USER CREATION IN PROVISIONING TOOL

An example output of user creation with the provisioning tool in the model supporting system. Sensitive information such as IP addresses have been deleted and substituted with random symbols.

```
[C3:0][2010]
LDAP1:?xml=L_SRD_GET1.xml&object=groupId&name=P00551801$SRD$XXX.XXX.XX.
X$V3;
CMD answer:RESP=0;

:GROUP,P00551801
:SERVPROV,elion
:GROUPNAME,Elion Ettevotted AS
:SIPBARRED,0
:GSRDSERVICEPACK,ARI_2
:GSRDDEFAULTDOMAIN,elion.ee
EXECUTED;

[C3:1][2011]
LDAP1:?xml=L_SRD_GET1.xml&object=spId&name=elion$SRD$XXX.XXX.XX.X$V3;
CMD answer:RESP=0;

:SERVPROV,elion
:ASADDRESS,xxxx.xxx.elion.ee
:WSADDRESS,xxxx.xxx.elion.ee
:SPNAME,Elion

EXECUTED;

[C3:2][2221]
DBC:sp_Srv_getObjectState:snb=3726402565@elion.ee,tact=ADDIPTEL1,number=NO
DATA,dev=P00551801,spack=;
DBC answer - OK;
SNB=3726402565@elion.ee
SPROFILE=ARI_2;

EXECUTED;

[C3:3][2228]
LDAP1:?xml=L_SRD_ADD1.xml&snb=3726402565@elion.ee&dev=P00551801&sp=elio
n&pin=XXXXXXXXXX&fn=6402565&ln=P00551801&pres=0
&priva=0&enum=NODATA&exst=NODATA&usertype=0&as=xxxx.xxx.elion.ee&ws=xxx
x.xxx.elion.ee&spack=ARI_2$SRD$XXX.XXX.XX.X$V3;
CMD answer:RESP=0;

EXECUTED;
```

[C3:4][2229]
CMD:?xml=OCIPModel01.xml&command=UserAddRequest14sp9&serviceProviderId=elion&groupId=P00551801&userId=3726402565@elion.ee&lastName=P00551801&firstName=6402565&callingLineIdLastName=P00551801&callingLineIdFirstName=6402565&phoneNumber=NODATA&password=XXXXXXXXXX&language=Estonian;
CMD answer:RESP=0;

:USERSERVICE,c:SuccessResponse,;

EXECUTED;

[C3:5][2094]
CMD:?xml=BS_modUserSysDEV.xml&snb=3726402565@elion.ee&device=sysDefaultDev;
CMD answer:RESP=0;

:USERSERVICE,c:SuccessResponse,;

EXECUTED;

[C3:6][2352]
LDAP1:?xml=HSS5_ADD1_Subscriber.xml&snb=3726402565@elion.ee&ipc=$HSS5$XXX.XX.X.XXX$V3;
CMD answer:RESP=0;

EXECUTED;

[C3:7][2353]
LDAP1:?xml=HSS5_ADD2_User.xml&snb=3726402565@elion.ee&pin=XXXXXXXXXX&aam=Digest$HSS5$XXX.XX.X.XXX$V3;
CMD answer:RESP=0;

EXECUTED;

[C3:8][2354]
LDAP1:?xml=HSS5_ADD3_UserServiceProfile.xml&snb=3726402565@elion.ee&as=IMT_CENTREX_xxxx.xxx.elion.ee&pct=elion.ee$HSS5$XXX.XX.X.XXX$V3;
CMD answer:RESP=0;

EXECUTED;

[C3:9][2355]
LDAP1:?xml=HSS5_ADD4_PublicIdDataSip.xml&snb=3726402565@elion.ee&irs=1$HSS5$XXX.XX.X.XXX$V3;
CMD answer:RESP=0;

EXECUTED;

[C3:10][2356]
LDAP1:?xml=HSS5_ADD5_UserSrvProfile.xml&snb=3726402565@elion.ee$HSS5$XXX.XX.X.XXX$V3;
CMD answer:RESP=0;

EXECUTED;

[C3:11][2000]
LDAP1:?xml=HSS5_GET1.xml&snb=3726402565@elion.ee$HSS5$XXX.XX.X.XXX$V3;
CMD answer:RESP=0;

:SUBID,3726402565@elion.ee
:PRIVID,3726402565@elion.ee
:USERBARRINGIND,0
:USERSTATE,not_registered
:CHARGINGPROFILE,IMT_Charging1
:MAXSESS,99
:ROAMIND,0
:PRIVACYIND,0
:ISPSI,0
:SIPLOCKIND,0
:PHONECONTEXT,elion.ee
:SERVICEPROFILES,
,SERVICEPROFILE,IMT_CENTREX_xxxx.xxx.elion.ee
:PUBDATA,
,PUBID,sip:3726402565@elion.ee,STATE,not_registered,LOCATIONDATA,,,,IMPLICITREGSETID,1,SESSIONBARRINGIND,0,DEFAULT,1,ACCESSALLOWED,,ACCESSLINELIST1,,ACCESSLINELIST2,
:PUBIDSIP,sip:3726402565@elion.ee
,SSTATE,not_registered
,SLOCATIONDATA,,,
,SIMPLICITREGSETID,1
,SSESSIONBARRINGIND,0
,SDEFAULT,1

[C3:12][2001]
LDAP1:?xml=L_SRD_GET1.xml&object=userName&name=3726402565@elion.eeSRDXXX.XXX.XX.X$V3;
CMD answer:RESP=0;

:USER,3726402565@elion.ee
:GROUP,P00551801
:SERVPROV,elion
:FIRSTNAME,6402565
:LASTNAME,P00551801
:E164,NODATA

:EXTENSION,NODATA
:PUBID,sip:3726402565@elion.ee
:ASADDRESS,xxxx.xxx.elion.ee
:WSADDRESS,xxxx.xxx.elion.ee
:USERTYPE,END-USER
:PRESENCE,0
:PRIVACY,0
:PRIVID,3726402565@elion.ee
:SIPBARRED,0
:USRDSERVICEPACK,ARI_2

EXECUTED;

[C4:5][2201] IPWORKS1: create enumdnsched +3726402565.e164.arpa -set naptrflags="nu";naptrorder=10;naptrpreference=10;naptrservice="sip+e2u";naptrtxt= "/^.*$/sip:3726402565@elion.ee/"

CMD answer:RESP=0;

EXECUTED;

Appendix D

DATA IN THE ISMST

An example list of data in the IMS application server management support table (ISMST) within the model provisioning tool.

Id	33034
Spid	elion
groupid	P00632847
addInfo	
alarmcat	0
asAddress	xxxx.xxx.elion.ee
billing	0
e164	+3726180013
extensionNumber	NODATA
firstName	6180013
imsPrivateId	3726180013@elion.ee
lastName	client name
maContactList	
maExtension	
monitoring	0
presence	0
privacy	0
sipBarred	0
sipUrl	sip:3726180013@elion.ee
srdUserAlias	default_3726180013@elion.ee
username	3726180013@elion.ee
userPassword	{SSHA}xAA6aMZ5G6cg9v0UtICQ1wpr3j+NJ3o3NRgoQA==
userType	END-USER
wsAccountBarred	0
wsAccountLocked	0
wsAccountLockingEnabled	0
wsAddress	xxxx.xxx.elion.ee
wsOTPEnabled	0
wsPassword	{SHA}DpdVXnaMrDp4SA8SmqxVtqaEpis=
wsPasswordCurrentFailure	0
wsPasswordMaxFailure	3
wsPasswordMustChange	0

created	
modified	
EncryptedUserPassword	¼³ŗJ@7”é8ęŚŽbšŃ'¬Ó(“3dāę±n»‘¦š³23¬2Ų2Õ%±¸a Æ—#/
EncryptedWsPassword	¼³ŗJ@7”é8ęŚŽbšŃ'¬Ó(“3dāę±n»‘¦š³23¬2Ų2Õ%±¸a Æ—#/
timeZone	Europe/Tallinn
countryCode	372
language	ee
privAccess	0
srdServicePack	ARI_2

Appendix E

PROCEDURE LOGIC FOR CALL RESTRICTIONS

An example of the procedure logic when activating call restrictions for a user. The procedure is started in the provisioning tool to restrict the account '3726210927@elion.ee' from making calls to 'elion_mobile'

```
EXEC sp_Srv_OCB_multiple_adm
'3726210927@elion.ee','MOD','OCBUC','elion_mobile','','','',''
```

The database node initiates a procedure [sx_MTAS_srv_ocbuc_proc] and the current document is requested.

The modified document is sent back to the AS (for the sake of simplicity the login information has been omitted)

```
[02/11/15,12:46:54.693] - [238666]xp_MTAS_command_v12:
http://mtas_hki1.emm.elion.ee:8095, /axis2/services/CAI3G, CAI3G#Set, <?xml
version="1.0" encoding="ISO-8859-1"?>
<soapenv:Envelope xmlns:cai3g="http://schemas.ericsson.com/cai3g1.2/"
xmlns:mc="http://schemas.ericsson.com/mtas/mmtel/cai3g"
xmlns:soapenv="http://schemas.xmlsoap.org/soap/envelope/"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://schemas.xmlsoap.org/soap/envelope/
../../cai3g/schemas/Soap-Envelope.xsd

                              http://schemas.ericsson.com/cai3g1.2/
../../cai3g/schemas/cai3g1.2_header-fault-corrected.xsd

                              http://schemas.ericsson.com/mtas/mmtel/cai3g
../schemas/mmtel_aggregated_service.xsd">
    <soapenv:Header>
        <cai3g:SessionId>[SESID]</cai3g:SessionId>
        <cai3g:TransactionId>1</cai3g:TransactionId>
        <cai3g:SequenceId>[SEQID]</cai3g:SequenceId>
    </soapenv:Header>
    <soapenv:Body>
        <cai3g:Set>
            <cai3g:MOType>MMTel@http://schemas.ericsson.com/mtas/mmtel/c
ai3g</cai3g:MOType>
            <cai3g:MOId>
                <mc:publicId>sip:3726210927@elion.ee</mc:publicId>
            </cai3g:MOId>
            <cai3g:MOAttributes>
                <mc:setMMTel publicId="sip:3726210927@elion.ee">
                    <mc:outgoing-barring-programs>
                        <mc:obp-operator-configuration>
                            <mc:activated>true</mc:activated>
                            <mc:scheme>multiple</mc:scheme>
                        </mc:obp-operator-configuration>
```

```
                        <mc:obp-user-configuration>
                                <mc:active>true</mc:active>
                                <mc:provisioned-program>
                                        <mc:multiple-programs>
                                                <mc:category-
name>elion_mobile</mc:category-name>
                                        </mc:multiple-programs>
                                </mc:provisioned-program>
                        </mc:obp-user-configuration>
                </mc:outgoing-barring-programs>
            </mc:setMMTel>
        </cai3g:MOAttributes>
    </cai3g:Set>
  </soapenv:Body>
</soapenv:Envelope>


[02/11/15,12:46:54.834] - [238666]MTAS_command_v12 answer (len:605): <?xml
version="1.0" encoding="ISO-8859-1"?>
<soapenv:Envelope xmlns:soapenv="http://schemas.xmlsoap.org/soap/envelope/">
    <soapenv:Header>
        <cai3g:SessionId
xmlns:cai3g="http://schemas.ericsson.com/cai3g1.2/">A195D50D219D242Z1417016501S
100614P65541</cai3g:SessionId>
        <cai3g:TransactionId
xmlns:cai3g="http://schemas.ericsson.com/cai3g1.2/">1</cai3g:TransactionId>
        <cai3g:SequenceId
xmlns:cai3g="http://schemas.ericsson.com/cai3g1.2/">1511295388</cai3g:SequenceId>
    </soapenv:Header>
    <soapenv:Body>
        <cai3g:SetResponse xmlns:cai3g="http://schemas.ericsson.com/cai3g1.2/"/>
    </soapenv:Body>
</soapenv:Envelope>

[02/11/15,12:46:54.834] - [238666]xp_MTAS_command_v12: <end> w 0 sek.
```

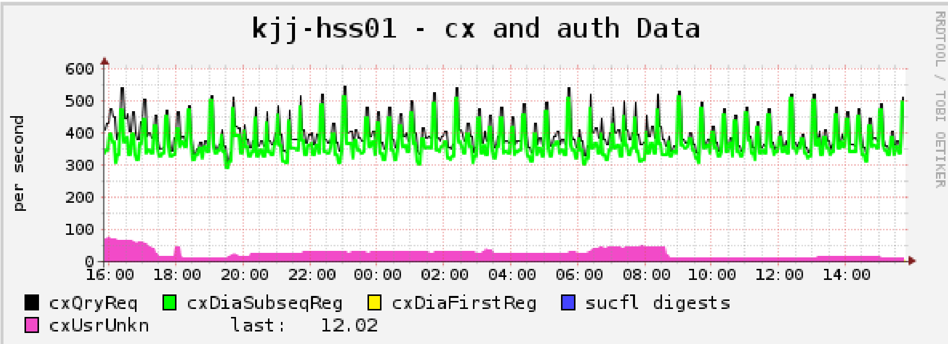

DBC answer
SNB=3726210927@elion.ee
EXECUTED;

Appendix F

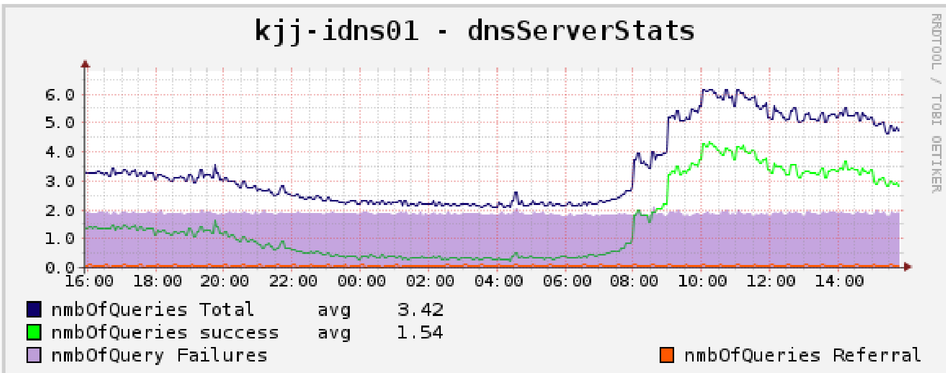
IMS MEASUREMENT EXAMPLES

Additional measurements performed by the model telco operator regarding the IP Multimedia Subsystem.

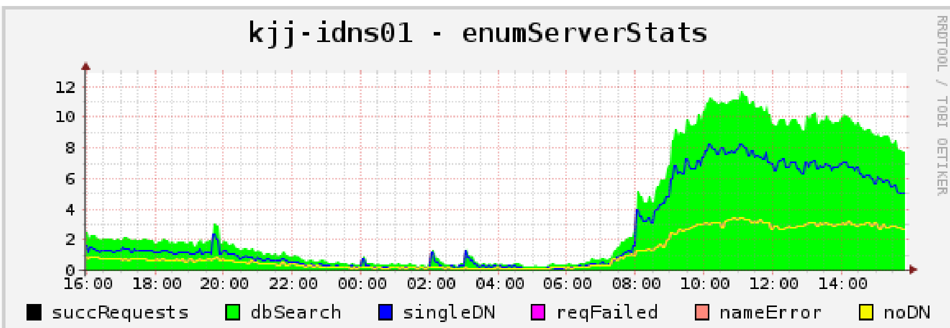
The Cx interface and authentication data on the HSS



DNS server statistics



ENUM server statistics



CURRICULUM VITAE

1. Personal data

Name	Sven Pärand
Date and place of birth	07.07.1982, Tallinn

2. Contact information

Address	Telia Estonia Ltd Sõle 14, 10611 Tallinn
Phone	+372 6402 565
E-mail	sven.parand@telia.ee

3. Education

Educational institution	Graduation year	Education (field/degree)
Tallinn University of Technology		PhD student
Tallinn University of Technology	2006	MSc (*cum laude*)
Tallinn University of Technology	2005	diploma
Gustav Adolf Grammar School	2000	middle school

4. Languages

Language	Level
Estonian	native
English	fluent
Finnish	fluent
Russian	average

5. Service record

Period	Organization	Position
2012 -	Telia Estonia Ltd	IMS applications expert, ICT services manager
2009 - 2012	SMIT	senior expert
2005 - 2009	Estonian Emergency Response Centre	leading expert

ELULOOKIRJELDUS

1. Isikuandmed

Ees- ja perekonnanimi	Sven Pärand
Sünniaeg ja –koht	07.07.1982, Tallinn

2. Kontaktandmed

Aadress	Telia Eesti AS Sõle 14, 10611 Tallinn
Telefon	+372 6402 565
E-post	sven.parand@telia.ee

3. Hariduskäik

Õppeasutus	Lõpetamise aeg	Haridus (eriala/kraad)
Tallinna Tehnikaülikool		doktorant
Tallinna Tehnikaülikool	2006	MSc (*cum laude*)
Tallinna Tehnikaülikool	2005	diplom
Gustav Adolfi Gümnaasium	2000	keskharidus

4. Keelteoskus

Keel	Tase
Eesti	emakeel
Inglise	kõrgtase
Soome	kõrgtase
Vene	kesktase

5. Teenistuskäik

Töötamise aeg	Tööandja nimetus	Ametikoht
2012 -	Telia Eesti AS	IMS rakenduste ekspert, IKT teenuste juht
2009 - 2012	SMIT	juhtivekspert
2005 - 2009	Häirekeskus	peaspetsialist