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MASTER THESIS

TITLE: Analysis of NFV Service Design and Management Processes Using ITIL and eTOM Best Practices

MASTER DEGREE: Master of Science in Applied Telecommunication Engineering & Engineering Management

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Abstract

The goal of this master's thesis is to carry out the analysis of network function virtualization (NFV) design and operations management process using two of the most widely accepted and adopted best practices in telecommunication and IT industries.

NFV have had a growing and wide acceptance in the telecommunication sector, even though not fully implemented as most telecommunication companies are still working on fully adopting NFV to address the competitive challenges of cost and time to market. The required transformation is going to redefine the initial products, standards, business processes and also the interoperability amongst different vendors. One of the most demanding challenge face is the NFV aligning with operational model and best practices for defining and developing an NFV operations strategy.

To get this desired transformation, networks will have to be more flexible and open to changes of its operation to match the steady changes in demands. These demand is expected not to impact on already existing traffic but ensure improvement on quality of service. To increase flexibility of a system, it means changing to reconfigurable and replaceable software approach. The NFV ideology is the transformation from what we have as the traditional fixed network function to a software based approach, typically in a virtualized environment.

Network virtualization, often grouped together as NFV and software defined network (SDN) although with different concept but best works together for the future transformation, these changes disrupt existing business models and processes, and enable new ways of doing business. Redefines the network delivery system, and also boost capital and operational efficiencies.

Adopting NFV means operational support system (OSS) transformation, service providers must look at designing a target management architecture for a well-defined business process, derived from two most used and accepted telecommunication and IT best practices, such as ITIL and TM Forum Business Process Framework (eTOM), but extended to address NFV, based on solid pillars guaranteeing a futureproof journey and a smooth transition from the current situation, systems, platforms, and processes.

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NFV, With the broad growth and wide awareness and acceptance in the telecommunication industries, even though not fully implemented as most telecommunication companies are still working on migrating to NFV to address the competitive challenges of cost and time to market. This transformation will be redefining standards, business process and interoperability as well as changing in products. Aligning with the operational model and best practices for developing an NFV operations strategy is one of the draw backs in NFV deployment.

In order to achieve this landmark transformation, the network will have to be much more flexible and open to changes of its operation to match the continued change in demand. It is an ideology that is keyed on software-based approach and proposes an innovative and cost-effective network infrastructure and also ease ways to market.

Network virtualization, often grouped together as NFV and SDN although with different concept but best works together for the future transformation, bringing increased agility in delivering network services with improved capital and operational efficiencies. Also adding, simplification, automation, and achieve operational benefits by reducing the costs associated with manual and complex processes. These changes disrupt existing business models and processes, and enable new ways of doing business.

Future growth in the industries, relies on the service provider being able to create two fundamental abilities:

- The ability to quickly attend to customer demands.
- The ability to build sustained and deep customer relationships.

The first means agility (fast response), while the second is about creating and sustaining customer relevance. This two requirements have impacts to four highly interrelated organizational elements[1]:

- Business processes (this defines the organisational goal)
- Roles and responsibilities
- New software skills
- Culture

Having done some research on this topic, I have got ideas from white papers and documents from European Telecommunications Standards Institute (ETSI), publications from international telecommunication ITU-T on telecommunication management and network maintenance. also, key fact from TMForum documents specifically on eTOM (GB921 version 12.2 and others) have also being read and used in the analysis of the major part of my work, alongside with other documents

from BMC on ITIL and white papers from Cisco, Huawei, Juniper, Nokia amongst other, as will be properly referenced at the end.

Not to forget, a major part of the introduction was inspired/build-up from a recent UPC Thesis on ‘‘Deployment of NFV and SFC scenarios’’ by Pau Capdevila i Pujol.

This document is divided into chapters to better clarify and describe the phases of the project:

- Chapter one gives an in depth introduction of current and future communication and service provider’s (CSP) network, also introduction to NFV and the two most popularly used business processes (ITIL and eTOM),
- Chapter two highlights the key players in NFV business models, Secondly on the relationship with cloud computing. Third part is on Projects directly focusing on NFV service orchestration.
- Chapter three, being the main body of this thesis, focuses on analysing the design and management process of NFV, and why all standard bodies working in collaboration with ETSI or working to promote the concept of NFV should follow a defined business process, using two of the most accepted best practices in IT and telecommunication industries (eTOM and ITIL)
- Chapter four is the conclusion part of the work done and stating the difference between and similarities between eTOM and ITIL.

CHAPTER 1. INTRODUCTION TO NFV, ITIL AND eTOM

1.1 OBJECTIVE

The objective of this project is to analyse the design and process management of NFV and its operations using two of the most widely used and accepted best practices in telecommunication and IT industries. Focusing majorly on the NFV operations, assurance and fulfilment processes amongst other processes in NFV operation.

Analysis of other project focusing on promoting the NFV concept, and why they all need to be aligned with the two best practices, in other for continuity and process compatibility when integrated to achieve a common business and operational goal. This is essential because it creates a general language for using across processes both internal and external, reducing risk of system implementation and integration, also eliminate gaps and duplication in process flow. Also comparison with the current CSP and impact of the needed NFV transformation to CSP.

1.2 Introduction

This chapter provides a baseline and an introduction to the current communication service provider (CSP) and its limitations. Secondly, NFV which ideology and drivers was as a result of the current CSP limitations. And finally, an introduction to the two most widely and accepted best practices in the IT and Telecommunication industries. Some other information will be in the Annex due to stated standards and space constraints.

1.2.1 Current CSP and Limitation

The present telecommunication network consists of statically chained network function connected in certain ways to achieve the desired aim and functionality that the network is designed to provide. [2].

Traditionally, telecommunication companies have been leading the market before Internet; however, the Internet tech companies such as Google or Facebook have focused on their own network and its redesign, developing switches more suitable for their traffic patterns.

Major reason is improper planning and consideration of a virtualization strategy in the Telecom industry compared to the information technology (IT) industry. With the adoption of SDN technologies recently, changes already started in the re-defining of operation but this is still not enough to cope with the speed of change required to actualize the demands.

Current CSP limitations includes,[3]:

- Total reliance on the application locked-in hardware devices, which also had a draw back to the flexibility and skill needed to manage the network equipment
- Increased energy consumption due to steady increase of hardware devices.
- Operational capability reduction due to different network infrastructure and management platforms.
- As a result of lack of test facilities, time for innovation is unnecessarily prolonged.
- Static network capacity, resulting to overprovisioning and oversubscribing. Service cannot scale based on immediate demand from its users.

1.2.2 Introduction to NFV

NFV is a network architecture concept that rely on the technology of virtualizing the network functions of a typical legacy server by separating this locked-in functions from the hardware components and then chaining together this separated network functions to create communication services, see [4]

The NFV framework consists of three main components:

1. **Management and orchestration (MANO)** this handles the management of the entire life-cycle of the NFVI through the VIM, and also manages the VNF through its VNF manager and also interface and interact with the OSS and BSS of the legacy network management tools.
2. **Network functions virtualization infrastructure (NFVI)** comprises of the hardware and software components required for VNFs deployment. Inclusively, the different locations of point of presence (infrastructure) and its connectively can also be grouped as NFVI.
3. **Virtualized network functions (VNFs)** On the NFVI, the expected software (network function) to run on it are the VNFs.

1.2.3 NFV and SDN Relationship

Software-defined networking(SDN) is a concept related to NFV but different, the both best works together for the future transformation.

SDN open interfaces permits the development of software that can determine the flexible connectivity and flow of network traffics, as was achieved by the previous network control room. This was achieved by building data networking equipment and software that distinguishes the roles of the control plane and data plane from each other, such that the control plane resides centrally and the forwarding

components remain distributed.

Figure 1.1 as shows explains the high compatibility between NFV and SDN. NFV is not dependent on SDN, so also SDN to NFV. Meaning NFV can be implemented without a SDN being required, although the two concept when combined gives greater value of achieved [5].

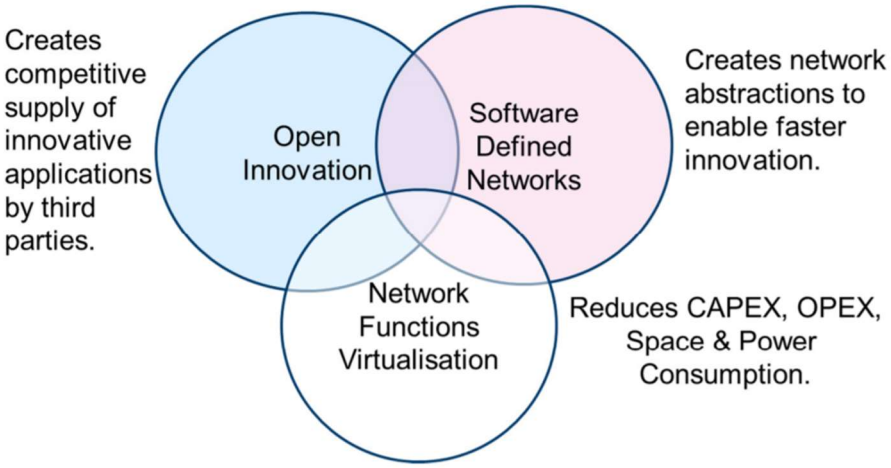

Figure 1.1 NFV Relationship with SDN Source: NFV-Introductory white paper[5]

NFV provides support for SDN by enabling the infrastructure where SDN can run. NFV goals can be achieved using non-SDN mechanisms, relying on the techniques currently in use in many data centres, while SDN approaches as said is keyed on separating of the data plane and control plane to ease operation and maintenance procedures, enhance and ensure expected performance, and interoperability with already existing deployed.

1.2.4 Pros and Cons of NFV

NFV, despite having lots of advantages and being the future anticipated transformation in the telecommunications industries (service providers), it also has some disadvantages. Find below some of the advantages and disadvantages of NFV.

NFV promises the following improvements:

- **Deployment Automation and Operations Simplification:** it promises more flexibility and ease in scaling up and down or changes in services.
- **Openness:** Redefine the locked-in function on servers and create more opportunities for virtual appliance market (software suppliers)
- **Complexity Reduction:** It ease in integrating and deploying any required software appliances in a network.
- **Service Agility:** Improved ease marketing time for new network services.
- **Enhanced Optimization:** Better usage of server capacity, reduced power

consumption and rack space.

- **Cost Efficiency:** NFV impacts positively on CAPEX and OPEX through low cost equipment it promises and also greater long term returns of investment from new services.

But poses the following challenges:

- **Compatibility with Legacy Networks:** Compatibility should be ensured during service transition with legacy hardware network, as some organisations might be running on hybrid network before fully migrating fully to virtualized network.
- **Standardized Management Interfaces:** Should support the re-using of the present OSS/BSS (Operations Support System/Business Support System).
- **Reliability and Resiliency:** Ensure readiness to accommodate failure both on hardware and software
- **Interoperability and Portability:** Appliances and Network functions should be portable between the different vendor equipment(servers)
- **Automation at scale:** Virtualizing the network functions should bring simplicity and better managed compared to the existing networks.
- **Security:** should guarantee protection from attack and also misconfiguration.
- **Performance:** During transition, network must maintain stability and expected service level.

NFV which obviously if achieves all its fulfilment requirements is the takeover concept of the telecommunication infrastructure was initiated in the SDN and Open Flow congress in 2012 by some groups of network providers. Later, the ETSI which is an acronym for “European Telecommunications Standards Institute” was agreed to be the industry specification group (ISG) for NFV.

1.2.5 ETSI NFV Architectural Framework

Figure 1.2 below shows the NFV architectural framework and pointing out the functional blocks, connectivity between them and reference points in the NFV framework. The solid lines are the main reference points and execution reference points which are the main scope of NFV. The dotted lines are part of the legacy network reference point but might need extension for handling NFV[2].

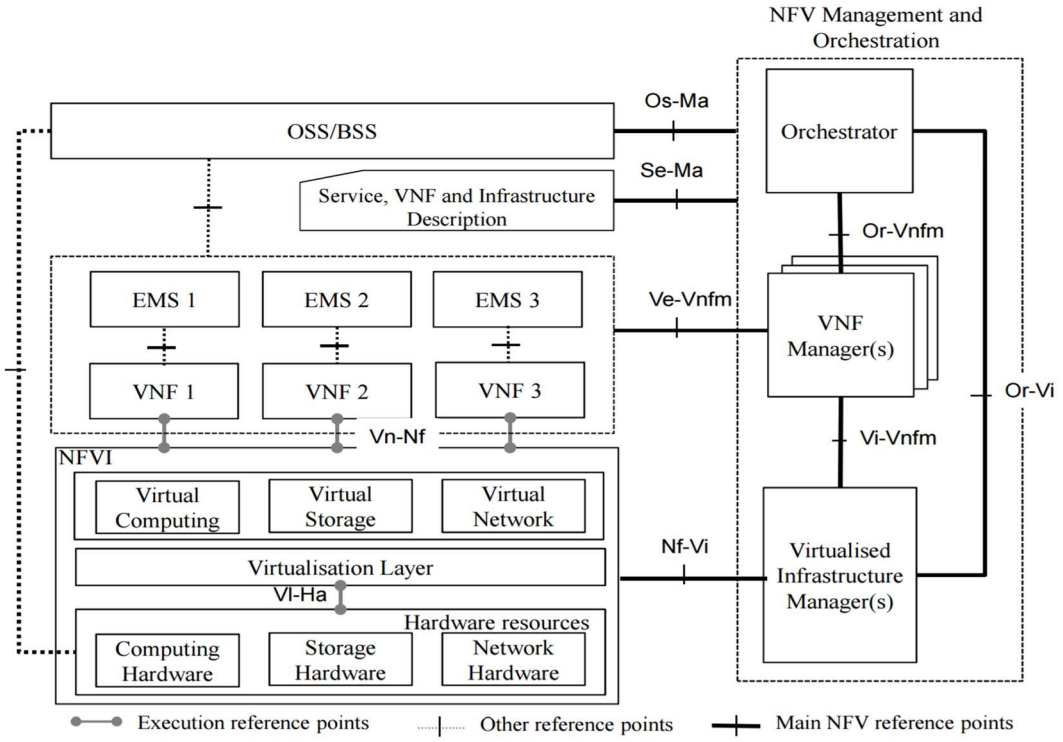

Figure 1.2 NFV ETSI Architecture Source: ETSI GS 002 V1.1.1 "Network Virtualisation(NFV) architectural framework [2]

Overview of the functional blocks

The overview of the functional blocks are as follows[2]:

1. **Network Functions Virtualization Infrastructure (NFVI)** is the combination of hardware and software(network function) components which build up the environment for where VNF can be deployed, managed and executed. "NFVI consists of the virtualized layer, storage, compute, and networking hardware as defined by the ETSI."

"The NFV Infrastructure (NFVI) when actualized should support several use case and mostly used applications as already identified by NFV ISG for the transformation of VNF ecosystem. [15].

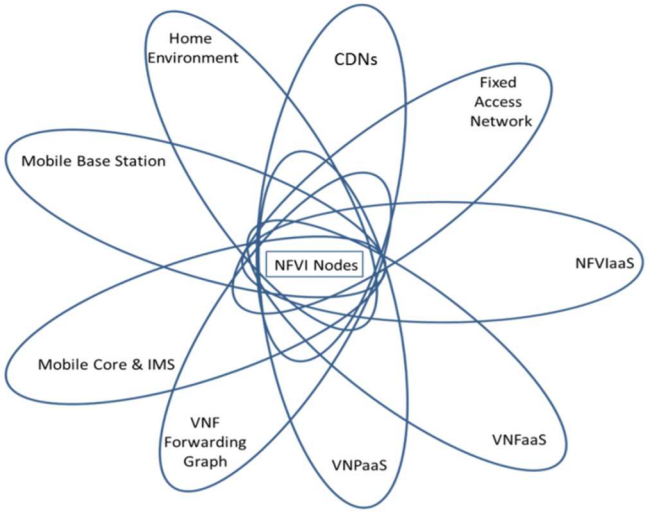

Figure 1.3 NFVI Supports Multiplicity of NFV Use Cases and Fields of Application
Source: ETSI white Paper 3[15]

2. **Element Management System** (EMS): This is part of the legacy network that will manages the functionality of one or more VNFs. In this context, it will control the functionality and management of one or several VNFs.
3. **VNF Manager(s):** The management and orchestration, through the VNF manager manages the life-cycle of the VNF which includes the instantiation, update, query, scaling, termination. Multiple or single VNF Managers may be deployed for the management of one or more VNF as the case maybe.
4. **Hardware Resource:** The hardware resources in NFV architecture comprises of the storage, computing and the network hardware as it were in the present network infrastructure, but this does the processing, storage and connectivity to VNFs through the Virtualization layer.
5. **Virtualized Layer:** The virtualisation layer interface between the virtual resources and the hardware resources thereby ensuring the hardware independent lifecycle for the VNFs.
6. **Virtual Network Functions** (VNFs) are the software (network function) to be executed on the NFVI.
7. **Virtualized Infrastructure Manager** (VIM) handles the management of NFVI which consist of the compute, storage and networking resources.
8. **NFV Orchestrator** (NFVO**):** This handle the orchestration and management of the NFVI and also the software resources of the NFV, and NFVI network service realization.
9. **Service, VNF and Infrastructure Catalogs:** for NFV deployment templates, its forwarding graph, information model and all the other service

related information, is generated by this data-set

1.3. INTRODUCTION TO ITIL

IT infrastructure library (ITIL), being the most widely used and accepted approach and best practice in IT service management globally, it is accepted by several organisations the wants to align IT and their business needs. It provides a comprehensive and consistent defined best practices that could be adopted to promote high quality of business effectiveness and efficiency. It was developed in the United Kingdom during the 1980's and now being used and accepted worldwide. The idea was as a result of client server challenges, and increasing IT operational complexity. It is presently represented and revised by the IT service management forum (itSMF), which has branches in about 30 countries[6].

The ITIL framework five stages include[7]:

- **Service Strategy**: It is perhaps one of the most controversial service management concepts. It's can be described as the IT planning phase that structures the operating model or enterprise architecture. Service strategy is about "how to distinguish your organisation and make it unique from becoming an option". Strategy as well known is a plan of action designed to achieve a particular goal by applying strategic thinking to service management.
- **Service Design:** This has to do with the application of service strategy stage, followed by gathering service requirements from the business, understanding the capacities and resources required to deliver and support the service and then determining which IT resources will provide the integrated services. Service design helps in defining a blue print.
- **Service Transition:** Service transition defines expected service deliverables. It covers the assessment of the predicted performance of a service against the actual performance and management of any deviation and associated risks, before service acceptance.
- **Service Operation**: It cover the daily activities, processes in an organisation which is responsible for delivering value through technology to the business.
- **Continuous Service Improvement**: It ensures continuous business improvement through reports gathered, aligning services with changing business needs by the identified business process that needs to be improved. This enhance process improvement and services, bringing efficiency and effectiveness.

ITIL version 2 was announced in 1991 and the current version three (3) was announced in 2004 and was published in 2007, it emphasis more on IT business

integration[9]. The ITIL version three (3) consists of the Official Introduction book and five core books of the service lifecycle, which are the Service Strategy, Service Design, Service Transition, Service Operation, and Continual Service Improvement as shown in Figure 1.4.

Figure 1.4 ITIL Best Practice Version 3 Source: BMC [7]

ITIL does not tell any particular organization all the capabilities that it needs because it is not a standard, but its application in defining service processes in an organisation gives practical guidance on strategy and services alignment.

ITIL can be useful in all sectors to solve business needs, especially bridging the gap between an organisation's operations and business, also as well as improving its capability that provides business values.

ITIL is not a standard but set best practices, it gives organisations the liberty to adopt as much as is required to sole the organisation challenges.

1.3.1 Benefits of Adopting ITIL

Some of the organizational benefits of adopting ITIL best practices include[7]:

- Better alignment of IT and business
- Customers satisfaction through improved service delivery
- Greater use of organisational resource there by reducing cost
- Greater visibility of IT costs and assets
- Better failure, service disruption and business risk management
- More stable service environment to support constant business change

1.4. INTRODUCTION TO eTOM

The Business Process Framework generally referred to as (eTOM) is a reference framework for categorizing all the business activities used by an enterprise associated with the delivering of on-line Information, Communications and Entertainment services. This is achieved by a well-tailored areas of business procedures, in form of process elements that can be further decomposed into other levels for detailed visible progress. The process elements are well placed to clarify the relationships, functional and organisational model. And the processes can be combined used to trace the business flow and activity paths[8].

TM Forum, being a non-profit industry association for the telecommunication sector is globally accepted. “In late 80’s to be specific, 1988, eight companies came together to form the OSI/Network Management Forum this companies include Amdahl, AT&T, British Telecom, HP, Northern Telecom, Telecom Canada STC and Unisys. In year 2000 the name was changed from what is use to be known as “Tele Management Forum” to a present to what we know today as TM Forum where the lunching of the Next Generation Operating Support System (NGOSS) was done, with a drive to actualize the ‘plug and play’ interoperability. its releases include eTOM which is one of the business process to be used in this thesis, also included are the Information (SID) and Application (TAM) frameworks. [9].

As shown in the Figure 1.5 the eTOM business process framework represents the whole of a service provider's enterprise consisting of three major process areas, which are see[10]:

- **Strategy, infrastructure and product** this is the planning and lifecycle management.
- **Operations**, this covers the operational management.
- **Enterprise management,** this covers the corporate management or business support.

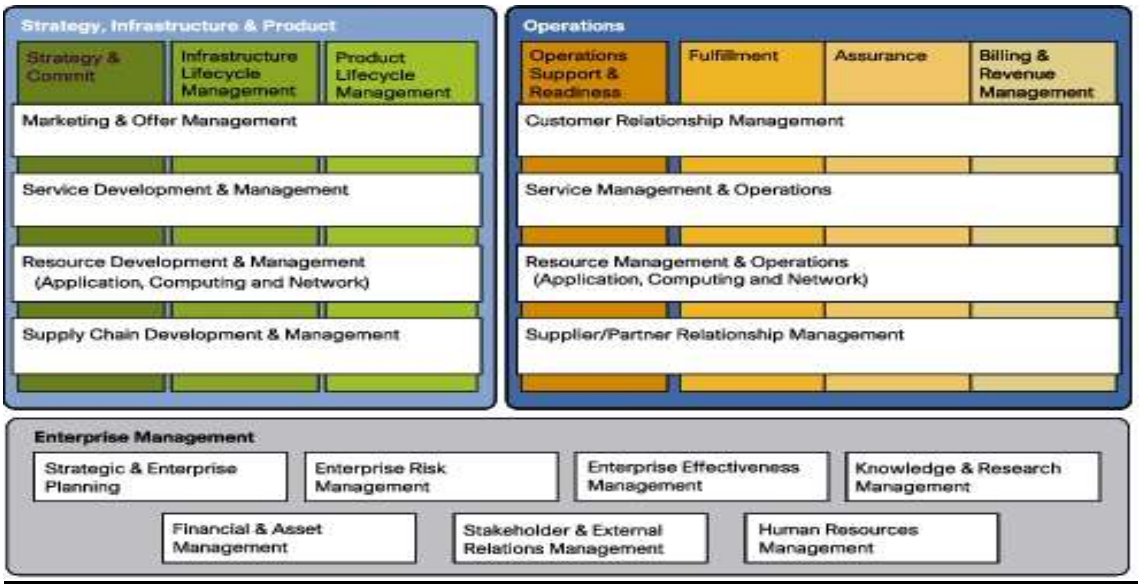

Figure 1.5 eTOM Level 1 Business Process Framework Source: Cisco ''Introduction to eTOM'' white paper[11]

The eTOM layers decomposition can generally be described as following see[11]:

- **Level0**: shows and explains the business Activities that differentiates operational customer-oriented processes from management and strategic processes.
- **Level1**: explains the process groupings and also business functions that highlights standard end-to-end processes.
- **Level2**: explains the core processes that can be joined together to deliver services and other end-to-end processes.
- **Level3**: explains tasks associated with success model and business process flows.
- **Level4**: details the operational process flows and associated steps including error conditions and product and geographical variants (where necessary).
- **Level5**: More decomposition into the operational process flow if only necessary.

Figure 1.6 gives a pictorial view of the process decomposition by example.

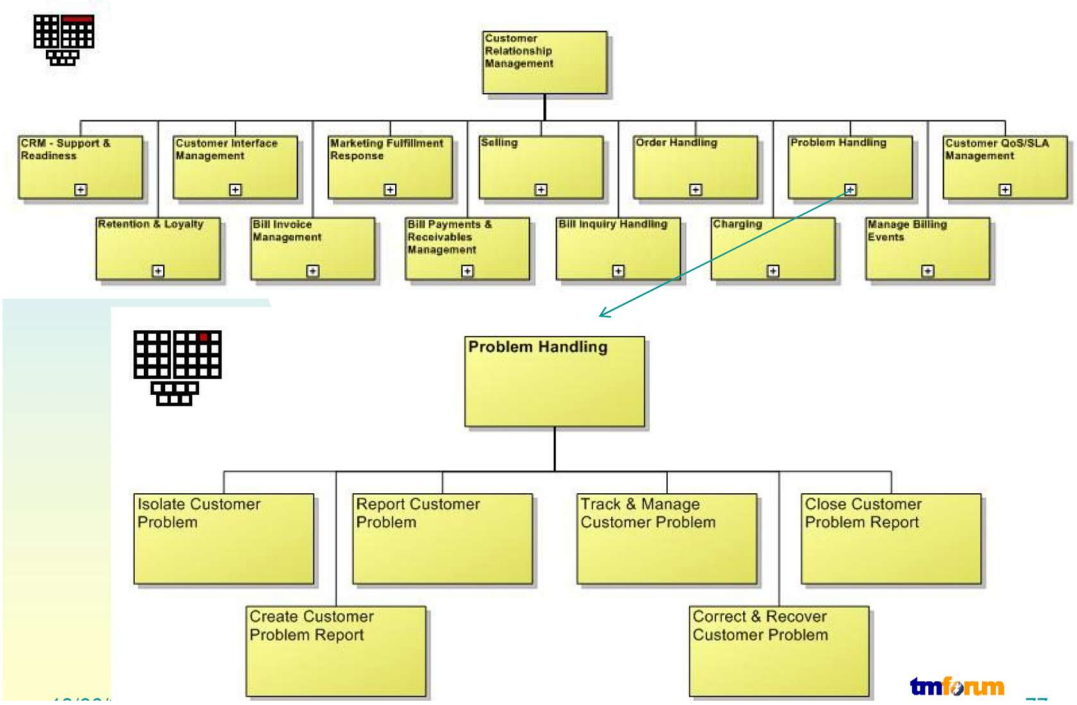

Figure 1.6 eTOM Process Decomposition Example Source: TMForum

1.4.1 Benefits of using eTOM

eTOM is mostly preferred in the telecommunication sector (service provider industry) because it provides some needed benefits, such as[11]:

- It creates a standard structure and terminology, for describing business processes.
- It aide understanding of business processes, helps in streamlining and managing portfolios of IT applications and also closes the gaps and duplication among processes.
- Its use in the industry will help in defining organisational expenditures and processes at a lower cost than custom-built applications.
- It ensures enterprise-wide discipline and business process alignment.
- It ensures end-to-end consistent high quality process flows, it also impacts on cost and performance by enabling re-usability of existing processes and systems.

CHAPTER 2. STATE OF THE ART IN NFV BUSINESS, DESIGN AND OPERATIONAL MANAGEMENT

This chapter is aimed at first highlighting the key players in NFV business models. Secondly on the relationship with cloud computing. Third part will be on Projects directly focusing on NFV service orchestration, including T-NOVA project.

2.1 NFV Business Models Key Players

NFV have five (5) key players [30]

1. **VNF Providers (VNFPs) and Server Providers (SPs)**: NFV divides the role of traditional network equipment vendors like Cisco, Huawei, and Alcatel-Lucent into two (VNFPs and SPs). VNFPs provide software implementations for NFs, while SPs provide industry standard servers on which VNFs can be deployed. VNFP and SP can also be one entity for development, but the major difference is that they are not tied together. VNF can be purchased from different entity and server from different entity.

2. **Infrastructure Providers (InPs)**: InPs handles the deployment and management of the physical resources in form of data centers and physical networks. The virtual resources will be provisioned and leased on this physical resources through programming interfaces to one or more TSPs. The InPs may also determine how the pool of the available resources are allocated to the TSPs.

3. **Telecommunication Service Providers (TSP)**: TSPs lease resources from one or more InPs, which they use for running VNFs. They handle the chaining of these functions to create services for end users. TSP may also be an InP, where it is one entity subleasing their virtual resources to other TSPs.

4. **VNF Providers (VNFPs) and Server Providers (SPs)**: NFV divides the role of traditional network equipment vendors like Cisco, Huawei, and Alcatel-Lucent into two (VNFPs and SPs). VNFPs provide software implementations for NFs, while SPs provide industry standard servers on which VNFs can be deployed. VNFP and SP can also be one entity for development, but the major difference is that they are not tied together. VNF can be purchased from different entity and server from different entity.

5. **Brokers**: They offer resources and or functions to TSP. Their role is to discover, negotiate and aggregate resources and functions from multiple InPs, VNFPs and SPs.

6. **End Users**: They are the final consumers of the services provided by TSPs. They can choose from a wide range of services provided by TSPs. Also they can also connect to different TSPs for different services.

2.2 NFV Relationship with Cloud Computing

The idea of virtualisation and need for innovation, agility and resource sharing is not a new concept. It is already existing in the cloud computing and SDN. These technologies are being developed rapidly and are expected to become more robust, advanced and affordable in the future. In chapter one, similarities of NFV and SDN have been talked about but in this chapter, highlighted comparison and differences with cloud computing will be discussed.

Cloud computing is a model for enabling the practical use of network remote servers hosted on the internet which guarantees ubiquitous, convenient, on-demand network access of a shared pool of resources [30]. its characteristics are:

- **Measured services** (cloud systems automatically control and optimize resource use)
- **Broad network access** (Availability of capacities over the network and it can be accessed through standard mechanism)
- **On demand self-service** (no human interaction)
- **Rapid Elasticity** (Capacities can be elastically provisioned and released)
- **Resource pooling** (able to serve several consumers using a multi-tenant model.

Cloud Computing Service Model

The three cloud computing models are[31]:

1. **Platform as a service PaaS)**: Which could also be called application as a service enables user to deploy onto the cloud infrastructure applications created without the stress of building and maintaining the infrastructure.

2. **Infrastructure as a Service (IaaS)**: The user is granted a defined access to virtualised components were leased, in order to be able to carry out their processing, storage, build networks on this defined space, and access other important computing resources.

3. **Software as a service (SaaS**): Its user is able to use the provider's applications running on a cloud infrastructure.

Cloud computing similarity with NFV

As discussed earlier, the concept of virtualisation is not totally new, as cloud computing has some similarities with NFV. Some of which are;[30]

1. IaaS corresponds to both the physical and virtual resources in the NFVI,
2. The services and VNFs in NFV are similar to the SaaS service model in cloud computing.

Comparison of NFV in telecommunication networks and cloud computing

The table 2.1 below highlights the comparison of NFV in telecommunication networks and cloud computing.

Issue	NFV (Telecom Networks)	Cloud Computing
Approach	Service/Function Abstraction	Computing Abstraction
Formalization	ETSI NFV Industry Standard Group	DMTF Cloud Management Working Group
Latency	Expectations for low latency	Some latency is acceptable
Infrastructure	Heterogeneous transport (Optical, Ethernet, Wireless)	Homogeneous transport (Ethernet)
Protocol	Multiple Control Protocols (e.g NETCONF, SNMP)	OpenFlow
Reliability	Strict 5 NINES availability requirements	Less strict reliability requirements
Regulation	Strict Requirements e.g NEBS	Still diverse and changing

Table 2.1 COMPARISON OF NFV IN TELECOMMUNICATION NETWORKS AND CLOUD COMPUTING Source: [31]

2.3 Projects Directly Focusing on NFV

Following the standards bodies in NFV under the standardization activities discussed in the Annex part of this documents, the projects to be discussed in this section are guided by standardization described, in particular ETSI, 3rd generation partnership project (3GPP) and distributed management task force (DMTF). Below is a brief discussion of some of the Collaborative NFV Projects, some of which are research based and open source projects.

1. **ZOOM PROJECT**

Zero-touch orchestration, operations and management (ZOOM) is a TM Forum focused at operations environment necessary to enable the delivery and management of VNFs, and identifying new security approaches that will protect

NFVI and VNFs[30].

This project targets establishing best practices to tackle the technology and business transformation brought about by the introduction of SDN and NFV.

The project targets on actualizing end-to-end automated management, security orchestration, function and service modelling, by adopting the concept of big data and open software for its workload placement.

The project is divided into several collaborative project areas, which are;[32]

- **Hybrid Infrastructure Management Platform**
- **Network Resource lifecycle management**
- **The Operations Center of the Future**,
- **Catalysts Proof-of-Concept**

2. Open Platform for NFV (OPNFV)

OPNFV is one of the open source project seeking the advance of the evolution of NFV, founded and hosted by the Linux Foundation, but collaborated and composed of TSPs and vendors. Its target is to ensure compatibility and consistency while encouraging a standard performance among other open source components.[30]. It targets at ensuring the delivery of a de facto NFV platform by other standard bodies, commercial suppliers and open source communities.

“OPNFV builds NFVI and VIM by integrating components from upstream projects such as OpenDaylight, Open Network Operating System(ONOS), OpenStack, Ceph, Kernel-based Virtual Machine(KVM), Open vSwitch, and Linux”[33].

GOALS FOR OPNFV

The goals for OPNFV are;

- To ensure consistency, compatibility with other open source by supporting and participating in other open source projects that will be leveraged in the OPNFV platform.
- To establish an integrated and tested open source platform for building NFV functionality and instigating the drive to introduce new products and services.
- To include the engagement of leading end-users to always endorse and provide feedbacks and ensure OPNFV meets the needs of user community.

3. OpenMANO

OpenMANO led by Telefonica, and also one of the open source project that [34]. It targets its focus on addressing aspects related to performance and portability by applying Enhanced Platform Awareness (EPA) principles[30].

The three software modues provided by OpenMANO incudes[34]:

- **OpenMANO-GUI** This is the web Graphical User Interface **(**GUI) to interact with OpenMANO API in a graphical and user-friendly manner.

- **OpenMANO** Through its application it establishes an interaction with NFV VIM and also interfacing with the VNF manager, where NFV services are offered, including the creation and deletion of Network Services or VNFs.

- **OpenVIM** Through it OpenVIM application, it interfaces with the compute nodes in NFVI to provide computing and networking capabilities for virtual machines deployment, deletion and management.

Mobile Cloud Networking (MCN)

MCN is a joint effort of network operators, cloud providers, vendors, university and research institutes[35]. Its objective is to maximize the vast commercial potentials and opportunity of cloud computing. The idea is to cloudify all components of a mobile network operation, the Radio Access Network (RAN), evolved packet core(EPC), IP Multimedia Subsystem (IMS), Content Delivery Networks (CDN) and Digital Signage (DSS), the Operational Support Systems (OSS) and the Business Support Systems (BSS)[30].

The aim of MCN is to;[35]

- Designing a Mobile Network Architecture that focuses on exploiting and supporting cloud computing.
- To extend the concept of cloud computing for end-user's benefit as well
- Enabling a novel business actor, the mobile cloud provider
- One Service (atomic): Including mobile network, computing and storage
- On-Demand, elastic, and Pay-As-You-Go capabilities
- Enabling the delivery and exploit the Concept of an End-to-End mobile cloud for novel applications.

OpenStack

Being managed by OpenStack foundation, OpenStack, is among the open source

project focused NFV and cloud computing. I's keyed on deploying infrastructure-as-a-service thereby making virtual servers and resources available to end users. [36].

Why OpenStack

- Open standards (through ETSI and OPNFV, including reference architecture)
- Network Agility (Enabling greater flexibility, scalability and resiliency)
- Cost saving (reduced cost both on installation and management)
- Vendor support (industry-leading solutions are based on OpenStack)

T-NOVA

T-NOVA, an integrated project by the European commission 7th framework programme, is promoting NFV concept, by proposing an enabling framework, where customers can benefit from the deployed operator's VNF as value added services. T-NOVA adopts the SDN and cloud management architectures to design and implement a management and orchestration platform for provisioning and managing services to end users, also monitoring and optimization of Network Functions-as-a-Service (NFaaS) over virtualized network and IT infrastructures.

T-NOVA establishes a "NFV Marketplace", (playing the role of a broker) "*in which network services and Functions by several developers can be published and traded".* The market place establishes a medium whereby customers can come and browse, and negotiate a selected services and virtual appliance as well as SLA and be charged under various billing. T-NOVA market place establishes a platform for interaction between all stakeholders and not only to the final customer.[29]

Another category of the NFV project is an initial generation of commercial solutions put forth by telecommunications vendors in order to recognising new market opportunities as telecom infrastructure becomes virtualised and software based. With the aim of expanding their platform, software and integration services to adapt to the disruptive change in the industry. more details on the annex part of this project under "NFV implementations and products from industry".

3.0. APPLYING ITIL AND eTOM BEST PRACTICES TO NFV DESIGN AND MANAGEMENT PROCESS

When it comes to service management, it does not matter whether it is a critical performance indicator (KPI), operations and technology change, development of service level agreement (SLA), service, management set-up, or service unit restructuring, the procedure must be aligned to the business process to achieve the desired goal. Notably, it is crucial that there is the usage of the methodology and the reference model.

This chapter goal is to give an analysis of the design and NFV management process as well as why all the standard bodies should collaborate with ETSI to promote the NFV concept as defined in the business process. In particular, the chapter will concentrate on the management of OSS, BSS, and NFV. Also, the section will focus on the NFV management and orchestration (NFV-MANO) utilizing the best and most accepted practices in the telecommunications and IT industry as previously stated.

ITIL (IT Infrastructure Library), a combination of “best practices” currently referred to “good practices” in control of IT service-which are currently indispensable in the IT service area.

eTOM (enhanced Telecommunications Operations Map) originates from the TeleManagement Forum (TMF) and is rapidly becoming the de facto standard used in design and planning of business processes within the telecommunications industry.

[1]” Culture refers to the peoples' behavior such as thinking and acting. The change to a “software-centric” mentality will imitate the Web services and media companies culture while needing to maintain customer trust, standard network performance, and quality, which are the service provider brand basics. Therefore, there is need to create a unique culture for the service provider.

First, it is essential that the culture is evaluated to the degree that aligns with the external environment attributes. The evaluation should be facilitated by the local market within which the service provider operates, together with the internal environment characteristics which enable the organization to have the desired behaviors. Notably, the external environment comprises of the team outside interactions with customers, and consequently, the brand establishment, since the internal culture impacts accomplishments and results [1].

Apparently, the NFV and SDN transitions necessitate that customer interactions and service delivery are changed which, in turn, improves business processes. Most importantly, the developments brought about by NFV and SDN enables shifting from connectivity mentality to solutions provider which is a concentration of consumer experience. Notably, attention on customer needs and delivering of customized services efficiently as well as accountability of the highest level is the

brand core attributes.

Strategically, the NFV will reconstruct the CSP operations support system (OSS) and business support system (BSS). Notably, the CSP must redefine its operations by changing the business process when transitioning to NFV. When NFV is adopted, then there must be the transformation of the OSS as well as an approach that is related to the OSS component of the NFV deployment. As a result, when transiting to NFV the service providers must be aware of the target management that is achieved by the current approaches such as eTOM and ITIL but extended to address NFV adoption for smooth transitions [12].

NFV comes with a new virtualization layer, which, in turn, complicates the existing OSS in the present CSP, thus requiring further orchestration. The process allows the management of the new virtual network functions (VNFs) and network services (NSs) life cycles. Notably, the complexity and challenge NFV brings requires new orchestration function called NFV management and orchestration (NFV-MANO) as defined by ETSI and NFV industrial specification group (ISG). Figure 3.1 gives a pictorial description of NFV-MANO.

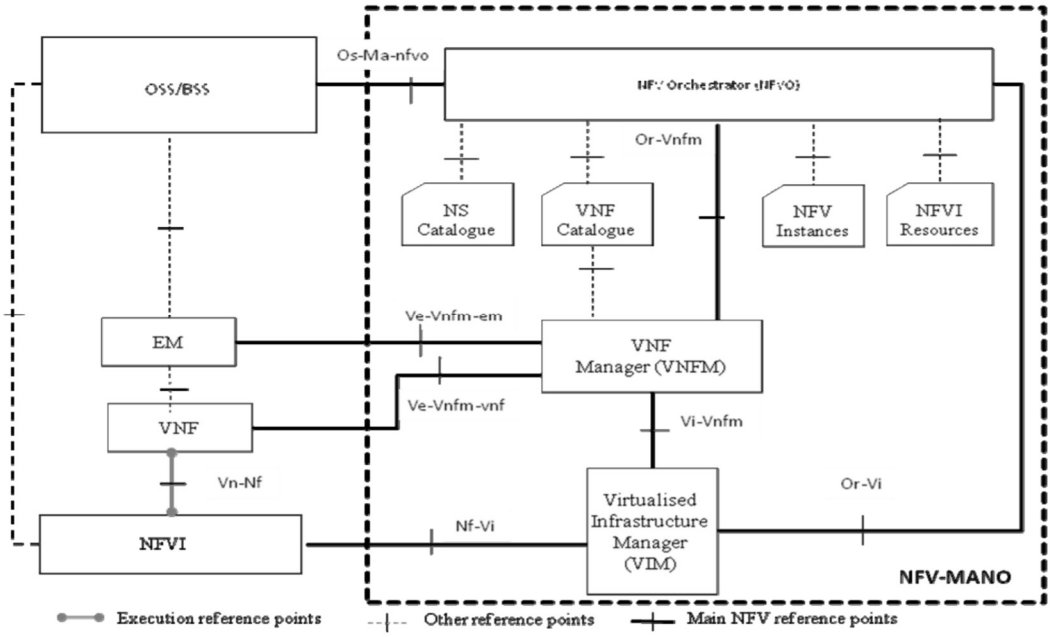

Figure 3.1 NFV-MANO Architectural Framework with Reference Point Source: ETSI GS NFV-MAN 001 V1.1.1 [13]

Further, the functions of NFV-MANO can be grouped into three categories which is discussed in detail in chapter 1.

- Networks services
- Virtualized resources
- Virtualized network functions

Below is Figure 3.2 which shows the description of the three different

categories of NFV management and Orchestration services.

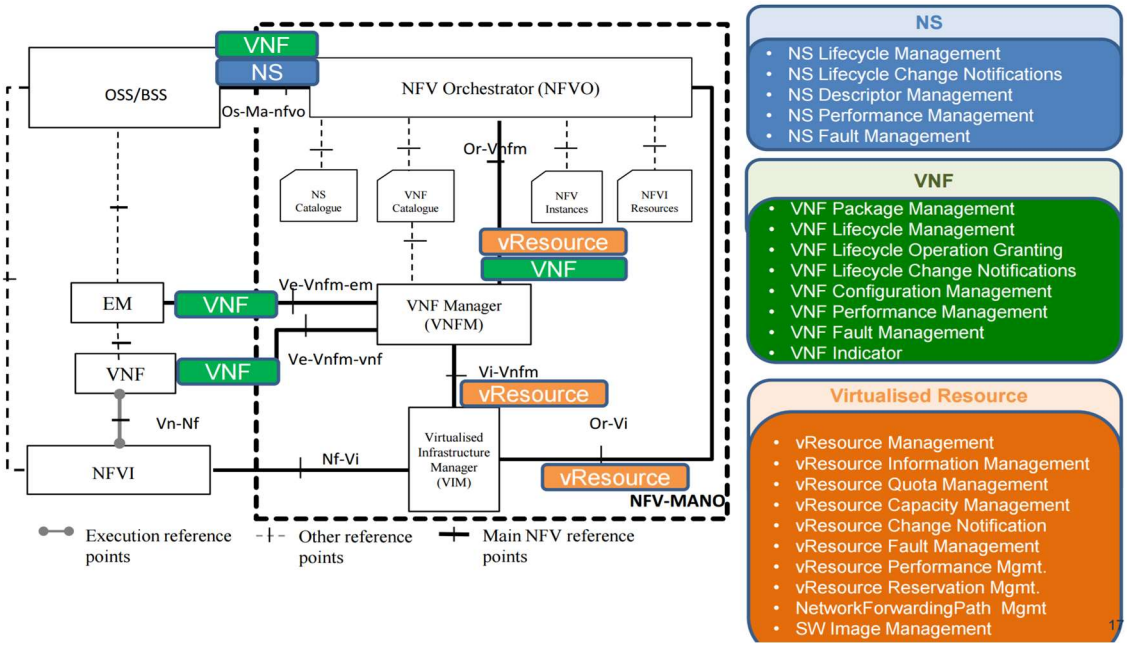

Figure 3.2 NFV MANO Functions Source: ETSI NFV INTERFACES AND ARCHITECTURE [14]

"*In the context of the NFV ISG, a network service is constructed by chaining VNFs and/or Physical Network Functions (PNFs*)"[15].

The virtualized resources' management and orchestration give good coverage and requirements for VNFs and network services (NSs) with the necessary factors so that it can operate appropriately. Notably, the virtualized resources comprise of those in the virtualization containers which are cataloged and given for consumption and consist of those within NFVI as identified such as storage, network, and compute resources.

Following the (FCAPS) which is acronym of fault, configuration, accounting, performance and security management, the NFV's introduction of Management and Orchestration to its framework adds new set of management functions to that of the present network. This added feature is responsible for the lifecycle management of a VNF. The NFV ISG has concentrated on defining the new sets of management functions, which include: onboard a VNF, instantiate a VNF, scale a VNF, update a VNF, and terminate a VNF. [13]

3.1. WHY ADOPT A BUSINESS PROCESS FRAMEWORK?

It is essential that the business adopts a new business framework that is needed for reconstructing the new or existing business processes. also for the NFV standardization body and supporting standard, alongside with other projects promoting the concept because of the following[16];

- It enables the creation of a general language that can be used across systems, departments, external partners, suppliers and other stakeholders, thus reducing the risks and costs of system integration, implementation, and implementation.
- Leads to the formation of a standard culture, classification and terminology schemes for the business processes thus, simplifying internal operations as well as maximizing any chances to partner with other companies within and outside the organization.
- It facilitates the application of consistent and disciplined enterprise process development in the whole organization to enable cross-organizational re-use.
- It eases the modification of IT applications design, and development through understanding of the business requirement so that they can facilitate achievement of business needs.
- Also, it allows the creation of high-quality and consistent end-to-end process models, which, in turn, reduces the duplications and gaps in the previous flowcharts.
- It establishes chances for improvement of cost and performance by redesigning the present systems and processes.

3.2. APPLYING eTOM TO NFV ADOPTION AND OPERATIONAL MANAGEMENT

Following the different standard bodies working toward the actualization of NFV, either working with ETSI or towards promoting the NFV concept as a research project or open source as detailed in the chapter two of this work, it has to be properly aligned to a business process in order to achieve a desired goal. The usage of a methodology or reference model also called framework is absolutely essential.

eTOM, the enhanced telecommunication map is a framework that shows the steps such as creation, selling, terminating, and sustaining that are associated with a particular service. The structure is highly detailed; nevertheless, it is divided into layers that give a comprehensive picture of the operation from top to the bottom in an organization.

Mostly, eTOM tasks are integrated with the human and automated activities as well as the management tools and other operations. As a result, as part of the modification of services offered, the NFV must take and change its business culture and process to be similar to those of eTOM. Noting a key point that most current telecommunication sector also uses this framework.

Evidently, the NFV in the strict context of the ETSI ISG is a combination of specifications that describes how the actual network activities hosted could instead be used as cooperative software elements on the particular agile set.

When the NFV is invented in the already existing networks it results to intermediary components which, in turn, allow management of resource relationships in the VNFs.

NFV activities must concentrate on the eTOM framework so that they can relate to operations and development activities. TM Forum groups the critical business activities of its Business Process Framework (BPFs) as already described in details in the work opening part:

Strategy, Infrastructure, and Product- handles plans, designing, and management of product lifecycle

Operations- handles the significant operational control

Enterprise management- handles business or corporate support management

The following Figure 3.3 shows a graphic description of eTOM frameworks level 1, which is further expanded in more details in other stages. The level 1 model consists of seven end-to-end vertical process subsets necessary to assist clients and enterprise management. Among the upright subgroups, the concentration of eTOM is fundamentally on the critical consumer operational process of fulfillment, assurance, and billing (FAB) [11]. Operations Support and Readiness (OSR) is the "back-office" set-up that allows FAB automation which could be used in operating and designing of the NFV to have a complete, detailed, and well-flowing processes as well as a transparent operation networks that enable monitor center.

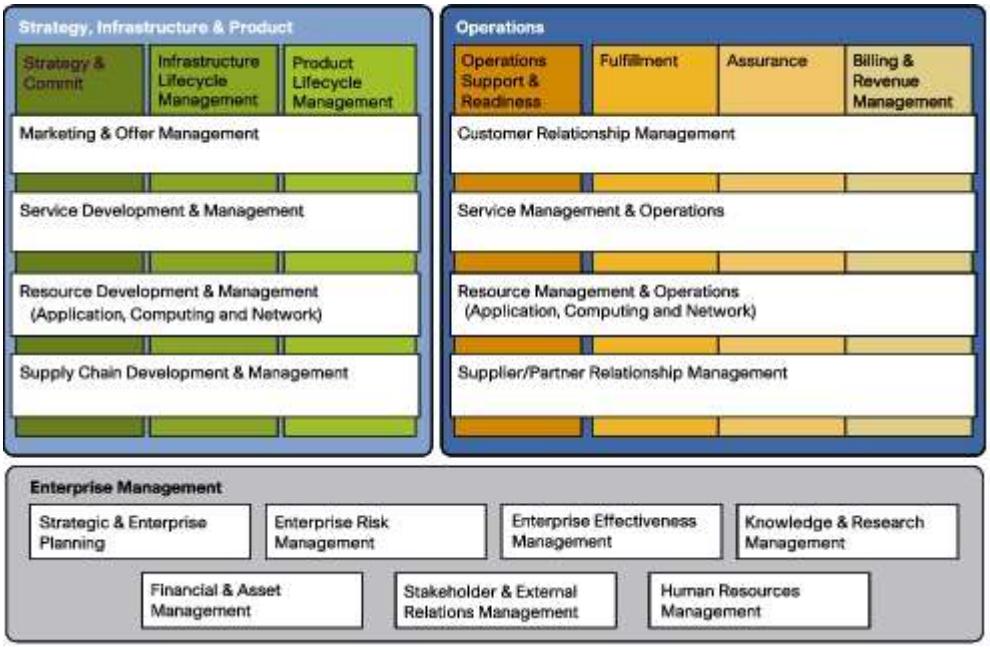

Figure 3.3 eTOM Framework level 1-Source: Cisco ''Introduction to eTOM'' White Paper [11]

Each process in the eTOM framework is consequently subdivided through decomposition to smaller eTOM levels as indicated in figure 3.4, 3.5, and 3.6.

The subgroups are achieved through analysis of the processes and partitioning the functionality of each level into the specific desired business goal. The subdivision goes as further as possible depending on individual needs.

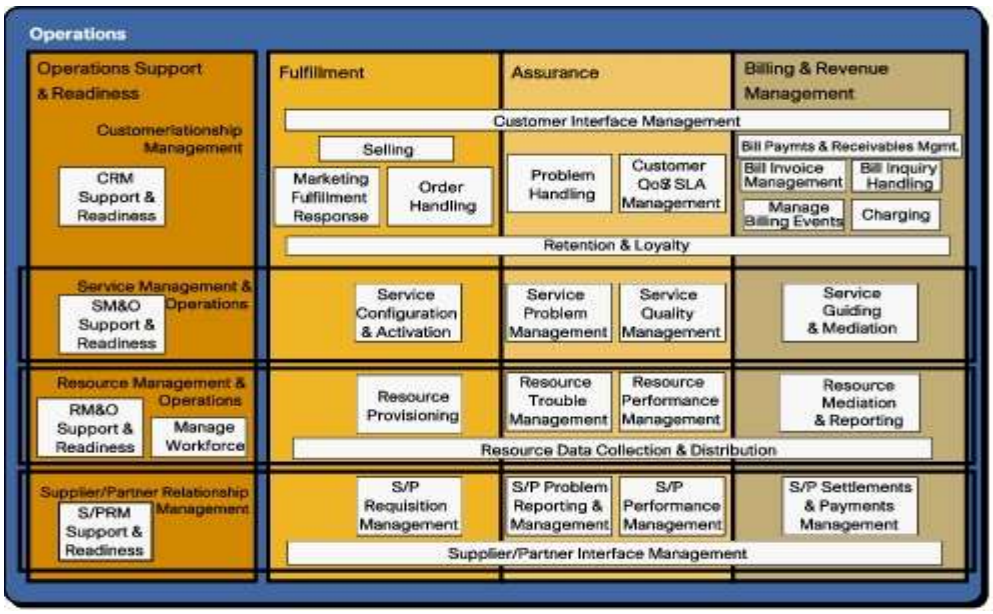

Figure 3.4 Operations Level 2 Processes of eTOM Framework Source: Power Consulting TM Member[17]

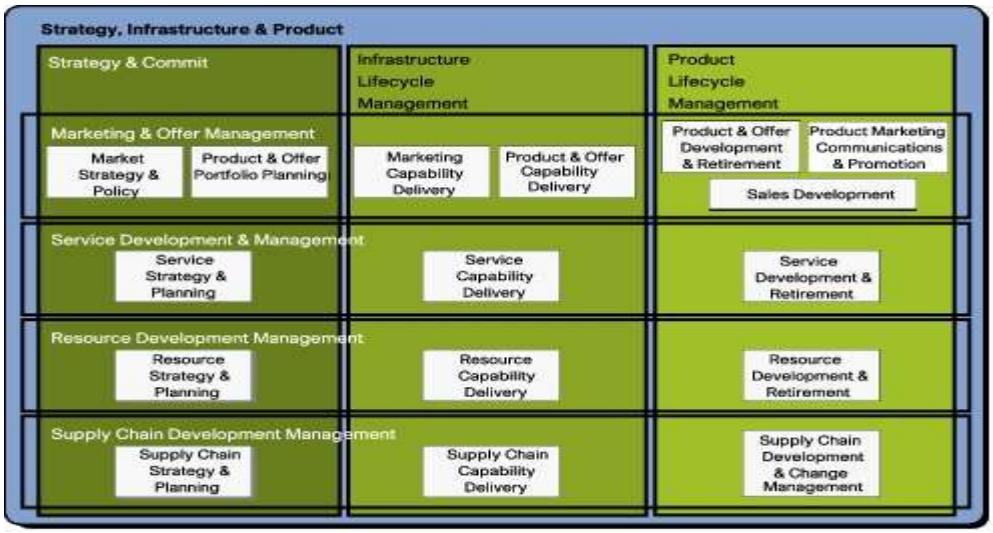

Figure 3.5 SIP Level 2 Processes Source: Power Consulting TM Member[17]

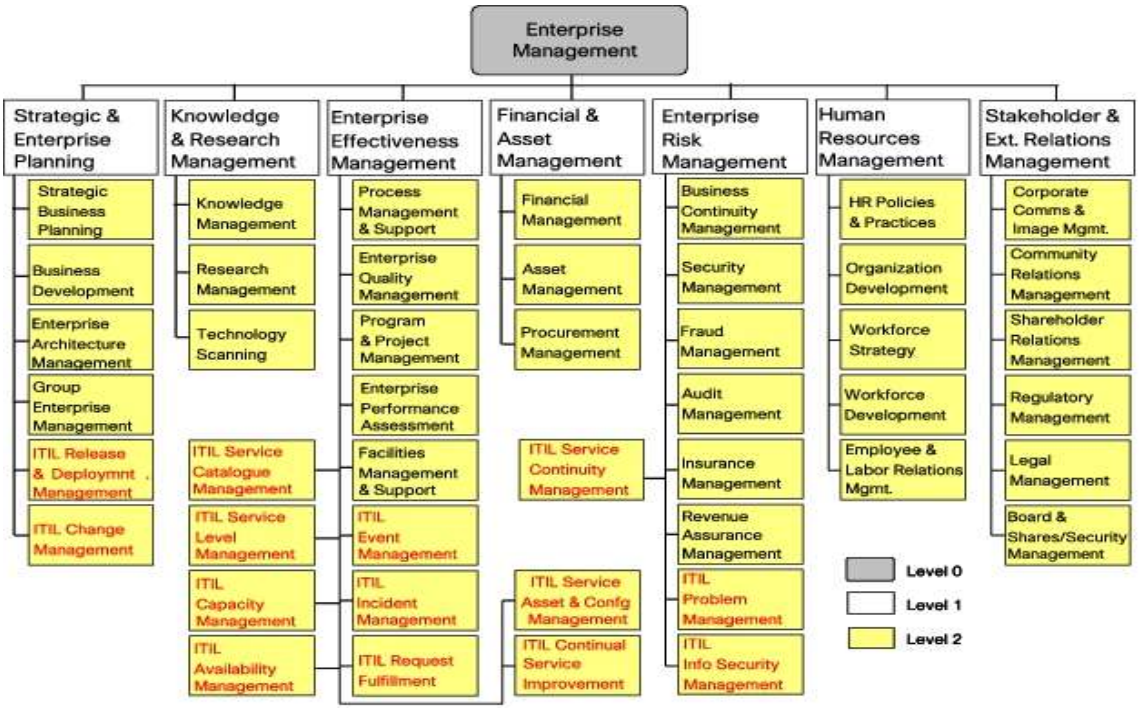

Figure 3.6 Enterprise Management Level 2 Processes of eTOM Framework
Source: Power Consulting TM Member[17]

3.2.1 eTOM PROCESS INTERACTION AND FLOW

eTOM concentrates on defining the business processes utilized by service providers, the connections between the business process, interfaces identification, as well as utilization of the customer, partner, resource, service, and any other data by multiple processes .

eTOM can also be used in the analysis of the present enterprise processes to realize the gaps as well as eliminate any imitation and prioritize processes. Notably, the framework can be utilized in forming the new organizational processes by expanding the existing operations or using part of the available ones to complete the regulatory methods that are necessary .

Further, the eTOM framework can be expanded by decomposing the Level 3/4 processes together with the summation of other specific details at the organizational lower level processes. Notably, there are two main processes which are mostly used in regulatory processes analysis in which are process flows and process interactions as demonstrated in Figures 3.7 and 3.8.

A. Process Interaction

Figure 3.7 demonstrates the process relationships of a new client order using the level 2 eTOM operations process. Notably, the consumer places their order in the Customer Interface Management which leads to Order Handling that initiates the

Initiate Service Configuration and Activation. Consequently, the process leads to Resource Provisioning which later leads to Supplier/Partner requisition Management which then ends to Bill Invoice Management. Nevertheless, this diagram does not demonstrate the interactions timeline. Notably, the NFV-MANO diagram above can identify all these steps as it relates to the virtual resource (VR) and VNF manager functions [11].

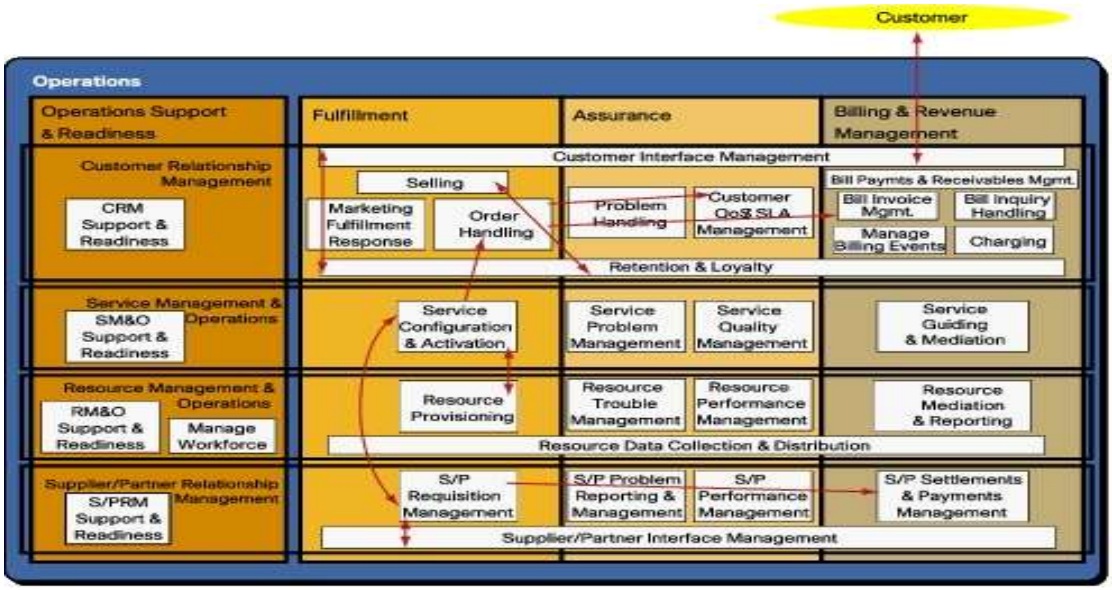

Figure 3.7 Process Interaction Example- Source: Cisco Technology White Paper 'Introduction to eTOM' 2009[11]

B. Process Flow

Figure 3.8 describes process flow representation of the process interactions sequence. The following diagram shows the same new order actions as represented in the process interaction. The process flows define the relationships between processes at various levels. The level 1 methods are those at the four blue boxes while the level 2 ones are in the yellow boxes. The broad green arrow that is shown by the arrow is an external trigger to the flow process while the large red arrows represent external trigger in the diagram [11].

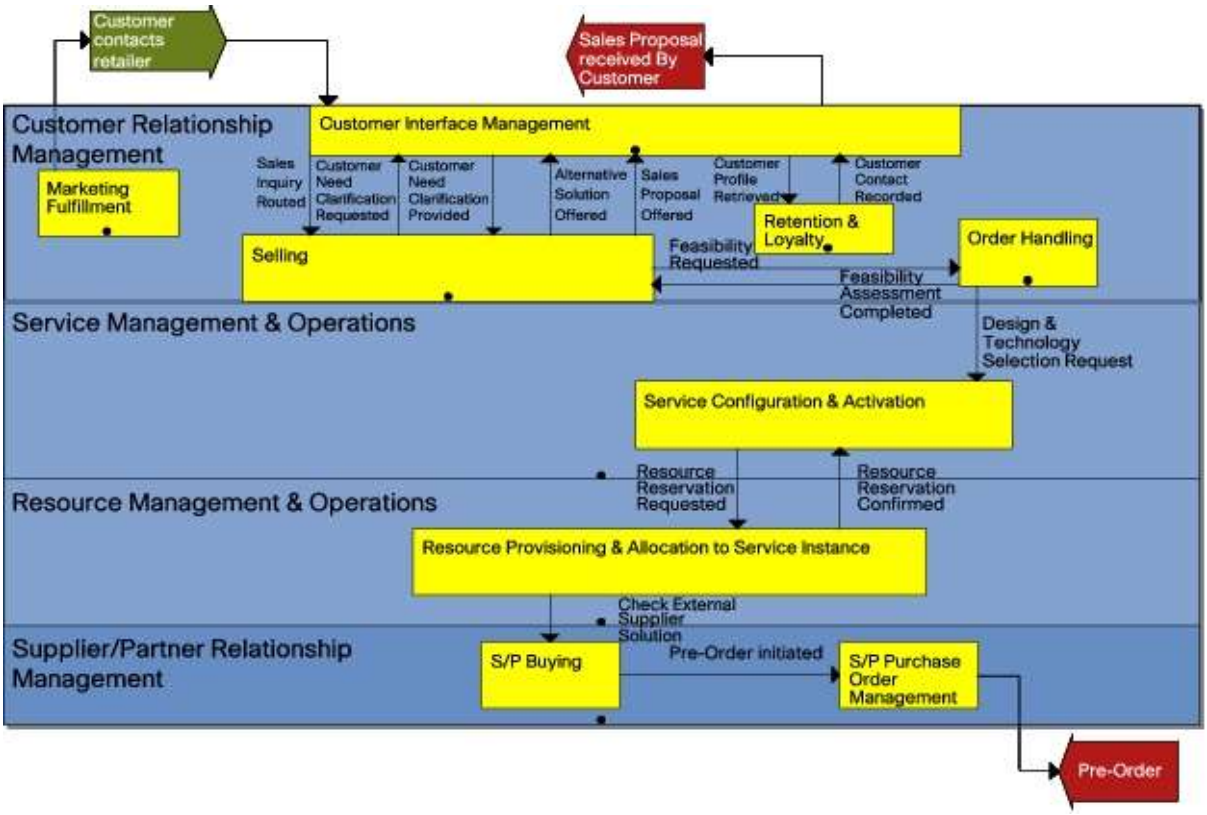

Figure 3.8 eTOM Process Flow-Source: Cisco Technology White Paper 'Introduction to eTOM' 2009 [11]

Apparently, it is allowable, and indeed expected, that eTOM can be extended to address NFV business processes. In other to be more focused as in related to the area of interest of this thesis, the main goal is to use eTOM operations business process to analyze NFV operational management.

3.2.2 ANALYSIS OF NFV USING eTOM's OPERATIONS BUSINESS PROCESS

To gain maximum output from NFV agility and automation, the current NFV Management and Orchestration and OSS organizations should align with Information Models and Business Processes (Fulfilment, Assurance, Billing, Security, Operations support, and readiness) interfaces. The alignment must be in the most efficient way using Resource Management & Operations and through Service Operations and Management [18].

The operations major areas are the Fulfilment, Assurance, and Billing (FAB) model. Additionally, in the original TOM FAB model, the Operations Support and Readiness (OSR) are added through the eTOM operations. Notably, FAB operations are directly linked to consumer services while OSR facilitates the monitoring of the operational environment to ensure the success of FAB. On the

other hand, eTOM adds service functions and processes such as service quality control, service definition as well as customer functionality management [19]. eTOM can greatly be utilized when it comes to NFV operation processes definition.

eTOM models are made up of vertical functions such as operational support readiness (OSR), FAB, as well as functional process groupings that are found in the horizontal layers. The features are [19]:

- Customer Relationship Management (CRM)
- Service Management and Operations (SM&O)
- Resource Management and Operations (RM&O)
- Supplier/ Partner Relationship Management (S/PRM)

On the other hand, the eTOM operations comprise of the customer support process, network management and operations. Additionally, it also includes a supplier/partner relationships and sales management [19]. **N/B The primary knowledge for this part of my work was read from business process frameworks (eTOM) GB921 "PROCESS DECOMPOSITION AND DESCRIPTION."**

3.2.2.1 eTOM Model Vertical Processes

eTOM is made up of four vertical functions that show the major areas of operations. It describes the end-to-end view such as those that involve customers overall satisfaction with the services. Notably, the Operations Support & Readiness, and billing, assurance, and fulfillment are the vertical processes of Operations in the process area. Also, the Operations Management/ Provisioning are the heart of the eTOM operations.

A. Operational Service Readiness

OSR process gives the management, administrative, and logistic support to FAB business process alongside with enabling the FAB areas operational readiness. In fact, OSR comprises the CRM, SM&O, RM&O, Manage workforce, and S/PRM support &readiness. Apparently, the OSR is similar to the present CSP which is referred to network monitoring center (NMC) which gives customers the operations support that they need.

B. Fulfilment

Fulfilment ensures that the customers' requests are delivered in the correct manner and timely. In short, this aspect provides that the personal and consumer needs are turned into solutions. Fulfilment gives the responsibility to deliver the consumers goods and services. Some of the actions carried out during this period are resource provisioning, order handling, service activation, and configuration. Further, this stage initiates the Key

Performance Indicator (KPI) measurement as well as SLA monitoring. Finally, it gives the necessary data structures that allow analysis and correlation [12].

Notably, the NFV introduction comes with a significant impact on operations and also on the static service order fulfillment process which is mostly associated with complicated procedures and time demand. Further, the NFV implementation is a way of reducing the management and operations complexity drastically through the transformation of OSS/BSS process towards automation and agility. Most importantly, the primary goal is to ease deployment of any services as well as increase the customer experience.

Figure 3.9 represents the typical process of order fulfillment activities that correspond to sub-processes. After an order is entered, it goes ahead to be verified and submitted, later after internal fulfillment procedure of the work starts, then verification and inventory are done to ascertain that activation of the customer order.

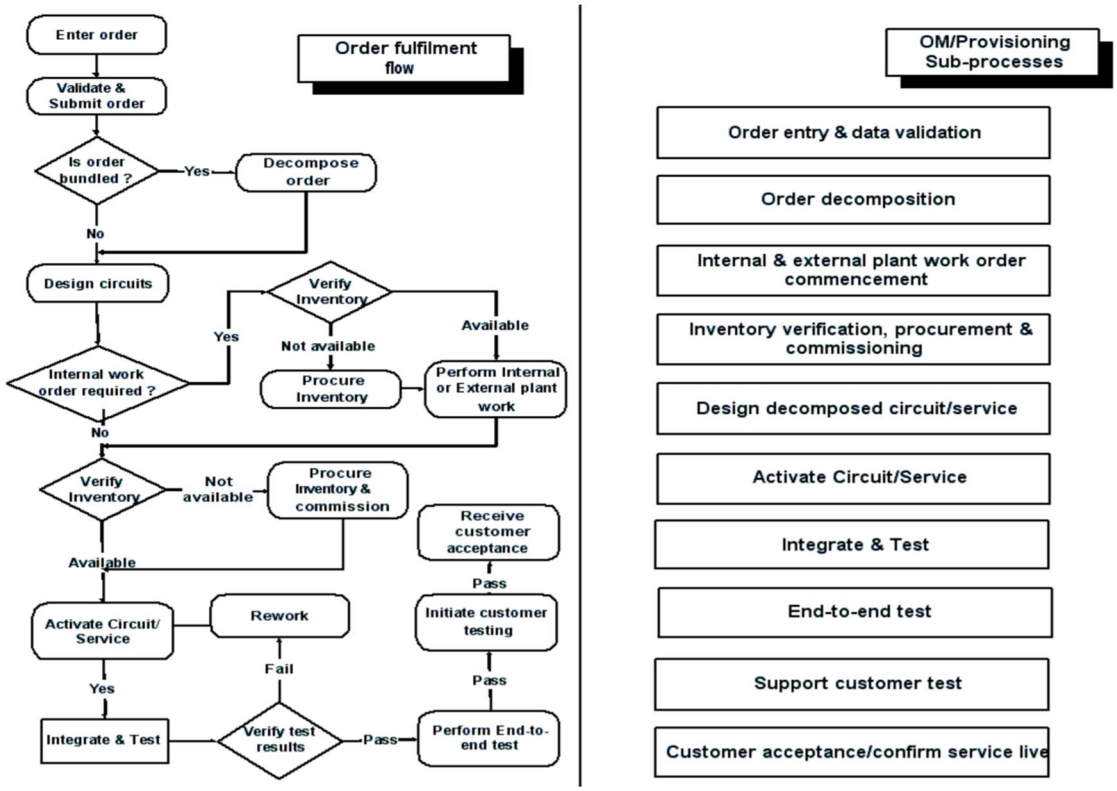

Figure 3.9 Order Fulfilment Flow And Sub-Processes-Source: Order Fulfilment Core Processes & Pain Areas, WIPRO Technologies, White Paper [20]

The table 3.1 shows how the sub-processes can be illustrated in the eTOM processes;

eTOM / Sub Processes	Order Handling	Service Configuration & Activation	Resource Management & operations	Resource provisioning & Allocation	Supplier Purchase order Management	Supplier Interface management
Order entry & data validation	v				v	v
Order decomposition	v					
Internal & external plant work order commencement			v	v	v	v
Inventory verification, procurement & commissioning			v	v	v	v
Design decomposed circuit/service		v				
Activate Circuit/Service		v				

***Ta**ble 3.1 Mapping Typical Order Fulfillment Sub-Processes With eTOM- Source: Order Fulfillment Core Processes & Pain Areas, WIPRO Technologies, White Paper [20]*

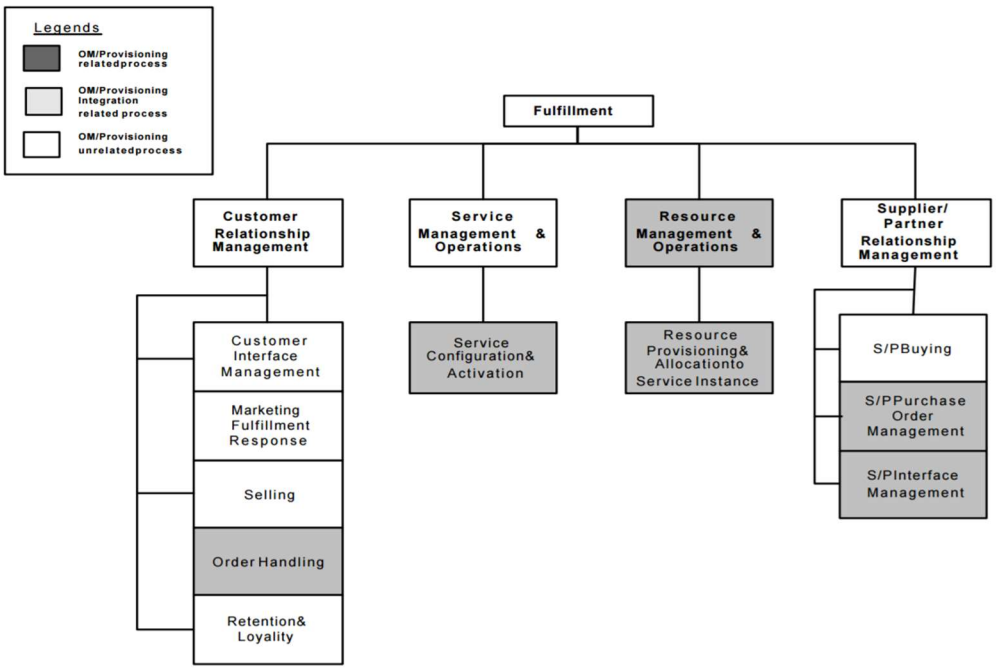

Figure 3.10 eTOM Fulfillment Level 2 Processes- Source: Order Fulfillment Core Processes & Pain Areas, WIPRO Technologies, White Paper [20]

C. Assurance

Assurance deals with the active and proactive maintenance activities such as

QoS/SLA monitoring, troubleshooting, performance, and resource status monitoring. It also includes activities such as consistency in resource status, performance monitoring, and detection of possible failures, performance data collection, problems identification, and solution resolution. As a result, assurance gives the support for service, triggers fulfillment capabilities that lead to change and management of the lifecycle to support an agile planning. The following are the two approaches of service assurance:

1. **Assurance Reactive maintenance activities (PROBLEM HANDLING)**

Steps to reactive guarantee:

- Isolate Customer Problem
- Report Customer Problem
- Track and Manage Customer Problem
- Close Customer Problem Report
- Create Customer Problem Report
- Correct and Recover Customer Problem

2. **Assurance Proactive maintenance activities (CUSTOMER QoS/SLA MANAGEMENT)**

Steps to proactive maintenance:

- Assess Customer QoS/SLA Performance
- Manage QoS/SLA Violation
- Report Customer QoS Performance
- Create Customer QoS Perf Degradation Report
- Track and Manage Customer QoS Performance Resolution
- Close Customer QoS Perf Degradation Report

D. Billing

"Billing collects usage data records, and applying various rating functions, then bill operations and store the customer invoice for the period of time to address regulation and internal requirement. Billing includes generation of timely and accurate bills, providing pre-bill use information, reflective of the final charges for services and billing to customers, processing their payments, and performing payment collections.

The SDN and NFV adoption in the future telecommunication operations have contributed to the need of billing to ensure result flow-through provisioning and automation in the real time.

3.2.2.2 NFV impact to Fulfilment and Assurance

The effects of NFV on fulfillment and assurance methods of the OSS are[12];

A. Service Fulfillment

It is useful in delivering services with the velocity and exactness that is key for NFV. Cloud-based methodologies permit such mechanization by linking producing a well-organized surrounding to ensure the following benefits are realized;

- Zero-touch commissioning: This refers to the capability of anyone installing any tool straight away from the box. Zero-touch does away with the need for local configuration or human intermediation.
- Flow-through provisioning: This mechanism is responsible for realization and provision of needs to the relevant network components. The requirements may arise when there is the sudden demand for a service. Fulfillment solutions must immediately support automatic delivery of cross-technology elements.
- Network optimization: it is essential for services to adjust from time to time due to the changing levels of demand for services that are required by consumers that originate from service demand changes. Therefore, maintaining a positive quality of experience while using the changed capacity demand from the network is necessary. This process results in the efficient use of resources and captivates customers hence ensuring a positive quality of experience. The service assurance deals with the analysis of the demand and quality of experience analysis and study. In the OSS domain, the closed loop response between the assurance and fulfillment is another essential change.

B. Service assurance

Service assurance should be defined before a new service is ordered and received by a customer, this also holds for NFV or an amalgam of traditional network and NFV know-hows. It is also essential for the service provider ensures that the conditions of the quality of experience (QoE) and SLA are followed as specified. This process refers to checking the critical factors such as recognition of faults in available resources, latency, unexpected changes in network site and latency. In networks that are technically distributed, the most challenging and time-sensitive activities include; checking the main performance pointers, forecasting resource faults that impact service and setting up data collection.

To get an optimized network in an NFV surrounding means that the service inspection is linked to service fulfillment by a closed loop response system. The current OSS cannot achieve this because of the rigid relationship between the fulfillment and assurance domains with latency in coordinating stored information between the two areas. Therefore, it does not depict the expected flexibility that was proposed by NFV.

Cloud technologies have some contributions in the monitoring domain. In spite of

NFV ensuring that the data center is more centralized in monitoring activities, its immediate insight into the service and QoE effect, technical diagnostics and its ability to separate and eliminate faults increase its complexity.

For NFV to meet the standards of assurance systems, it must satisfy the following;

- Immediate inspection of the end to end service quality; hence, assuring that the consumer realizes QoE and SLA's by ensuring availability, security, usability, and performance.
- Detection of the end to end service can be achieved by using virtualized and classical surroundings which are then synchronized with services that are understood by fulfillment.
- Offering a closed-loop; automated response to fulfillment system, inspecting lag in inspection, inefficient use to gather more resources or giving out available resources to compare the service needs usual and affinity rules.

3.2.2.3 eTOM Model Horizontal functions

Functionally linked processes are represented by the eTOM model horizontal method. The four parallel processes of operations are; CRM, which is an acronym for customer relationship management. SM&O, which is an acronym for service management and operations, S/PRM which is an acronym for supplier/partner relationship management and RM&O which is an acronym for resource management and operations.

A. CRM – Customer Relationship Management

The consumers' wants, which include, maintenance of customer relationship, acquisition and enhancement are all handled by the horizontal functioning process grouping. CRM has numerous applications such as, identifying potential opportunities for increasing customer satisfaction, synchronizing service delivery to customers. It’s simply in brief, about the customer support and services. The CRM having a database of consumers' information, could be used to better identify and increase customers value to the enterprise, vice versa.

Figure 3.11 shows the decomposition of consumer relationship into level 2 processes.

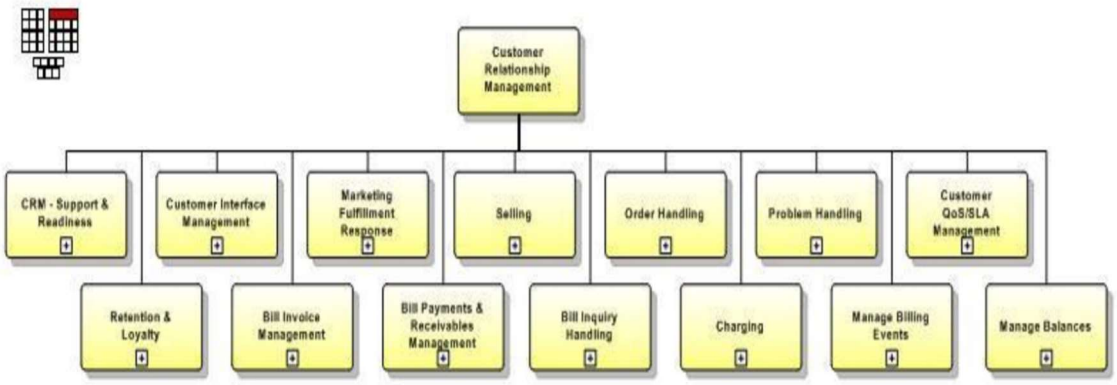

Figure 3.11 Decomposition of Customer Relationship Management into Level 2 Processes-Source: TM Forum, Business Process Framework (eTOM) GB921 version 12.2, April 2012[8]

The concentrations will primarily be in three significant areas of interest, in brief, having discussed on some of these areas in previous sections above.

- CRM support & Readiness
- Problem solving
- Customer SLA and QoS handling

Customer Resource Management Support and Readiness

In an attempt to ensure that customers fulfillment, assurance and Billing processes efficiently operate, the CRM support and availability is of utmost importance.

Key responsibilities of these methods amongst others include;

- Customers interactions, and support knowledge to customers, policy and decision maintenance.
- Up keeping the sales, customer data and products by the OSR, FAB and CRM processes by maintaining inventories.
- Inspecting and giving feedback on the abilities and expenses with regards to the CRM and FAB processes.
- Establishing the limits to which an enterprise targets for methodologies are met and the need for modification of processes by ensuring a lengthy trend examination on the product, sales, and customer FAB procedures.

Problem Handling

To restore and overhaul an activity to a customer, provide valuable information on status, analyzing and solving a problem to a customer's satisfaction, the problem handling process is of meaningful use. The process occurs because it is responsible for receiving reports, specifically trouble reports, from customers. Decomposition of this procedure into further level involves creating and closing trouble ticket of customer's statement [10]. This process covers most of the network monitoring centers (NMC) and field engineer as the case may be.

Some key responsibilities of the problem handling processes include [10];

- Examination, apprehension, managing and giving feedback on issues raised by a customer on purchases item offerings.
- Starting and handling a customer’s issues reports
- rectifying a customer's concerns
- Providing a feedback on the process of a customer's problem, feedback to a customer and other procedures.
- handing over and locating customer problem retrieval activities
- Handling a customer’s problem jeopardy (managing the life of customer report)

Figure 3.12 below gives the defined steps on managing a customer reported issues, correcting customer’s problem, reporting and tracking recovery activities.

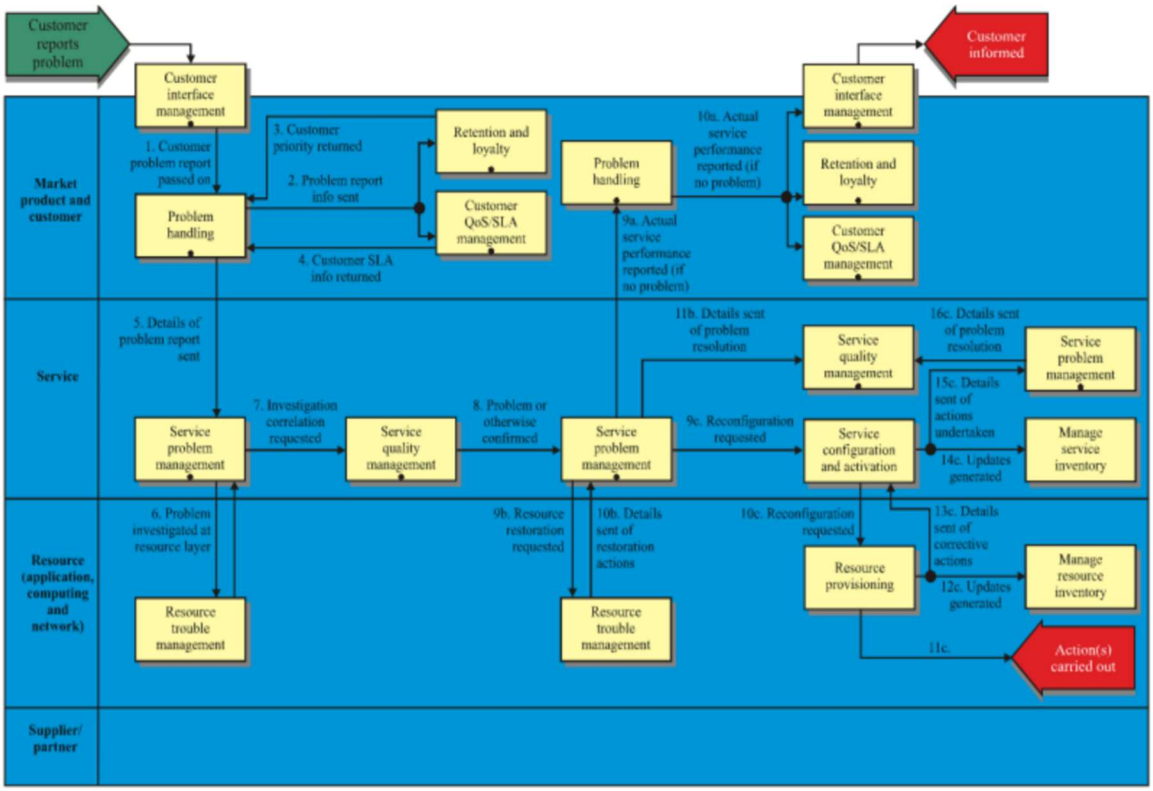

Figure 3.12 Customer detected SLA violation- Source: Stefan L., ''eTOM and ITIL Mapping'' [10]

Handling Customer QoS/SLA

The process is responsible for inspecting, managing, and feedback on services that have been delivered and ensuring that the input reaches the QoS and SLA as defined and agreed. It is also responsible for solving the issues that arise with enterprise performance and its association to its (SLA - acronym for service level agreements) for specific products and other documents that are self-related. These include; parameters of operations such as; the availability and performance of resources among others. Furthermore, also depicts the performance and settings across all products, for example, commitment repair time, performance of customer contact and season for order requests performance time. Lack of adhering to the service level agreements may lead to adjustments in billing by the Billing and Collections management.

B. Service Management and Operation (SM&O)

The Figure 3.13 shows the decomposition of SM&O in eTOM level 2.

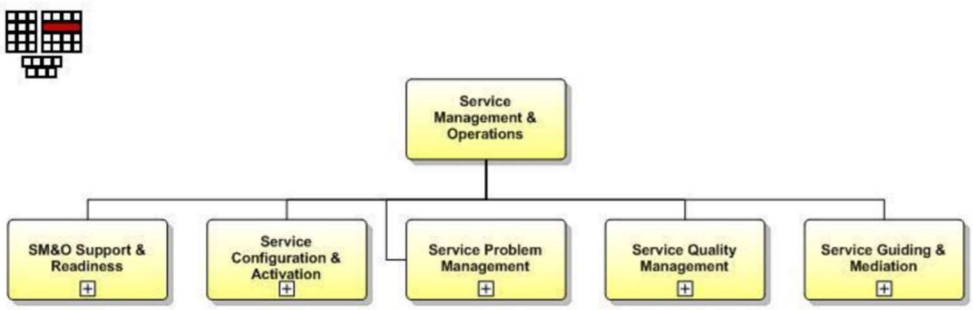

Figure 3.13 Decomposition of Service Management and operations into Level 2 Processes- Source: TM Forum, Business Process Framework (eTOM) GB921 version 12.2, April 2012[8]

Matters about content, configuration, connectivity and service access are all handled by the SM&O, which is an acronym for service management and operations. In addition to this, the requirements of services with regards to the customer as pertaining to communications and activities are all handled by the SM&O[8]. The target of service quality such as service cost, the levels of satisfaction by a customer, and support from forecasting are all accountable to the SM&O processes.

Activation and Service Configuration

It is essential to have the service configuration and activation processes to meet customer demands, such as activation, conformation, application, and distribution. In response to other procedures wishes in matters concerning service capacity activation, failure concerns in the service level agreements also cover customer's premises equipment.

To be more detailed, it also includes verification, allocation of parameters to support service, implementation, configuration, and activation of specific services, testing, updating service inventory database, tracking service provisioning activities and reporting progress of service orders to other processes.

Service Problem Management

This process handles customer's challenging request, responding immediately to affected service or failure to decrease their impact on customers, it none the less, also works to meet specified SLA on downtime and to appeal to the repair of service.

This process covers detecting, analysis, managing and reporting on service alarm event notifications, then initiating and managing ticket by starting service localization, correction and reporting progress to all other processes being more detailed. In cases when it was becoming frequent, assigning and tracking service problems is always advised.

Service Quality Management

On service performance, service quality management is responsible for, handling, locating, inspecting, examining, improving and providing feedback [8].

Service Guiding Mediation

This procedure is useful in handling events by showing a relationship between them and then by arranging them into and also directs them to the responsible service section.

C. Resource Management and Operations

The Figure 3.14 below shows RM&O decomposition into eTOM level 2.

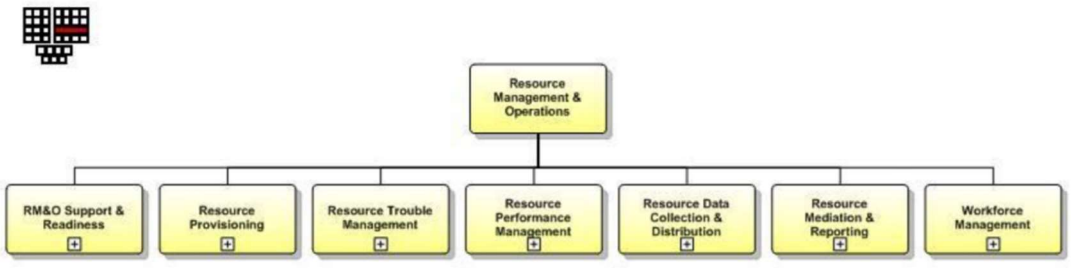

Figure 3.14 RM&O Decomposition into Level 2- Source: TM Forum, Business Process Framework (eTOM) GB921 version 12.2, April 2012[8]

The need for resource management can never be overemphasized as it is as important as any other aspect of the network if not most vital. With the invent and adoption of NFV for the future telecommunication advancement, the need for resource management gets more and more demanding as NFV targets on real-time network request activation and deactivation, zero-touches commissioning and flow-through provisioning.

Matters arising and about resources such as; servers, networks, IT systems, routers and support services that customers require are all accountable and are

managed by the RM&O. None the less, it also plays a part in the direct management of the aforementioned resources that are used in the enterprise. These procedures are vital in ensuring that the CSP framework and the network are in tandem with the end-to-end delivery of the services that are required.

3.3 APPLYING ITIL TO NFV ADOPTION AND PROCESS MANAGEMENT

Having had an introductory part for ITIL in chapter one, the second part of this section aims to analyze the application of ITIL to NFV adoption and process management.

In the latter part of this work, I will be discussing the similarities and differences and how it has become accepted when combined with eTOM to achieve an organizational business goal especially.

3.3.1 ITIL Processes and Functions

Service strategy, service design, service transmission, service operation and continual service improvement are the service lifecycle modules in the ITIL best practices framework as introduced in chapter one. The modules in ITIL entails an array of ITIL procedures and functions within it.

The ITIL processes and functions will be used in the analysis of NFV design and operations. Figure 3.15 gives a pictorial breakdown of the ITIL processes and services.

Figure 3.15 ITIL Processes and Functions-Source [42]

3.3.2 ITIL Service Assurance Operation and Processes to NFV

ITIL service operation addresses majorly IT operations role in running the

business and where it has most significant impact on the customer. The following are required to have a successful service operation; an efficient problem management system, collaboration, and an active planning system. It is said that an ideal service operation is one in which there arise no incidents when services are offered to the customer. None the less, it is essential for the company to ensure that its operations are not stagnant in spite of maintaining stability [37].

Some of the IT resources that are entirely dependent on Information technology asset availability are; PaaS, which is an acronym for the platform as a service, SaaS, which stands for, software as a service, and IaaS, which means, infrastructure as a service. It is essential for ITIL service operations to deliver the promised warranties and service level agreements by focusing on processes and capabilities of the service they are producing.

Service assurance gives surety that the services that are being rendered are in line with the promises delivered to customers. Therefore, if the service seizes to work, it then must be fixed. Thus, it should meet the promised warranty and SLA. The procedure can be achieved by dialoguing with customers to enable them to know the terms of commitment, continuity, capacity, availability, and security of the utilization of service.

ITIL service assurance is focused on some fundamental operational processes in other to guarantee SLA. [21] QoE can be maximized by monitoring the service not only for availability but QoE. A function is defined as unavailable if QoE falls below thresholds.

To achieve NFV promises as related to assurance, ITIL service operational processes and functions can be applied in the analysis of NFV operations. The methods to be considered for this work are incident handling, problem handling, and event handling. In the latter part of this chapter, some of the operational processes under service transition will as well be used in the analysis and finally ending with service improvement and reporting.

A. Event Management

An event in ITIL refers to an alteration of the normal state that affects the management of an IT service or item. On other terms, it can be defined as a notification or rather an alert that is created by an IT service, inspecting tool or configuration item. The primary objective of event management is to identify events, examine them and then determine the right action, (if any). By doing this, the procedures of event management also assists in service assurance, providing a feedback and service improvement [22].

The process differs from the incident because the event might mean minor alarm that has little or no impact on the operations. On the other hand, conflict is a critical alarm that requires instant attention. Figure 3.16 depicts the event management process.

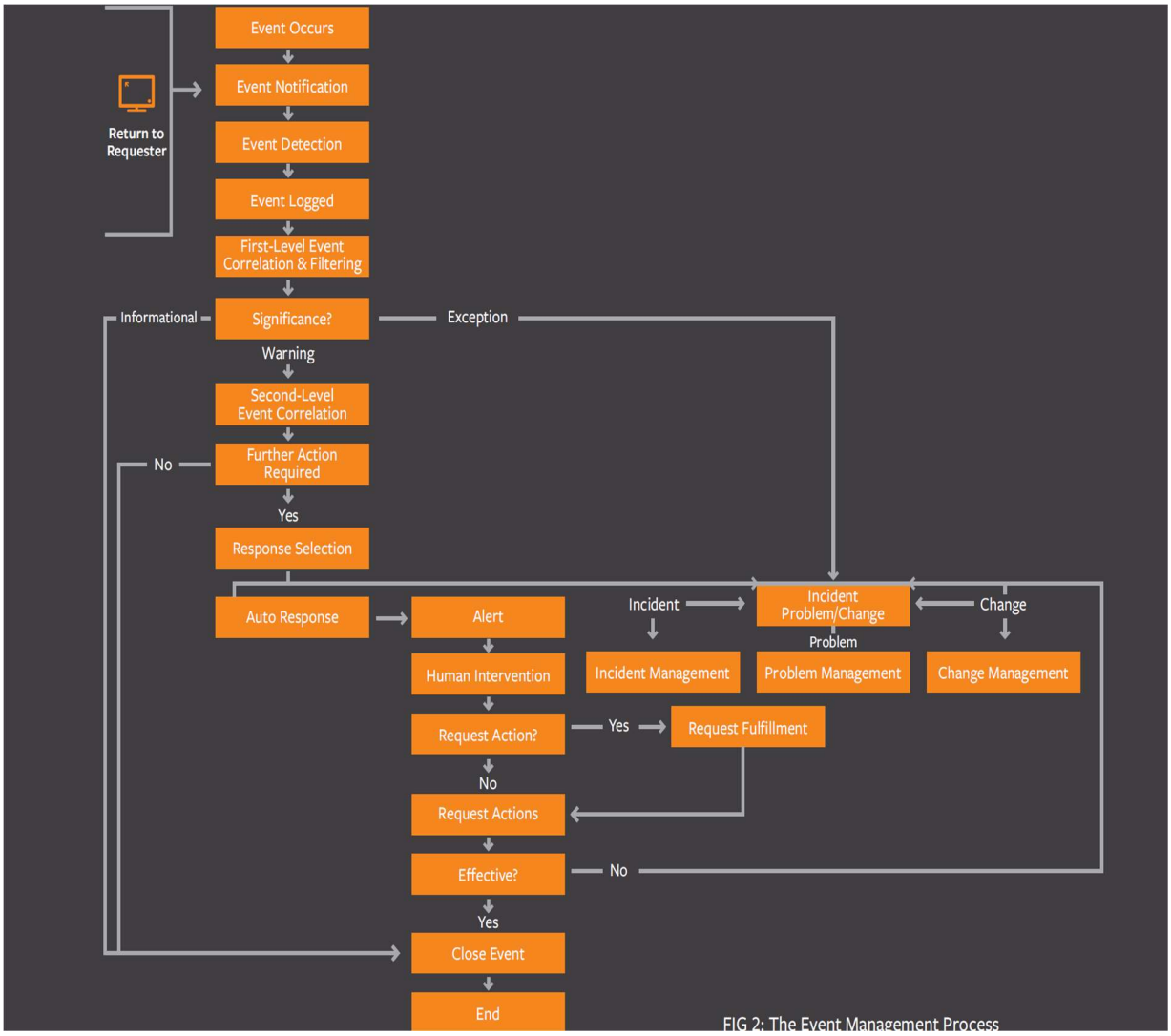

Figure 3.16 Event Management Process- Source: BMC Best Practice Insight, Focus On Service Operation [22]

B. Incident Management

In IT service management, the process responsible for handling the lifecycles of all incidents are referred to as incident management. In case of a conflict, the incident management attempts to resolve an issue at the shortest time possible hence reducing the impacts on the business. The process occurs because the incidents cause time wastage, therefore, reduction of profits.

Figure 3.16 shows the process flow for incident management.

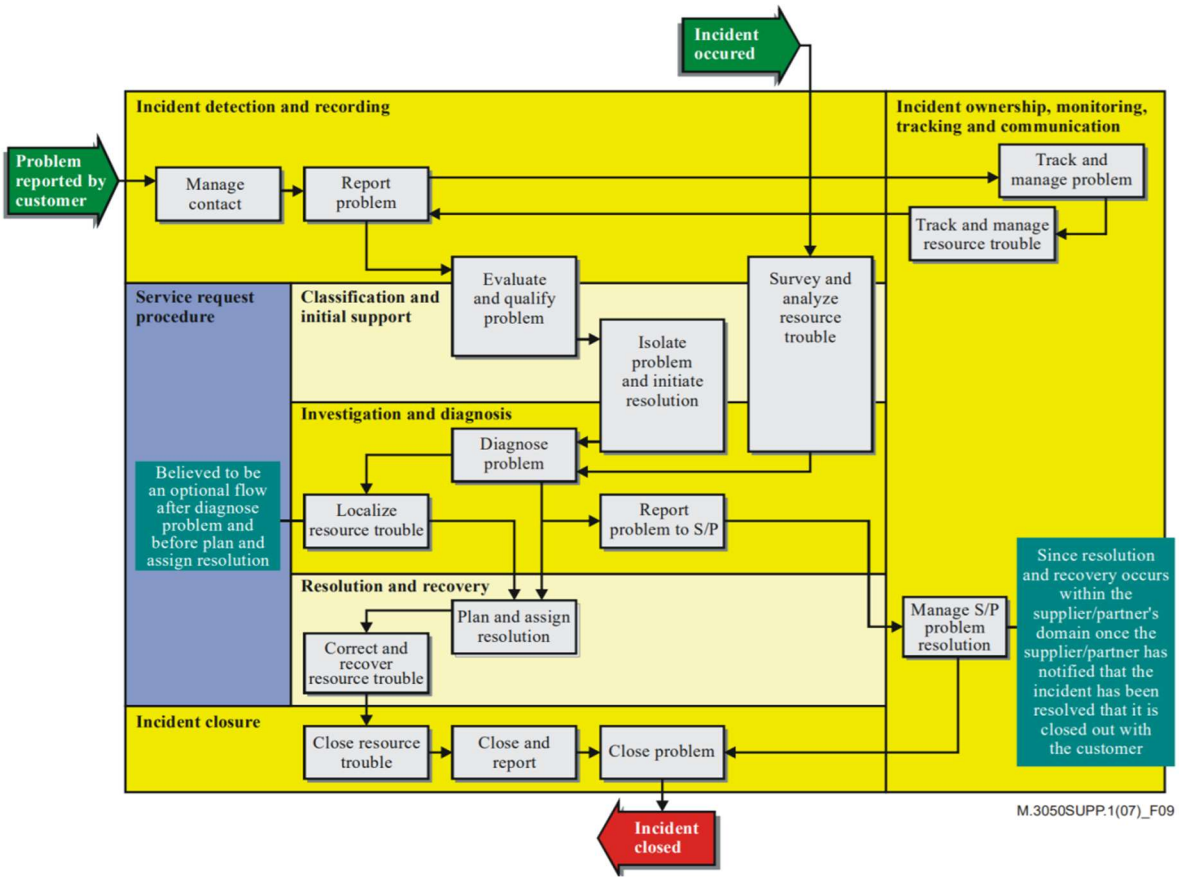

Figure 3.17 ITIL Incident Management Process Flow (Internal Environment)- Source: ITU-T M.3050 [6]

It is expected that with the invent of NFV incident becomes much more comfortable to investigate and localize what happened if all of the logs are located on the same server instead of having to hunt across several or possibly several dozen servers in the case of PNF precisely.

C. Problem Management

Problem Management is the process that is responsible for actively preventing an incident from taking place, in case an event cannot be stopped; it then reduces the impact of the conflict. This management process can either be the reactive or proactive process. Just as incident management, problem management aims to ensure availability quality and reducing the time spent on fir fighting [7].

With NFV and one of its promises of self-healing and Automatic detection of performance anomalies, problem management becomes more exciting and easy to fix and also automatically mapping problems to trouble tickets so an engineer can set them if need be.

3.3.3 Service Transition

Service transmission benefits businesses by ensuring that the consumer and a business receive the expected result as promised. Such outcomes include high

success rate, fewer hazards and risks, retirements with less work, and ability to handle high rate transactions.

Service transition is a significant aspect to be considered for the anticipated change in NFV and SDN which brings the future of telecommunication sector. The process to be found under service transition in this work among others will be service asset, change management and configuration management.

A. Change Management

Changes in the IT service and IT infrastructure are all accounted for in the change management process. All such modifications should show a benefit to the business [24]. These changes are characterized to be; operational, strategic and tactical. Therefore, they can be classified as either reactive or proactive depending on the circumstance. When a business aims at, for example, streamlining its operations to reduce risk, a dynamic change is the one that is sought after. On the other hand, a reactive adjustment is required when a situation that needed immediate attention arises that affects customer and interferes with the service levels promised such as experience and quality. In general, terms, for a business to have reduced risk, operational values and to have business continuity, proper change management is critical.

There are many factors to be considered when change is in view to avoid high-level risk and unplanned high expenses as a result of weak or improper strategy analysis and design. Some of which are internal factors and also an external factor that can limit the anticipated outcome of the service transition. This element includes technological, economic, social, legal, environmental, communication and company culture.

Change Type

There are four types of change to be considered in the anticipated transition from current CSP to the future CSP. Figure 3.18 gives an illustration of the four types of change.

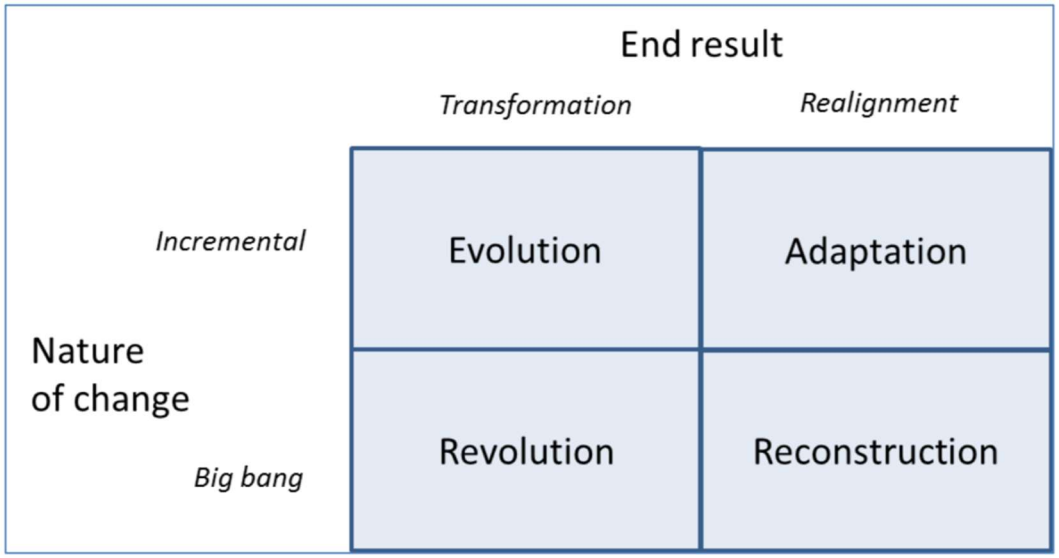

Figure 3.18 Change Type- Source: [9]

Adaptation refers to a non-definitive restructuring that is implemented step by step whereby the nature of the alteration is incremental; hence it is done in phases. On the other hand, reconstruction can be defined as a non-definitive alteration mainly intended to realign the organization's operations in a more streamlined manner than adaptation.

Evolution, on the other hand, refers to a transformational change that occurs at different stages gradually. Revolution, on the other side, is similar to development but takes a relatively shorter period.

The future CSP which NFV promises is termed as an evolutional change since it is a transformational change implemented gradually through different stages and interrelated initiatives". It can be said to be a parallel change with the current CSP as the case may be. It can also be termed as a Revolution change, depending on the organizational culture and strategy for change [9].

Other Types of Change from ITIL are;

Standard changes; these are typically preauthorized and have low-risk with similar activities and a reasonable outcome. These changes can also be routine, low-impact IT changes.

Regular changes; are the changes that take place from when a process starts to when it ends and includes all the associated activities. This change can be prioritized, authorized and then scheduled for changes.

Emergency changes; this is similar to an average change; however, it takes place at a faster rate than the average difference. High risks are always involved in emergency changes.

Change Management KPIs

Metrics keep tabs on the changes that take place during the transition. Hence, it enables you to understand the causes, effects, trends and the speed of the IT response [24].

Metrics for Measuring Change

These parameters show how essential changes have taken place in the planning phase at the start of the service strategy phase [23]. The following can be used to determine the effect and impact of the change;

- Performance developments
- Continuity and adherence to the laid out plan
- Business and modification readiness
- Velocity of execution
- Adherence to the time frame
- Benefit realization and return on investments
- Project KPI measurements

B. SACM – Service Asset and Configuration Management

Service asset and configuration management are responsible for managing all the service assets. The aspects of it are; release management, incident, change, and service management processes. The primary objective of the process is to document all the configuration items (CIs) and shows the relationship between them in the CMDB, which is an acronym for configuration management database. SACM also ensures that the CMDB is up to date, controls, monitors, and reports on the status of the CI and service framework. None the less, it also plays a part in managing the entire lifecycle of the asset from purchase to retirement [38].

With the current CSP, operators rely mainly on static asset and configuration management systems that are dependent on human input to extract configuration data. Real-time virtual elements are needed to support SACM to match with NFV flow-through provisioning and self -healing for fault and change management with speed and accuracy.

C. Capacity and Availability Management (CAM)

Capacity and availability management is vital in the success of NFV, it helps to meet current and future needs of the business. CAM can be used to forecast the impact of traffic event to determine resources required to balance supply against demand. It also requires preparing for variations based on the time of day and seasons. The preparation requires integration with business to ensure IT is ready for any change in variation of traffic and business initiatives that will impact capacity.

In CAM, automated thresholds should be well defined to allow reduced impact of situations that can occur when targets are breached or threatened by variation of traffics. CAM should also play an active role in the support, negotiation, and

verification of SLAs. Meaning it should be included in any planning activities and continuous service improvement[25].

D. Continuous Service Improvement (CSI)

CSI is vital in increasing the efficiency and effectiveness of any business and also help in optimizing cost of service by improving the underlying IT service management processes[26]. It also helps to determine processes to be improve, through continuous reporting, SWOT analysis, Operational level agreement (OLA) and SLM, Service improvement plan (SIP) can be determined. CSI cuts across all lifecycle stages as illustrated in Figure 3.19.

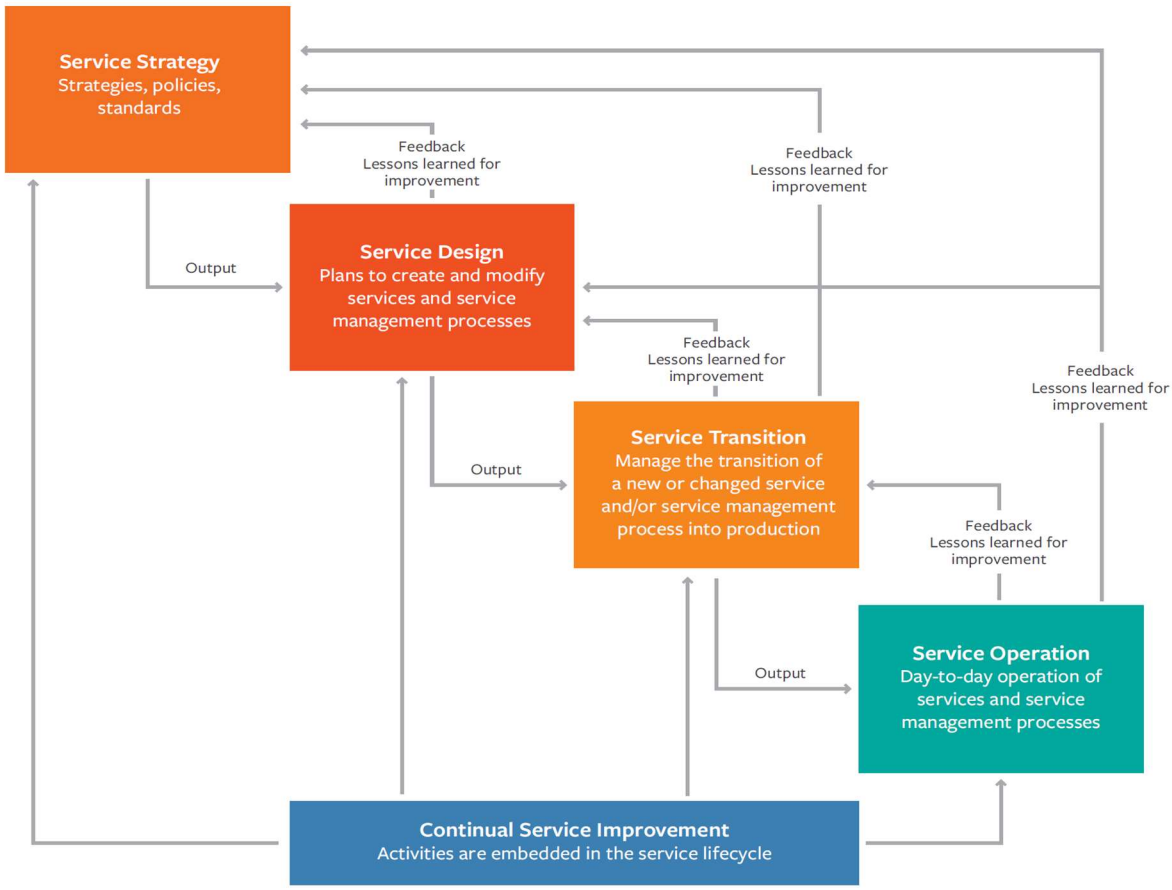

Figure 3.19 CSI support all lifecycle Source: [27]

Since NFV relies on software-based innovation, it supports CSI improvement and help tackle the key challenges faced by present CSP on heavy investments in hardware-based functionalities to create new services or add features because of the evolving demands. The ideal approach promises increased flexibility of a system to scale software more precisely of reconfigurable and replaceable software to match demands, instead of the traditional CSP that requires huge investments that affects CAPEX and OPEX expenditures.

E. Service Reporting

Reporting is important for change and upgrade of any system and process. From the collected data, the strength, weakness, opportunities and treats (SWOT analysis) could be analysed and determined. Some of this types of data relates to past performance, especially past event that could be a threat to future performance, as well as its plans to migrate any potential threat.

While carrying out reporting, what matter most is the customer's experience with the service you have provided such as uptime, QoS, QoE and user satisfaction with the service.

Adopting some of the processes in ITIL best practice to properly align NFV processes generally will help close the gap between business and operations in the telecoms industry. it will aid proper flow and interactions between business and operation.

Chapter 4 CONCLUSIONS

This chapter concludes the main part of the document with highlights on achievements of works done and a more detailed difference between the two best practices used during this work and which is best to be adopted for defining NFV business process for NFV standardization body and other supporting standards and also for the projects promoting NFV concepts. Also this chapter concludes with recommendations and future lines of study and research.

4.1 Conclusions

Having started this documentation by stating critically the challenges posed by the current CSP network and followed by a well introduced NFV and the two most important best practices (eTOM and ITIL) in the IT and telecommunication industries. Analysis of other project focusing on promoting the NFV concept and why they all need to be aligned with the two best practices in other for continuity and process compatibility when integrated to achieve a common business and operational goal have been well analysed in details in chapter 3. The advantages of having a general language for use across processes both internal and external, reducing risk of system implementation and integration, and also eliminate gaps and duplication in process flow.

There are always steps taken towards achieving any existing or new business goal, some of which are always not well tailored to current best practice that support and defines every process towards actualizing the expected goals.

With the Birth of NFV concepts and being pushed by ETSI and other supporting standards, alongside other projects promoting NFV concept, a vital question to be asked after accepting the adoption of a business process as advised by this document “Which is the best practice to be adopted?

4.2 Comparison and Similarities between eTOM and ITIL Best Practices

This section answers the most important question of “Which is the best practice to be adopted? The table 4.0 details a comparison between eTOM and ITIL.

eTOM	ITIL
• eTOM is a standard primarily adopted by ITU-Telecom Sector, and mostly used by the telecommunication sector (ICT&IT). eTOM is maintained by TM Forum.	• ITIL is a set of best practices adopted by tens of thousands of companies worldwide and it’s maintained by the itSMF.
• eTOM being focused on customer satisfaction, its major aim is on external customers. It analyses a top-down approach as it cuts across all departments	• With ITIL, process flow can be analysed and developed as it explains how this business process can fit into IT. Its major focus being on the internal

in an ICT &IT sector. Its processes can be further stretched to fit organisational plan.	customers, it defines step-step approach in form of guide toward implementation of services, its management, then delivery and continued improvement.
• eTOM framework is a blueprint for service provider's business process to enable them streamline their processes. As well as effective communication among department and a general language with customers and suppliers and within the enterprise.	• ITIL framework emphasis on how best to align business needs to IT so as to enclose all gaps and process duplication. It focuses on improving the service delivery is achieved by defining a business standard terms generally for use across business and IT.
• eTOM is a prescriptive catalogue of business Process Element for the ICT industry.	• ITIL is a not a prescriptive guidelines, it can be used by IT and ICT Service Management.

Table 4.0 eTOM-ITIL Similarities and Differences

A strong similarity between eTOM and ITIL is that they are both frameworks that can be adjusted to fix and properly define any organisation business process.
eTOM constantly evolving its business process framework to work in freely with other best practice.
ITIL encompasses a set of good practices widely recognized and applied by many organisations, and shows how these can be orchestrated in a service management lifecycle, see[39.]

eTOM, having been accepted widely by the telecommunication industry as a standard, defines a common language and a complete activity mapping and classification for use by service providers within the telecommunications industry. eTOM compared with ITIL, it is a more detailed, and most explains process framework necessary to fit into service providers to plan, deploy and operate their services, see[40].

Following the table above, it is evident that NFV standardization bodies and other supporting standard, alongside projects working to promote the concepts should model their operational process in a standard way. This can only be achieved by

using the process elements of eTOM but complemented with ITIL to assist in creating a more complete Enterprise Business Process Framework which includes all the functional elements needed for IT support processes.

For other companies desiring to achieve greater results, a use of these two frameworks is needs, a clear and unique business advantage can be achieved from applying these two practices together to get the best result.

4.3 Sustainability Consideration

Having seen the numerous notable advantages of NFV to the CSP and the anticipated changes it promises which includes faster service life cycle, scalability and elasticity, operational efficiency and agility, faster time to market, and many more, for no doubt adopting a standard business process will enhance the ease achievement of this numerous advantages. It will as well eliminate duplication of processes, ensure defined proper flow of stages across business processes. eTOM is a standard that defines a top-down approach which is customer centric, of which part of the aim of NFV is the ability to boost sustainability and added value to the customer in order to serve them better.

4.4 Ethical Consideration

eTOM is a standard that defines an organisation’s consistent process flow by enabling interaction across process and providing a general language for use across stages and various processes and departments. Towards the fulfilment of NFV, there are many organisations and project working to promote the concept. The proper application of a general business process framework by all supporting organisation and project will ensure the ideal interoperability. Compatibility and the easy flow between processes is one of the present work in progress by ETSI towards the achievement and actualisation of NFV, so a general language across processes is most important for the success of NFV.

Annexes

A. NFV Design Considerations

Following the steady and fast growth of NFV and the anticipated changes it promises, it is vital to note that it is not only sufficient to deploy NFs over virtualized infrastructures. The expectations of network users are keyed on getting the defined QoS and agreed on SLA. For NFV to be acceptable, it has to meet the following considerations [30]:

1. **Network Architecture and Performance**: To be accepted, it's important for NFV architecture to also achieve and better the performance compared to what is obtainable when compared to functions running on dedicated hardware. This requires that all potential challenges at all layers of the stack are evaluated and solved.

2. Security and Resilience: Following the dynamic nature of NFV it is required that security technologies, policies, processes and practices are prioritized and added. Functions of different subscribers are protected and also isolated. Both the NFVI physical and virtual resources should be protected.

3.**Reliability and availability:** The high reliability and availability needs are not just for customer's satisfaction but also a regulatory policy. Multiple alternative for redundancy should be put in place to accommodate failure and recovery. This also has to be supported by NFV framework.

4. Support for Heterogeneity: One of the major advantage of NFV is on breaking the locked-in functions from proprietary hardware-based service provision. InPs should have flexibility of choosing specific hardware and software. NFV platform must be open to run applications from different vendors.

5. Legacy Support: Compatibility and need for heterogeneity have to be strongly considered as needs for simultaneous test bed is vital in making the transition to NFV as they may need to manage legacy physical assets alongside virtualized functions for some time. This is because of some uncertainty issue posed by any new technology.

6. Network Scalability and Automation: In order to achieve the full benefits of NFV, a scalable and responsive networking solution is necessary. NFV will only scale as expected when its functions are automated. Therefore, automation of processes is of importance to the success of NFV. In addition, the need for dynamic environments requires that VNFs can be deployed and removed on demand and scaled to match changing traffic.

B. NFV Standardization Activities

Following the steady growth of NFV, there are involvements of other standard bodies in NFV activities. Some of which are work in line with the ETSI and others are working on some specific aspects, like the ATIS and 3GPP working on aspects of NFV that have not yet been sufficiently developed by the ETSI. Table A1 summarizes the different standard organisations.

	Description	Focus Area	Description of NFV-Related Work
ETSI	Industry-led ETSI Standards Group	NFV	NFV architectural framework, infrastructure description, MANO, security and trust, resilience and service quality metrics.
3GPP SA5	3GPP's Telecom Management working group	Mobile Broadband	Working in liaison with the ETSI. Studying the management of virtualized 3GPP network functions.
IETF SFC WG	IETF Working Group	NFV	To propose a new approach to service delivery and operation, an architecture for service function chaining, management and security implications.
IRTF NFVRG	IRTF Research Group	NFV	Organizing NFV-related research activities in both academia and industry through workshops, research group meetings etc. at premier conferences.
ATIS NFV Forum	Industry-led Standards Group	NFV	Developing specifications for NFV, focusing on inter-carrier interoperability.
ONF	Industry-led consortium for standardization of OpenFlow	SDN	Standardizing the OpenFlow protocol and related technologies. Defines OpenFlow as the first standard communications interface defined between the control and forwarding layers of an SDN architecture.
DMTF OVF	Industry-led consortium	Cloud	DMTF's OVF and the CIM may be used as one option for capturing some or all of the VNF package and/or VDU [18] Descriptor.
BB Forum	Industry-led consortium that develops broadband network specifications	NFV in Broadband Networks	Collaborating with the ETSI to achieve a consistent approach and common architecture for the infrastructure needed to support VNFs.

Table A1 Summary of NFV Standardization Efforts Source:[30]

B. NFV implementations and products from industry

Below are some of the industries promotion the NFV implementations:

1. HP OPENNFV

HP being one of the pioneers in the development of the legacy server is also working on its OpenNFV platform upon which services and networks can be dynamically built. Its working towards aligning its solutions to each functional blocks as defined in the ETSI architecture.

2. Huawei NFV Open Lab

Huawei is working on providing an enabling environment to ensure compatability between its NFV solution and carrier grade infrastructure with the emerging NFV standards and with the OPNFV.

3. Intel Open Network Platform (Intel ONP)

Intel is working on open solutions for NFV and SDN. ONP server is its major result. This is a reference architecture that integrates open-source and hardware ingredients optimized for SDN/NFV.

4. CloudNFV

This is a joint effort of six companies (6WIND, CIMI Corporation, Dell, Enterprise Web, Overture Networks, and Qosmos) working on enabling a platform for NFV, SDN and cloud computing. It focused its strength on three main elements which are active virtualization, NFV orchestrator and, NFV manager. The first, being "active virtualisation" tackles aspects of services, functions and resources. NFV orchestrator will determine the location of the functions that make up the service as well as connections between them while the VNF Manager uses a resource model structured in line with TMF rules and the concept of derived operations is used to manage VNFs.

5. Alcatel-Lucent CloudBand

They working on a two-level platform implementing NFV. First, it includes nodes that provide resources like VMs and storage, then the CloudBand Management System which is the functional heart of the process. It operates as a work distributor that makes hosting and connection decisions based on policy, acting through cloud management APIs.

6. Broadcom Open NFV

Is working on an Open NFV platform with the aim to creating NFV applications across several systems on chip (SoC) processors, creating flexibility for vendors to be able to migrate virtual functions between platforms based on vendor desired solutions.

7. Cisco Open Network Strategy

They are working on evolved services platform (ESP) and an evolved programmable network (EPN) which include a service orchestrator, a VNF manager, and SDN controller, with the aim at providing ETSI MANO framework functional blocks.

8. F5 software Defined Application Service

IT provides a compactible layer from 4-7 to supplement existing 2-3 network layers and compute initiatives such as SDN. Its aim is to enables a service injection, consumption, automation, and orchestration across a unified operating framework of pooled resources, see [30].

9. ClearWater

"It is an open source implementation of an instant messaging (IMS) built using web development methods to provide voice, video and messaging services to users.

10. Overture Virtual Service Edge (vSE)

It's an open carrier Ethernet platform for hosting VNFs at the service edge, which

allows TSPs to instantly deploy on-demand VNFs at the customer premise. "*It combines carrier Ethernet access with the benefits of virtualization, openness and software-defined services"*. The result is a single platform for both services and network access, which allows for VNFs to be turned up, down, expanded and removed dynamically so that compute and storage resources are used only when needed.

Table A2 gives a brief summary of NFV implementations from different industries, stating their functionality, the standards bodies they closely follow and platforms on which they run.

	Functionality	Platform	Driving Standards
HP OpenNFV	Open standards-based NFV reference architecture, labs as a sandbox in which carriers and equipment vendors can test vEPC.	OpenStack	ETSI
NFV Open Lab	Supports the development of NFV infrastructure, platforms and services.	OpenStack, OpenDaylight	ETSI
Intel ONP	Provides developers with a validated template for quickly developing and showcasing next-generation, cloud-aware network solutions.	OpenStack, OpenDaylight	3GPP or TMF
CloudNFV	Provides a platform for virtual network service creation, deployment, and management.	OpenStack	TMF and ETSI
Alcatel CloudBand	Can be used for standard IT needs as well as for CSPs who are moving mobile networks into the cloud.	Red Hat Linux OpenStack Platform	ETSI
BroadBand NFV	Migrate virtual functions between platforms based on various vendor solutions.		ETSI
Cisco ONS	Automated service delivery, improved network and data center use, fast deployment of personalized offerings.	OpenStack, OpenDaylight	ETSI
F5 SDAS	Extensible, context-aware, multi-tenant system for service provisioning	OpenStack, BIG-IP, BIG-IQ [122]	IETF, 3GPP, GSMA, ETSI, ONF
ClearWater	SIP-based call control for voice and video communications and for SIP-based messaging applications.	Apache Cassandra, Memcached	3GPP IMS, ETSI TS
Overture vSE	Host multiple VNFs in one box, Accelerate service creation, activation and assurance, Decrease inventory and management costs, Optimize service flexibility, Eliminate trucks rolls	Linux Overture Ensemble OSA [24], OpenStack	

Table A2 Summary of NFV Implementation from Industries Source: [30]

D. Service Assurance Lifecycle

Service Assurance comprises the management and operations functions that are used to ensure that the required service levels and KPIs are met through throughout the life-cycle of a service. [21]. Assuring an SLA is a lifecycle process, as illustrate in figure A1

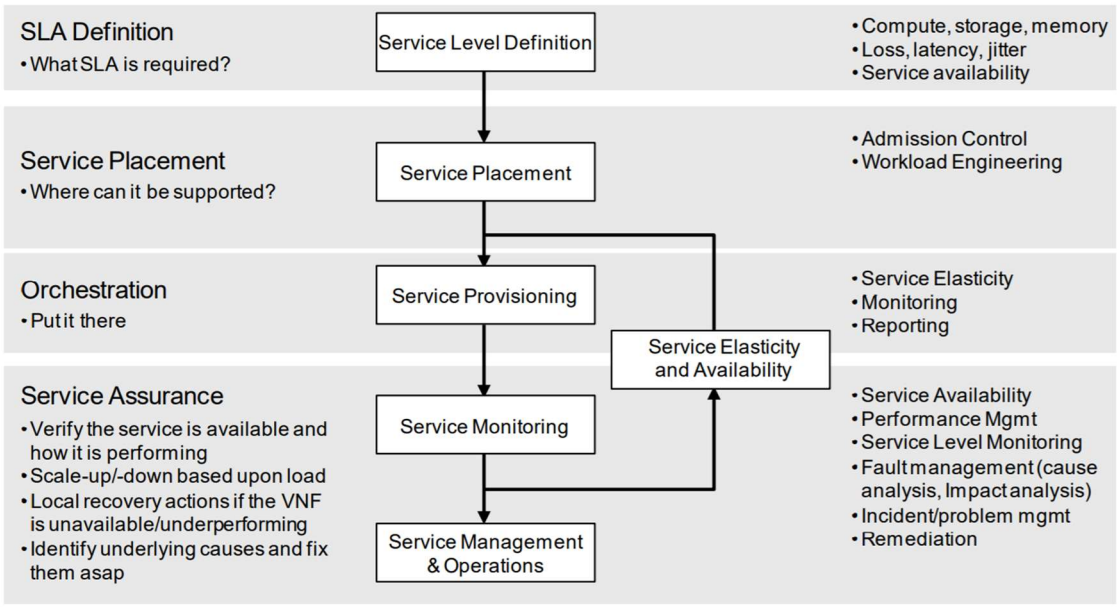

Figure A1 Service Lifecycle Assurance ***Source:*** *[21]*

The goal of life-cycle assurance is to develop a service assurance system that:

- Maximizes Quality of Experience (QOE)
- Minimizes costs of development
- Minimize cost of operations

E. SWOT Analysis

A SWOT analysis is a framework that aides structuring and evaluation of a projects or organisational business process and deliverables by analysing the possible strengths, weaknesses, opportunities, and threats. The strengths and weaknesses have to do with the internal considerations, while opportunities and threats are external considerations.

A SWOT analysis is an effective strategic planning tool for generating requirements for possible input strategies. SWOT analysis can only give a description of conditions; it is not a strategy itself. For SWOT analyses to be effective, it has to be properly aligned with the organization's vision, mission, goals, and objectives to be of value. A SWOT analysis can be useful at all organizational levels, as well as for a service or process in the organisation[43], See figure A2

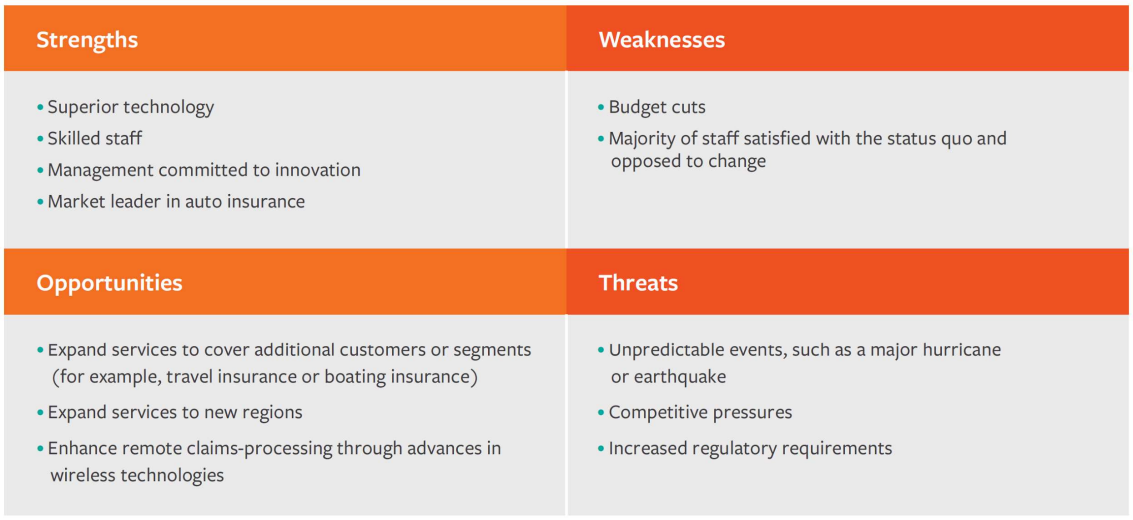

Figure A2 SWOT Analysis

ACRONYMS

3GPP - 3rd Generation Partnership Project
API - Application Programming Interface
BPF - Business Process Framework
BSS Business Support Systems
CAM - Capacity and Availability Management
CAPEX - Capital Expenditure
CDN - Content Delivery Networks
CIs - Configuration Items
CMDB - Configuration Management DataBase
CRM - Customer Relationship Management
CSI - Continuous Service Improvement
CSP Communication Service Provider
DMTF - Distributed management Task Force
DSS - Digital Signage
EMS - Element Management System
EPA - Enhanced Platform Awareness
EPC - Evolved Packet Core
eTOM Enhanced Telecommunication Operations Map
ETSI European Telecommunications Standards Institute
FAB - Fulfilment, Assurance and Billing
FCAP - Fault, Configuration, Accounting and Security
ICT - Information and Communication Technology
IETF - Internet Engineering Task Force
IMS - IP Multimedia Subsystem
IRTF - Internet Research Task Force
ISG - Industry Specification Group
IT Information Technology
ITIL Information Technology Infrastructure Library
ITSM - IT Service Management
ITU-T International Telecommunication Union - Telecommunication Standardization Sector
Iaas - Infrastructure as a Service
InPs - Infrastructure Providers
KPI - Key Performance Indicator
MANO - Management and Orchestration
MCN - Mobile Cloud Networking
NFV Network Function Virtualization
NFV-O - Network Function Virtualization - Orchestrator
NFVI - Network Functions Virtualization Infrastructure
NFaaS - Network Function as a Service
NGOSS - Next Generation Operating Support System
NMC - Network Monitoring Centre

NSs - Network Services
OLA - Operational Level Agreement
OPEX - Operational Expenditure
OPNFV - Open Platform for NFV
OSI Open System Interconnection
OSR - Operations Support and Readiness
OSS Operations Support System
PNFs - Physical Network Functions
PaaS - Platform as a service
QoE - Quality of Experience
QoS - Quality of Service
RAN - Radio Access Network
RM&O Resource Management and Operations
ROI - Return of Investment
S/PRM - Supplier/Partner Relationship Management
SACM - Service Asset and Configuration Management
SDN Software Defined Network
SFC - Service Function Chaining (IETF Terminology)
SIP - Service Improvement Plan
SIP - Strategy, Infrastructure and Product
SLA - Service Level Agreement
SLM - Service Level Management
SM&O Service Management and Operations
SPs - Server Providers
SWOT - Strengths, Weaknesses, Opportunities, and Threats
SaaS - Software as a Service
TSPs - Telecommunication Service Providers
TSPs - Telecommunications Service Providers
VIM - Virtualized Infrastructure Manager
VNF Virtual Network Function
VNFPs - Virtual Network Function Providers
VR - Virtual Resource
ZOOM - Zero-touch Orchestration, Operations and Management

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