eTOM to NFV mapping for flexible mobile service chaining in 5G networks: IMS use case

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ABSTRACT

Mobile network operators (MNOs) continually look to improve their business and become more agile and competitive within the quickly developing telecommunications industry. In turn, telecommunication professionals put forward and adapt advanced models and frameworks to assist MNOs to achieve their goals. In this context, the Business Process Framework (eTOM) was established by the TeleManagement Forum and on which we base this work to suggest a mapping of this eTOM business process model upon the network functions virtualization (NFV) framework. Thereby, the main purpose is to design a hybrid architecture by the combination of the aforementioned frameworks for dynamic service delivery with improved resource performance and quality of service so as to fulfill some of the purposes of the 5 generation (5G) technology with regard to a telecommunication system managed and orchestrated in a virtualized environment. Indeed, MNOs will be in a position to scale mobile services up and down fast and reduce costs to better align them with network usage. These procedures are performed based on flexible service chaining through implemented NFV management and orchestration modules along with SDN controller functions. In this article, we outline possible designs and analyses of flexible mobile service chaining to support end-to-end network slicing for dynamic service provisioning in order to provide a novel approach in the framework of the 5G technology, more especially from data and signaling based network perspectives. We project our proposal onto the IP Multimedia Subsystem (IMS) core network to discuss both dynamic and static signaling service provisioning approaches. In this situation, we set up a testbed platform with the goal of assessing the behavior of a virtualized IMS system, in a static signaling service provisioning environment through two signaling service chains to validate part of our proposed approaches. Experiment results confirm that virtualized IMS signaling resource performance indicators could be enhanced in the case of unpredicted performance degradation of one of the virtualized signaling resources assigned to the IMS virtual network functions composing the main signaling service chain by instantiating a second signaling service chain. Finally, IMS application performance indicators are improved regarding registration delay and session setup time.

1. Introduction

To permit mobile network operators (MNOs) to explore and rationalize their business processes, especially from resource performance and service quality perspectives, the New Generation Operations Systems and Software (NGOSS) standard [1], which has been renamed Frameworx, provides the Business Process Framework (eTOM) [2, 3, 4] that is a global framework abstracting many operational process groupings. This loose coupling allows MNOs to manage operations quickly and enable these processes to develop independently of each other. Typically, each process grouping is defined to reach a specific goal and consists of a collection of processes that work together.

In parallel with the development of eTOM, virtualization technology has positively impacted the information and communication technology sector in recent decades. It was the principal enabling technology for cloud computing approaches first and then was the central pillar of the emerging network paradigms [5], network functions virtualization (NFV) [6] and software defined network (SDN) [7, 8]. In effect, the virtualization of infrastructure and operations is one of the considerable actions that MNOs could exploit to lower costs, either capital expenditure or operational expenditure and then maximizing benefits.

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In recent years, a novel abstracted framework termed NFV architecture [9] has been developed by network professionals besides the eTOM business process standard [10, 11]. Its main purpose is to allow MNOs to virtualize the entire telecommunication system and rationalize the delivery of mobile services. This framework brings together many functional blocks, among which is the operations and business support systems (OSS/BSS) functional block which already exists in current deployments. eTOM is an integral part of these building blocks, as it properly belongs to the OSS/BSS functional block which collaborates closely with the element management system (EMS) block whose responsibility is to perform the fault, configuration, accounting, performance and security (FCAPS) network management capabilities for virtual network function (VNF) building blocks.

eTOM, NFV, and SDN are key enablers for the development of the four generation/long term evolution (4G/LTE) technology toward a virtualized, orchestrated architecture intended to be termed the fifth generation (5G) technology. But, for reasons of performance and quality of service (QoS) management [12] related to the 5G network technology, few research studies have been published to implement eTOM, NFV, and SDN based frameworks so as to take part in that development.

In this article, we present our contribution in two constituent parts. These two parts represent enhancements of the earlier work published in [13] and [14] respectively. Effectively, the new enhancements do not affect the simulation results made in the previous publications [13, 14] and which are also reported in this study, because of the fact that all those enhancements have no relationship with the implemented parts of our approach – we implement part of our eTOM to NFV mapping approach, and then we validate part of our SFC proposal for static signaling service chaining –, except for two improvements – the inclusion of the Resource Trouble Management (RTM) process and the inclusion of the VNF Manager (VNFM) – which were implicitly included in the previous publications and are explicitly included in the current work, as will be shown later.

In the first part of our contribution, we put forward a new virtualized business process mapping approach by combining two frameworks, eTOM and the European Telecommunications Standards Institute (ETSI) NFV framework, for dynamic service delivery with improved resource performance and quality of service in order to meet some of the purposes of the 5G technology with reference to a virtualized mobile environment managed and orchestrated by the mixture of the aforementioned frameworks.

In contrast to our former publication [13], this first part of our contribution includes many enhancements in terms of the function mapping between eTOM and NFV by defining only three subfunctions instead of four and by making corrections to some preceding false statements about the reasons for defining each new mapping subfunction – new mapped elements. Furthermore, we suggest an approach towards the mapping between the 5G network’s domains and the ETSI NFV framework’s functional blocks so as to introduce the 5G centric function mapping of the level 2 eTOM model upon the ETSI NFV framework through resource management and operations mapping as well as through service management and operations mapping. In addition, during simulations, we include a new eTOM level 2 process, the RTM process, in the process interactions diagram to validate our proposal through the implementation of a VNFM based on a computer script in order to dynamically manage the lifecycle of signaling service resource instances, including IP Multimedia Subsystem (IMS) VNF instances, according to predefined thresholds related to virtualized signaling resource performance indicators in the case of the delivery of video on demand (VoD) services over the IMS network.

In the second part of our contribution, we present our proposed approaches regarding service function chaining (SFC) [15, 16, 17] through probable designs and analyses of dynamic mobile service chain provisioning [18, 19, 20] to support end-to-end (E2E) network slicing [21, 22] inside virtualized mobile networks – the 5G network – in considering data and signaling traffic flows, respectively, for the SGI Local Area Network (SGI-LAN) and for the packet data network (PDN), which incorporates application platforms such as the IMS [23, 24] core network. Effectively, we base this dynamic implementation of the traffic into disparate technology domains on a paradigm that segregates the control plane from the forwarding plane by introducing new controller interfaces and functions.

In effect, compared to our previous publication [14], this second part of our contribution includes five main improvements: First, correlating network slicing and SFC for the delivery of E2E services within 5G in an automated fashion; secondly, enhancing the NFV orchestration layer of the proposed SFC centered mobile network design for the 5G network by splitting it up into two NFV orchestration sublayers – a multi-domain NFV Management and Orchestration (MANO) sublayer and a domain-specific NFV MANO sublayer; thirdly, improving the suggested IMS based dynamic and static SFC designs; fourthly, highlighting the role of the VNFM during the simulations in managing the lifecycle of the IMS VNFs composing the signaling service chain allowing for the signaling session establishment conforming to virtualized signaling resource performance thresholds while providing VoD services through the IMS network; and finally, detailing in the Benchmark Results subsection the signaling service chain delivery context, including signaling service chains – one signaling service chain and then two signaling service chains.

As discussed in Sections 4, 5 and 6, the two parts of our contribution are closely related for the reason that the NFV orchestration layer’s components – the ETSI NFV MANO’s components –, which are mapped to Resource Management and Operations (RMO) – part of the eTOM level 1 model –, contribute through SDN controllers to the application of our SFC approach in each of the 5G operator’s technology domains for delivery of end-to-end services in an automated fashion by selecting the efficient available path. In effect, the activation of SFC mechanisms is conducted by Service Management and Operations (SMO) – an eTOM level 1 model’s element –, which is mapped to NGOSS – an ETSI NFV framework’s element –, by interacting with the MANO functional block, especially its management function, the NFV Orchestrator (NFVO), through its exposed APIs. Taking into account the above considerations, the second part of our study – the SFC proposal – depends mainly on the first part – the eTOM mapping onto NFV approach. Additionally, this relationship between both of the parts is obviously established in the case of dynamic SFC. In effect, the experimental validation of our study was limited to static SFC, whereas dynamic SFC is planned for future research.

In this article, we regard the IMS core network as a use case for flexible signaling service chaining. Thus, we study, in connection with this signaling network, two approaches, static and dynamic SFC approaches, for effective steering of the signaling traffic with respect to load balancing [25, 26] specifications.

At the end, we implement part of our eTOM to NFV mapping approach, and then we validate part of our SFC proposal for static signaling service chaining through two signaling service chains in a virtualized, distributed IMS network using a testbed setup.

Indeed, our implementation was carried out within the OpenStack ecosystem [27, 28]. Within the Benchmarks section, we pinpoint our proof of concept and discuss resource performance and IMS performance indicators in this extended, virtualized business process context regarding the service delivery of media streams – VoD services – on top of signaling services through the signaling service chains in question, in the context of the IMS.

2. Background information

Given the continuous changes within the telecommunications industry, MNOs should take into consideration models produced by standards bodies to adapt to changing technologies. These models are either abstract or semi concrete, and they are, in effect, issued by telecommunication professionals, and updates are regularly delivered.
2.1. eTOM framework

To support telecommunications service providers (TSPs), which include MNOs, in managing their business through functional blocks and processes, the TeleManagement Forum has been developing the NGOSS standard – Framework. It is presented as a toolkit of specification guidelines incorporating key business and technical parts, namely:

- Telecom Application Map framework
- eTOM business process framework
- Shared Information/Data model

As a key part of NGOSS, eTOM is a submodel covering all of the business processes within the operations area for the delivery of high quality, E2E business services.

Four business domains compose the eTOM operations area in this manner:

- Customer domain
- Service domain
- Resource domain
- Supplier/Partner domain

The abstracted description of the various steps related to the delivery of the business service is outlined in the eTOM business map. In this context and through a given projection of their business on this mapping model, TSPs could tailor their operations to the specifications of the exposed business processes with the goal of having a telecommunication system functioning properly according to the recommendations issued by standardization bodies.

Four principal operations business process groupings compose the eTOM model, as follows:

- Operations Support and Readiness (OSR)
- Fulfillment
- Service Assurance (SA)
- Billing and Revenue Management (BRM)

With reference to the lifecycle of the business service delivered to the customer, the fulfillment of the service within the Fulfillment business process grouping is regarded as the most significant stage. OSR is the first involved process grouping. It permits support and automation for the benefit of the other vertical process groupings – Fulfillment, SA, and BRM (FAB). Within this E2E process lifecycle, the Fulfillment process grouping happens before the SA that is set off in considering QoS and service level agreement (SLA) management, plus the monitoring of provided services and resource performance, and finally, the BRM business process grouping is executed.

2.2. Network functions virtualization and service function chaining

Virtualizing and deploying network functions upon commercial off-the-shelf servers are one of the main aims of the NFV approach. In addition, the NFV principle aims, through a predefined operational system, at orchestrating the lifecycle of network services.

The ETSI NFV framework is a unified framework for NFV. It includes all the basic functional blocks to implement in order to establish a virtualized, orchestrated network ecosystem. This framework embraces five functional blocks including OSS/BSS, EMS, the VNF functional block, NFV Infrastructure (NFVI), and the MANO functional block [29] which includes, consecutively, NFVO, VNFM, and Virtualized Infrastructure Manager (VIM).

SFC is commonly thought of as an SDN approach. It is a novel process dedicated to take precedence over the basic forwarding based on the destination. It is often used in association with NFV when defining a chain of virtualized network functions that would have typically deployed as physical network appliances joined in series by the means of network cables. In effect, when using traditional physical routing appliances, data traffic passes through network nodes selected by routing table search on the packet’s destination IP address. However, with the SFC approach, data traffic flows through an overlying network [30] according to a defined path, called a service function (SF) chain in the IETF terminology [31].

2.3. The 5 generation technology

Proportional to the 4G/LTE architectural framework, the Evolved Packet System is composed of a radio access network (RAN) known as Evolved Universal Terrestrial RAN, also referred to as LTE, and a packet core network termed Evolved Packet Core, also called System Architecture Evolution. The core components of the 4G/LTE technology are Mobility Management Element (MME), Home Subscriber Server (HSS), Policies and Charging Rules Function (PCRF), Serving Gateway (S-GW), and PDN Gateway (P-GW). Authentication, control, and charging are among the key features of the core network. P-GW and S-GW process both the control and data levels’ traffic.

5G is a new technology in progression towards standardization by telecommunication standardization bodies by 2020. It is evolving from the 4G technology to enhance telecommunication system performance, to support openness, and to reduce infrastructure costs and time to market. Virtualization and the separation between the control plane and the data plane [32] characterize the 5G network technology.

Figure 1 displays the overall 5G system architecture. It consists of four planes, including three horizontal planes and one transverse vertical plane, as follows:

- Service Layer: This plane includes instances of the higher level services delivered to customers based on the related network architecture from the below plane.
- Network Layer: It includes a set of instances of logical networks, referred to as network slices, which are constructed on top of the Resource Layer by combining a group of physical and virtual network functions.
- Resource Layer: This layer provides support for the logical networks by making available physical and virtualized infrastructure resources.
- Network and Service Management and Orchestration [33, 34]: This transverse plane manages and orchestrates end-user service instance lifecycle, network instance lifecycle, and resources.

As a sublayer of the 5G service layer, The IMS [35] is a network architecture defined to request and provide multimedia and voice services via an IP network from and to wire-line and wireless technologies, independently of access networks. Convergence between mobile and fixed networks is the primary aim of IMS. The Session Initiation Protocol (SIP) [36] is one of the IETF protocols utilized within the IMS to establish
signaling mechanisms with the help of Call Session Control Functions (CSCFs), including Proxy-CSCF (P-CSCF), Interrogating-CSCF (I-CSCF), and Serving-CSCF (S-CSCF).

3. Related works

The first part of our contribution concerns the mapping between eTOM and the NFV framework. In relation to this subject, a small number of publications that deal with the question of the mapping of the eTOM business process model upon mobile network systems can be identified in the literature. In the same way, not many researchers have studied the projection of eTOM on the NFV architectural framework.

Compared to our preceding work [13], the first part of our contribution included four principal improvements: First, defining only three submappings in lieu of four; second, making rectification of some previous justifications for the definition of each new submapping – new mapped elements; third, suggesting an approach towards the mapping between the ETSI NFV framework's functional blocks and the 5G network's domains with the goal of introducing the 5G centric function mapping of the level 2 eTOM model on the ETSI NFV framework through resource management and operations mapping as well as through service management and operations mapping; and fourthly, incorporating, during the simulations, a new eTOM level 2 process, the RTM process, within the process interactions diagram to validate our proposal through the implementation of a VNF.

Miyamoto et al. [37] put forward an eTOM level 5 workflow, the HEAL Resource Trouble workflow, and they conducted mapping between that workflow's tasks and the NFV MANO framework. In addition, they validated their proposed approach in the context of a link down failure of a physical router owing to SF path (SFP) failure. Nonetheless, a main drawback of this research is that not a testbed system was set up nor simulation results were cited or discussed. Compared to this study, our approach considered the mapping of both the eTOM level 1 and eTOM level 2 models upon the whole ETSI NFV architectural framework taking into consideration the RTM eTOM level 2 process. Furthermore, we validated our proposal within a testbed environment through a process interactions diagram in considering a VNFM that was deployed based on a computer script in order to dynamically control and manage IMS VNFs depending on predefined threshold values linked to virtualized signaling resource performance indicators regarding VoD service provisioning over the IMS network, and we discussed the corresponding results that showed better performance in terms of virtualized resources as well as IMS applications.

Raouyane et al. [38] exposed an IMS management system based on eTOM for the management of E2E high-level services in the context of the IMS core network, with no considerations for virtualization. This study made a projection of the eTOM framework on the IMS network by implementing monitoring mechanisms of eTOM business procedures in real time for SLA verification. However, in our work, we conducted the mapping in a virtualized environment taking into consideration the ETSI NFV standard in accordance with the eTOM operations business area. Additionally, we validated, in this earlier study, a part of our proposed system principally regarding the performance side – resource and application performance. However, QoS aspects including SLA verification in this virtualized context will be addressed in our future works.

The author of the work [39] conducted a general analysis of NFV design and operations management processes using ITIL and eTOM. In our work, we carried out an analysis of the relationship between eTOM and the ETSI NFV framework based on the function mapping between them. In fact, in this study, we defined three mapping functions instead of four as we indicated in our previous work [13].

The second part of our contribution concerns our SFC proposal. In considering the question of the implementation of SFC in mobile networks, mainly within the context of the IMS ecosystem, few publications have been reported in the literature.

The second part of our study depends chiefly upon the first part because of the fact that the ETSI NFV MANO's components, which are mapped to part of the eTOM level 1 model – RMO –, contribute in addition to SDN controllers to the application of SFC mechanisms in each of the 5G operator's technology domains. Indeed, the SFC mechanisms are activated by SMO – an eTOM level 1 model's element –, which is mapped to NGOSS – an ETSI NFV framework's element –, by interacting with the MANO functional block, especially the NFVO.

As opposed to our previous work [14], this second part of our contribution included five main enhancements. Initially, we correlated network slicing with SFC for the effective automated provision of E2E services within the 5G network. In addition, we changed the NFV orchestration plane of the proposed SFC centered mobile network design for the 5G network by dividing it into two NFV orchestration subplanes – a multi-domain NFV MANO subplane and a domain-specific NFV MANO subplane. Furthermore, we enhanced the designs of the proposed IMS based dynamic and static SFC. Moreover, we emphasized the primary role of the VNFM during the simulations in managing the lifecycle of the IMS VNFs composing the signaling service. Lastly, we detailed the evaluated signaling service chain provisioning context that included signaling service chains – one signaling service chain and then two signaling service chains.

To conduct effective mobile service steering within the (S)Gi-LAN, an introductory 3rd Generation Partnership Project (3GPP) study [40] discussed different use cases to support network traffic classification as well as network service chain selection techniques per mobile operator's policies. Nevertheless, the main weakness of this study is that no experimental evaluations were accomplished. In comparison with this study, our work put forward network solutions based on SFC for the whole 5G network, counting the PDN, through the mapping between the 5G network and the ETSI NFV architecture and through the proposed architectures which included principles and components related to SFC. Additionally, an experimental assessment was performed to validate our proposal.

To analyze and evaluate architectural improvements on the former study [40], an additional 3GPP study [41] was published. The upgraded study exposed these enhancements to issue mobile service steering policies for each of the 3GPP service requirements defined in the technical specification (TS) 22.101 [42]. Moreover, this technical report discussed only the delivery of policies for traffic steering by means of 3GPP standardized interfaces, including the interface St. On the contrary, our contribution took a special interest in the NFV and SDN initiatives for handling mobile service steering within a virtualized environment by either the abstraction of the control plane from the forwarding plane or by the application of SFC mechanisms. Furthermore, we suggested a new function for routing signaling traffic to meet the new signaling steering specifications defined in our study.

Gromsund et al. [43] virtualized services upon the SGi-LAN through an implemented solution using NFV and SDN technologies. Unfortunately, the authors presented their results without charts in the case where the number of subscribers increases. In contrast to this study, our implementation was achieved in association with signaling services within an IMS network, as an unfinished implementation, through the implementation of a domain-specific VIM and a domain-specific VNFM for managing the virtualized network/signaling resources and the lifecycle of VNFs, respectively. Moreover, in the context of our new virtualized, scalable platform, we obtained promising results, mainly in terms of setup time and registration delay.

Based on the Intel Open Network Platform reference architecture, researchers from Intel [44] gave technical details about the assessment and testing processes of dynamic SFC. OpenStack, the OpenDaylight (ODL) SDN controller, Open vSwitches (OVSes) and the Intel Data Plane Development Kit composed the evaluation platform. Regarding our work, we used almost the same open source tools apart from Intel-specific tools to validate our static solution. In effect, we plan to develop, in
addition to a VNFM-related script, further computer scripts to get flexible and effective dynamic service chain delivery with the support of the ODL controller.

In their publication [45], researchers presented an experimental work about the OpenStack SFC extension. The limitations of this study are that the data plane was negatively impacted and also this study was solely based on the OpenStack extension without considering external SDN controllers. Similar to this work, we based our study on the OpenStack platform but without taking into account its SFC extension that we intend to implement in the upcoming work, but our work exposed theoretical designs and analysis of the principles and components of SFC besides an experimental setup using static SFC – static signaling service chaining – through one signaling service chain and then through two signaling service chains. Moreover, our study shed light over the theoretical integration of the SDN management plane.

Based on the NFV concept, Dandin et al. [46] carried out dynamic load balancing within the IMS core network. In opposition to this research, our common approach supported new functionalities for signaling services in the PDN, including IMS signaling services, with the aim of, for instance, conducting dynamic load balancing through a proposed signaling controller function. During the simulations, we carried out static load balancing using one signaling service chain and after that two signaling service chains.

Duan et al. [47] designed ScalIMS, a dynamic scaling system for geo-distributed VNF service chains in the context of the IMS. The main difference between ScalIMS and our SFC approach is that the scaling of service chains is both proactive and reactive in the case of ScalIMS. However, our VNF-related scaling approach is reactive founded, in this preliminary contribution, on a VNFM-related computer script that dynamically scales out and scales in certain of the IMS VNFs composing signaling service chains based on some specific thresholds associated with virtualized signaling resource performance indicators.

4. eTOM mapping onto NFV approach

In the previous study [13], we put forward a new approach mapping eTOM into the NFV framework. Nonetheless, in this study, we extend that work for enhancement purposes by defining only three subfunctions in lieu of four and by making rectification of some previous false statements about the reasons for the definition of each new mapping subfunction – new mapped components.

The diagram of the suggested function mapping of eTOM on NFV is drawn in Figure 2.

The NGOSS based OSS/BSS system offers innovative functionalities that conform to the evolution of the telecommunications industry nowadays by making eTOM as a reference framework for linking and exploring E2E business processes with regard to telecommunication management. Therefore, the first proposition is to advance the legacy OSS/BSS system to the NGOSS based OSS/BSS system.

We define a general function \( f \) from the eTOM business framework to the NFV architecture and an inverse general function \( f^{-1} \) from the NFV framework to eTOM in such a way:

\[
\begin{align*}
& f : \text{eTOM} \rightarrow \text{NFV} \\
& f^{-1} : \text{NFV} \rightarrow \text{eTOM}
\end{align*}
\]

The function \( f \) maps the eTOM operating model framework to the NFV framework, whereas the inverse function \( f^{-1} \) maps the NFV architecture to the eTOM business process framework. Furthermore, the subfunctions – mapping functions – we define are typically onto functions as every element in the codomains of those subfunctions there exists at least one corresponding element in their domains.

As a result, we define two sets along these lines:

\[
\begin{align*}
& \text{eTOM} = \{\text{OSR, CRM, SMO, RMO, SRM}\} \\
& \text{NFV} = \{\text{NGOSS, EMS, VNF, NFVI}\} \cup \{\text{NFVO, VNFM, VIM}\}
\end{align*}
\]

The diagram of the function mapping is therefore outlined within Figure 3.

In consequence of the mapping between eTOM and the ETSI NFV network architecture, we define three subfunctions. These subfunctions are \( M1(), M2(), \) and \( M3() \).

Concerning the subfunction \( M1() \), four ordered pairs are probable (1):

\[
\begin{align*}
& M1(\text{OSR}) = \text{NGOSS} \\
& M1(\text{CRM}) = \text{NGOSS} \\
& M1(\text{SMO}) = \text{NGOSS} \\
& M1(\text{SRM}) = \text{NGOSS}
\end{align*}
\]

This mapping function maps OSR, Customer Relationship Management (CRM), SMO, and Supplier Relationship Management (SRM) to NGOSS. Indeed, NGOSS agrees with the suggestion and implementation of telecommunication solutions besides the ETSI NFV architectural framework and at the same time encompasses eTOM as its basic component. However, OSR is the back office system that provides support and automation for other process groupings – FAB. CRM and SRM represent, respectively, all kinds of contact with the customer who

![Figure 2. Function mapping of level 1 eTOM upon ETSI NFV [13].](Image)
reasons the mapping between RMO and these ETSI NFV's elements is fulfilled, but the resource management, in this case, relates only to virtualized resources. In fact, the NFVO exposes APIs to SMO to manage the necessary NFV resources for the delivery of adequate network/signaling services. VIM controls and manages virtualized resources within the NFVI, whereas VNFM invokes either directly upon the VIM or indirectly upon the NFVO virtualized resources management operations.

Obviously two elements of the NFV ETSI domain are left unmapped because of the fact they are managed objects, not management functions. Those elements are, in effect, NFVI and VNF.

5. 5G mapping pattern

Network operators consider that NFV is a key enabler for 5G [48, 49, 50]. Quite a few NFV key features are addressed in standardization bodies, such as network slicing, cloud-native network functions, and E2E service management.

In our subsequent 5G mapping approaches, we consider network slicing, resource management, and E2E service management as NFV key characteristics in combination with eTOM and SDN [51] perspectives.

In effect, network slicing [52, 53] is an E2E concept spanning over the entire 5G operator's technology domains. For this reason, it is useful to propose an NFV-based architecture so as to manage and orchestrate network slices that support the E2E business services provided to 5G customers.

Figure 4 outlines the proposed 5G NFV MANO architecture, which reflects the mapping between the 5G network's domains and the ETSI NFV architectural framework's functional blocks. The architecture is an extension of the ETSI NFV framework, and it enables MNOs to manage and orchestrate NFV network/signaling resources, VNFS constituting network/signaling services, network and/or signaling services composing network slices in an abstract manner through isolated technology domains, including RAN, the core network, SGi-LAN, and PDN. The higher level includes a multi-domain E2E NFV MANO entity that interacts at the lowest level with domain-specific NFV MANO entities to coordinate the creation of E2E network services and slices.

Within both levels, each NFV MANO entity includes its own NFVO and VNFM in addition to the VIM that is hosted only in each of the lowest layer's entities to manage and orchestrate domain-specific NFVI resources in an independent way. Furthermore, each of the lowest level's NFV MANO entities exposes a northbound interface to the E2E NFV MANO level to be capable of creating E2E network services and coordinating the creation of E2E network services and slices that extend the operator's technology domains. A specific network slicing OSS functional area, which needs to be standardized, operates on top of the higher level NFV MANO entity to manage the lifecycle of network slices.

In the second 5G based mapping approach relative to the eTOM framework, the proposed model is somewhat similar to the model derived from the mixture of the ETSI NFV architectural framework and the eTOM business framework, as defined in the earlier section. Nonetheless, as depicted in Figure 5, the focus of the suggested 5G based mapping model is upon all the horizontal level 1 business process groupings in company with E2E vertical level 1 process groupings in the framework of the eTOM operations area.

Moreover, in the following subsections we examine the level 2 core processes that work together in order to deliver service streams and further E2E processes. Every core process within the operations eTOM framework is typically a fraction of one vertical process grouping and one horizontal level 1 process grouping. In a few situations, a level 2 process crosses quite a lot of level 1 verticals because the process in question is needed in numerous vertical level 1 groupings.

5.1. Resource management and operations mapping

As pinpointed in Section 4, the NFVO, VNFM, and VIM could be matched to RMO due to the fact both the ETSI NFV architectural framework's elements and the eTOM's elements get involved in the management of the lifecycle of virtualized resources beneath the lifecycle process of the network/signaling service.

As outlined in Figure 5, within the resource process grouping, we can define a composite business process for mobile resource provisioning by amalgamating three core level 2 processes, Resource Management and
Operations (RM&O) Support and Readiness, Resource Provisioning (RP) core process, and the Resource Performance Management (RPM) level 2 process. At the same time as the execution of those resource core processes, the Resource Data Collection and Distribution (RDC&D) process is conducted as well.

Indeed, the RM&O Support and Readiness represents the back office area that enables support and automation for both of the two core processes, the Resource Data Collection and Distribution (RDC&D) process is conducted as well.

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From the viewpoint of the NFV network architecture, resources could be physical or virtual. If they are physical, they will be the underlying hardware support for the domain-specific NFVI functional block, and therefore they will be typically managed by a dedicated OSS instance associated to the physical datacenter over which that NFVI is built. In the contrary case, the resources will be allocated in virtualized forms by the domain-specific VIM either at the direct request of the domain-specific VNFM or at the indirect request of the domain-specific VNFO with the aim of supporting VNFs. Indeed, the domain-specific VIM controls and manages virtualized resources within the domain-specific NFVI, whereas the domain-specific VNFM invokes either directly upon the domain-specific VIM or indirectly upon the domain-specific NFVO virtualized resources management operations.
5.2. Service management and operations mapping

As delineated in Section 4, the SMO can be mapped onto NGOSS as both the eTOM's element and the ETSI NFV architecture's element take part in the management of the lifecycle of the E2E business service provided to MNOs' customers. As shown in Figure 5, inside of the service process grouping, we can, similar to the resource process grouping, thoroughly define a composite business process for service delivery by chaining three core processes, Service Management and Operations (SM&O) Support and Readiness, Service Configuration and Activation (SCA), and the Service Quality Management (SQM) core process. In fact, SM&O Support and Readiness corresponds to the back office environment allowing support and automation for the two other core processes, SCA and SQM. Moreover, SCA makes possible the configuration and activation of the requested service, while SQM, as the closing core process in this service chain, allows MNOs to manage QoS requirements for the higher layer services provided to their 5G customers.

SMO interfaces with the higher level NFVO that exposes APIs for the proper execution of those NGOSS-related processes. The higher level NFVO functional block in turn manages the E2E network service lifecycle as well as coordinates the management of the E2E network service cycle, the VNF lifecycle being underpinned by the domain-specific VNFM, and the NFVI resources being supported by the domain-specific VIM to guarantee an optimized, automated allocation of related resources and connectivity. Within the 5G environment, the VNFs typically related to the RAN, core network [54, 55, 56], SGi-LAN, and PDN could be abstracted from the underlying hardware infrastructure and placed in the VNF functional block in order to get involved in the establishment of network/signaling service chains with reference to the service description provided by the NGOSS functional block. These 5G VNFs are indirectly managed by the higher level NFVO by the use of the higher level VNFM.

In general, SMO interacts with the MANO functional block, mainly the NFVO, for the activation of SFC mechanisms. Indeed, The MANO's components, which are mapped to RMO, in turn, contribute through SDN controllers to the application of the SFC mechanisms in each of the 5G operator's technology domains, as discussed in the next section.

6. Service function chaining proposal

6.1. Description of the problem relative to SFC

The provision of E2E services usually requires diverse SFs. The definition as well as the instantiation of a set of connected SFs – SF chains – in addition to traffic steering through them is referred to as SFC. In classical service delivery, the human intervention is required to set up and follow the SFC feature, which may require many manual steps. Moreover, the current mobile models related to SF deployment are fairly static, coupled to physical resources and network topology, which makes MNOs unable to dynamically create SF chains, to instantiate new services or to remove them as needed.

In terms of optimization and performance, these static models do not use the best available routing path and therefore do not enable MNOs to optimize the use of network resources and applications, which negatively impacts resource and application performance. The recent research which focuses on the question of service delivery within the framework of the 5G technology deals with the aforementioned constraints to some degree, but they do not propose a detailed solution as we did in this study. The current proposed SFC approaches are, in effect, related especially to the SGi-LAN for network services without considering the PDN for signaling services. In the same context, several studies discuss network slicing as one of the perspectives of the 5G technology, but they do not match it to SFC in a clarified fashion.

Effectively, our solution, as described later, addresses in a detailed manner all of the limitations of those classical models, for delivery of end-to-end services in an automated fashion by selecting the efficient available chain based on the NFV orchestration layer through SDN controllers. Furthermore, as mentioned in Sections 4 and 5, the MANO's components are well mapped to RMO – an eTOM level 1 model's element – which allows for the optimization of the use of network resources and thus to enhance resource performance as well as application performance for QoS considerations. Furthermore, in our contribution, we correlate network slicing with SFC for delivery of E2E services within 5G in an automated manner, as described in the following subsection.

The subsection below, which is dedicated to the description of the solution relative to SFC, describes an architecture used for the creation and supervision of SF chains in the context of the 5G network. It includes SFC-related architectural concepts and components, with a focus of including those concepts and components in both the SGi-LAN and PDN for handling and steering data and signaling traffic flows, respectively.

6.2. Description of the solution relative to SFC

The SFC mechanism supports dynamic chaining while building an SF chain and also a topology independent virtual network [57, 58] in a way that it depends neither on the underlying hardware nor on the underlay network. Indeed, this section defines the key designs and analyses of the SFC architecture [59, 60] that we put forward to be an extension of the proposed 5G architecture illustrated in Figure 4 of Section 5. It includes, in effect, SFC-related architectural details.

Typically, according to the network slicing concept, a network slice can serve as a logical network or an SF chain. As depicted in Figure 4, in each 5G technology domain we can define a specific SF chain as a sub-slice. Hence, combining those domain-specific subslices composes an E2E network slice. In our approach, we discuss network slicing at the lowest layer through SFC particularly in the SGi-LAN and PDN technology domains for data traffic and signaling traffic steering, respectively.

Both the NFV and SDN approaches are identical in nature in the sense that they include placing network management from the hardware plane to the software one. For this reason, we have to take account both those concepts while designing a new proposed architectural framework that meets 5G opportunities in accordance with virtualization, automation, and the abstraction of the control plane from the user plane.

The design of our SFC proposal is illustrated in Figure 6. This virtualized environment is controlled by an NFV orchestration layer that consists of a multi-domain NFV MANO sublayer and a domain-specific NFV MANO sublayer. The first sublayer represents a multi-domain NFV MANO system that manages the forwarding plane and control plane components in a distributed manner. However, the second sublayer corresponds to domain-specific NFV MANO entities that embrace an SDN controller each. In effect, the domain-specific NFV MANO entity interacts with the SDN controller for SFC implementation, whereas the SDN controller manages the control plane [61] at a central level through SDN applications in the form of VNFs.

The NFVI point of presence (NFVI-PoP) 1 hosts mobile access services in a disconnected manner, that is, the control functions of S-GW and P-GW are separated from their data plane functions. Consequently, the control elements, including MME, HSS, PCRF, P-GW-C and S-GW-C are moved to the control level, but the gateways that process data traffic, including P-GW-U and S-GW-U, remain in the user level.

The NFVI-PoP2 is a site for SGi-LAN in which network-based services are operated. Within this network, the concept of SDN is performed; therefore, at the control level we set a new function that is specified by 3GPP [41], called Service Chain Traffic Controller Function (SCTCF) for effective traffic steering. Moreover, the 3GPP technical review [41] defined an interface between the PCRF and the SCTCF, termed St. This interface supplies the SCTCF with traffic steering rules for dynamic and coordinated implementation of SFC inside the SGi-LAN. At the forwarding level, we specify our SFC-enabled domain that consists of two SFC-enabled subdomains: a service control function (SCF) subdomain for SFC encapsulation and traffic classification and an SFP subdomain for...
SFC. For the SCF subdomain, it includes two classifiers at the edge, Ingress and Egress nodes, which fulfill the roles of classification and reclassification, respectively, of mobile subscriber's data flows before and after performing the required SF chain. In addition, it includes a Service Function Forwarder (SFF) whose responsibility is to route SFC-encapsulated packets to suitable SFs or through an SFC proxy which de-capsulates packets before forwarding them toward SCF-unaware SFs. The SFP subdomain includes the SFP that draws a set of connected SFs that are engaged in providing requested network services. It comprises two forms of functions, SFC-aware functions and SFC-unaware functions.

Our main approach, which is related to the dynamic management of the signaling service, is defined with respect to the third fragment—the NFVI-PoP3—that hosts operator-based services referred to as application platforms including, for example, the IMS.

Accordingly, the PDN is considered in this study as it hosts operator-based services, including signaling services. In the control plane we suggest a new function that we name Service Chain Signaling Controller Function (SCSCF) for flexible signaling steering. In addition, the 3GPP previously standardized a reference point between PCRF and the Application Function in the TS 23.203 [62], called Rx. However in our common, proposed approach, that interface may change or remain as it is, in that it is located between the SCSCF and PCRF. This reference point, among other features, would enable the PCRF to provide signaling steering policies to the SCSCF for more coordinated and comprehensive implementation of dynamic SFC inside the signaling-related PDN. In the data plane, we define our SFC-enabled domain that consists of two SFC-enabled subdomains: an SCF subdomain for SFC encapsulation and for the classification of signaling traffic and an SFP subdomain for signaling service chaining. For the SCF subdomain, it comprises two classifiers at the edge, Ingress and Egress Edges, used for classification and reclassification, respectively, of signaling traffic flows before and after conducting the requisite SF chain. In addition, it comprises an SFF that routes SFC-encapsulated packets to the requisite SF or through an SFC proxy which de-capsulates packets before sending them on to SCF-unaware SFs. The SFP subdomain incorporates the SFP that makes a collection of signaling SFs included in offering an appropriate signaling service. It contains two kinds of functions, SFC-aware and SFC-unaware functions.

In this conceptual framework, a multi-domain E2E NFV MANO entity interacts with domain-specific NFV MANO entities. Each domain-specific NFV MANO entity is linked to the domain-specific SDN controller that, in turn, is connected to its correspondent technology domain for controlling the traffic that flows through virtual switches or SDN compliant hardware using an SFC-encapsulation protocol, by way of its southbound API. Nevertheless, the northbound interface is used to communicate with the domain-specific NFV MANO entity and the PCRF through the service chain controller functions—SCSCF and SCSCF. The SFC encapsulation is defined by Network Service Header (NSH) [63] which is typically carried by encapsulated packets in order to be processed by the SCFs and then forwarded to appropriate SFs, taking into account the information included in the SFC encapsulation. Several SDN controllers exist at the present time, but ODL [64] is one of the leading solutions being the most widely used by the SDN community.

NFV makes necessary the migration of network functions to the cloud computing environment. In accordance with this principle and in proportion to the ETSI NFV framework, the multi-domain NFV MANO entity helps in coordinating the management of the E2E network service lifecycle, the VNF lifecycle, and the NFVI resources. In effect, SDN applications could be represented as VNFs. For that reason the existence of both SDN and NFV technologies is complementary. Furthermore, the SGi-LAN-specific NFV MANO entity interacts with the SGi-LAN-specific SDN controller by way of the SCTCF which receives traffic steering policies from the PCRF by means of the interface St. However, the PDN-specific NFV MANO entity interacts with the PDN-specific SDN controller by way of the SCSCF which receives signaling steering policies from the PCRF through the interface Rx. These interactions between the domain-specific NFV MANO entities and the service chain controller functions are
conducted with the goal of implementing dynamic SFC within the requisite network depending on the service description.

7. Service function chaining mechanisms: IMS use case

The provision of services might take place according to two approaches existing at this time. The first approach is the static one, which focuses in providing services by connecting SFs in a static manner. The second one is the dynamic approach, which might be as an implementation of an NFV MANO framework like the ETSI NFV MANO model.

Within the PDN technology domain, the IMS SFC mechanism enables domain-specific network slicing in the form of subslices that are constructed of one or more virtual IMS entities.

7.1. Dynamic IMS service function chaining mechanism

Dynamic signaling service provisioning based on IMS must be found, apart from VIM, on an explicit paradigm. The ETSI NFV framework is broadly maintained by the NFV community as it provides an entire model to implement NFV solutions designed for dynamic service chaining [65]. An implementation of that paradigm might consider some modules, including:

- NFVO: NFV orchestrator is a functional block that generally manages the signaling service lifecycle and coordinates the management of the signaling service chain lifecycle – the signaling service lifecycle – and the IMS VNF lifecycle. Moreover, it coordinates the management of NFVI resources being supported by the VIM to make an optimized allocation of the necessary resources and connectivity.
- VNFM: VNF Manager is responsible for the lifecycle management of signaling service resource instances, including IMS VNF instances, based on the VNF component and VNF descriptor.

Three other modules could be deployed with the help of common software solutions, such as:

- NFVI: The NFV Infrastructure represents the totality of all hardware and software components that make the environment where IMS VNFs are deployed. The NFVI is mainly based on a virtual machine manager (VMM) that abstracts the underlying hardware and separates the software plane from hardware. Concerning networking connectivity, virtual devices, such as OVSes, can be set up within this virtual infrastructure functional block.
- VIM: The Virtual Infrastructure Manager is a functional block that manages and controls NFVI compute, storage, and network/signaling resources, usually in the MNO’s infrastructure domain, that is, NFVI-PoP, in which we can build up the requisite SF chains. The VIM might be widely based on a cloud manager such as OpenStack that offers different sorts of APIs to manage compute, storage, and network/signaling resources.
- SDN controller: It is a piece of software that is classed as a network operating system with two categories of interfaces, northbound and southbound APIs. The northbound interface communicates with SDN applications like the SCSCF for controlling signaling traffic based on SFC policies [66] sent by the PCRF by way of the interface RX. However, the southbound interface is employed to be in control of SDN conformant appliances either physical or logical with the help of SDN-related protocols such as NetConf or OpenFlow [67]. Within an NFV milieu, virtual network appliances act as classifiers and forwarders so as to process the encapsulated packets taking into account SFC needs.

Figure 7 presents the design of the proposed IMS based dynamic SFC. The SFC mechanism is first instantiated by the domain-specific NFV MANO by the provision of signaling steering policies by the PCRF to the SCSCF through the interface RX. It is then fulfilled by the SCSCF through NSH being added and then transported by signaling packets for effective, dynamic steering of signaling traffic by the SCFs to the SFP domain that consists of pools of virtualized signaling service resources – virtualized IMS entities [68] –, including virtual P-CSCFs (vP-CSCFs), virtual I-CSCFs (vI-CSCFs), virtual S-CSCFs (vS-CSCFs), virtual HSSes (vHSSes), virtual Domain Name System servers (vDNSes), and virtual Application Servers (vASes).

![Figure 7](image.png)
Other capabilities could be delivered by the SCSCF, including dynamic load balancing commonly between the IMS VNFs through signaling service chains for better performance in terms of virtualized signaling resource indicators and IMS application indicators.

7.2. Static IMS service function chaining mechanism

Overall, providing a multimedia service based on the IMS is always introduced by both a registration procedure and then a session setup process. In this paragraph, we describe briefly the procedure of static signaling service delivery. In a virtualized milieu, the scenario of conducting those two outlined actions is the same as defined in 3GPP recommendations, except that all the IMS entities, including HSS, CSCFs, the Domain Name System (DNS) server, and SIP Application Server (AS) are in the form of VNFs.

We consider the performance of the virtualized resources assigned to those virtualized entities. Firstly, we deploy and launch in a static way those virtualized IMS entities to properly deliver the multimedia service on top of the signaling service.

With the support of a cloud manager and a VNFM, we can at whatever time based on virtualized resource performance notifications received by the VNFM add or remove a virtual IMS entity to or from the signaling service path.

Figure 8 depicts a static SFC design based on a virtual IMS. The virtualized IMS network is controlled and managed by both a domain-specific VIM and a domain-specific VNFM. The provision of signaling services is completed in a static manner, but the lifecycle of the virtualized IMS entities is dynamically managed by the VNFM depending on predefined thresholds connected to the performance of the associated virtualized signaling resources. In this state, for example, load balancing procedures are accomplished statically by a DNS server based on what is specified in the DNS zone file. Additionally, the instantiation, scalability, and termination of the IMS VNFs are carried out either manually through the VIM, or dynamically through the VNFM.

8. Benchmarks

To prove the feasibility of our proposed function mapping between the ETSI NFV framework and eTOM, we define in this section a testbed system being composed of several virtual and physical appliances for an IMS use case. Then, we evaluate part of the projected mapping approach in giving emphasis on a static signaling service chain provisioning, as prescribed in Section 7.2. The evaluation is made with regard to resource and IMS application performance. Afterward, we are discussing the experiment results obtained.

8.1. Process interactions diagram

Figure 9 figures the possible implemented process interactions between level 2 core processes, especially for the two vertical process groupings, Fulfillment and Assurance, in close interaction with the subsequent horizontal process domains. Simulated IMS subscribers can request an example VoD service immediately after static configuration of the service, and after the allocation and delivery of virtualized resources by means of a VIM.

In turn, the NFV architectural framework is presented with six functional blocks, for ultimate signaling service provisioning. NGOSS and EMS are well illustrated within this diagram to constitute a legacy IMS based OSS designed for the Fulfillment and Assurance level 1 business verticals. Then, the signaling service resources are separate IMS entities in virtualized forms – IMS VNFs – functioning on top of the NFVI that is managed by the VIM. The lifecycle management of those IMS VNFs is performed by a VNFM based on virtualized signaling resource performance. The VNFM is deployed based on a computer script, in which we defined some threshold values related to virtualized signaling resource performance indicators to dynamically scale out and scale in certain of the virtualized IMS entities.

An E2E business service delivery process is set off by an IMS subscriber’s request to be then handled in the Service Request Handling (SRH) core process which communicates first with the Customer Profile Management core process and after that with the SCA process. Next, the RP process is triggered, and then the RDC&D process is executed so as to gather and distribute virtualized resource-related data aimed at managing resource performance by virtue of the RPM core process. In the case of virtualized signaling resource performance degradation, the RTM process is executed.

8.2. Simulation platform

For performance benchmarks, the testbed system is implemented using 5 machines having 4 × 3.2 GHz CPU, 8 GB RAM, and Ubuntu 16.04 as a host system for each machine.

Figure 8. IMS based static SFC design [14].
The testbed setting is schemed in Figure 10. The shape is given in such a way:

- The first machine is dedicated to simulated IP television (IPTV) clients being deployed based on UCT IMS Clients. The SRH process is set up within this physical appliance. A customer-related agent is deployed in this machine to collect requisite data.

- The second machine corresponds to the Transport Layer. It includes the Mininet platform used to deploy a virtual network topology using python scripts. The topology routes data and control traffic flows for effective control by an SDN controller. Additionally, a virtualized resource-related agent is deployed there to collect requisite data from virtualized network resources, counting virtual switches.

- The third host represents the Service Control Layer in which virtual IMS core settings – vP-CSCFs, vI-CSCFs, vS-CSCFs, and vHSSes – are deployed with the aid of the OpenIMSCore [69] package for simulated signaling service chains, Xen as a VMM, and OVSes for linking diverse virtual IMS entities. Two other virtual servers, a DNS server – vDNS – and an IPTV AS – vAS – [70], are also deployed therein. Actually, this physical server hosts the SCA process. In addition, virtualized resource-related agents are deployed in this host to collect requisite data from the involved, virtualized signaling resources.

- The fourth server corresponds to the Service Application Layer, and it contains virtual media servers. This machine hosts a virtualized resource-related agent as well.

- The Fifth machine is regarded as a monitoring system [71, 72] as it hosts performance system along with an SDN controller which controls traffic flows at the Transport Layer. This machine hosts a central agent involved in the RDC&D process to collect and distribute data to the RPM core process for managing virtualized signaling resource...
performance. Furthermore, this machine includes the RTM process to get involved in the case of virtualized signaling resource trouble management.

OpenStack as the VIM is used in our evaluation platform to control and manage IMS VNFs manually and all the virtual network constituents – virtual switches – for both SDN and NFV considerations, and also to manage the NFVI resources by carrying out the RP level 2 core process.

The VNFM is deployed based on a computer script in order to dynamically control and manage IMS VNFs according to specific thresholds associated with virtualized signaling resource performance indicators.

8.3. Benchmark Results

We chose the IMS as a use case for this study. In this context, we aim to assess the implemented features of the above-mentioned level 2 core processes in accordance with the static signaling service chaining proposal.

Measurements were fulfilled in relation to IMS-related key performance indicators (KPIs) – application performance – and signaling resource performance indicators – resource performance. Hence, two sorts of measurements were performed. The first kind is related to signaling resource performance, chiefly for the interrogating server, I-CSCF, and the following measurement is from the client’s point of view for evaluating accessibility performance [73] supplied by IMS and network performance.

Two main core business processes were deployed to gather and format performance data respectively. These involved processes are RDC&D and RPM. In addition, the RTM process was deployed to get executed in the matter of virtualized signaling resource performance degradation.

We executed load testing for a hundred of simulated IPTV clients within two dissimilar signaling service chain delivery backgrounds as illustrated in Figure 11; with one signaling service chain and then with two signaling service chains.

Indeed, at the beginning, we launched the first signaling service chain, but according to the decision of the VNFM with regard to virtualized signaling resource performance related to the vI-CSCF1 entity, i.e. in the case of the degradation of the performance of the virtualized resource granted to vI-CSCF1 because of supposed signaling network congestion due to the increasing number of the simulated IPTV clients – signaling requests –, two principal entities were instantiated at the same time, including vP-CSCF2 and vI-CSCF2 to form the second signaling service chain.

The measurements related to virtualized resource performance indicators – system usage – concerned only the vI-CSCF1 before and after instantiating the second signaling service chain, including an assisting virtual server, vI-CSCF2.

We limited resource performance measurements to the vI-CSCF1-related virtualized resource – The virtualized signaling resource or VM that hosts vI-CSCF1 –, because vI-CSCF1 participates most throughout the registration procedure for requests/answers and because of static load balancing considerations.

In effect, throughout the IMS registration operation, I-CSCF is the most requested IMS component, as it is the intermediary between the visited network and the home network apropos a roaming access. Moreover, it communicates all through that process with three entities, P-CSCF, HSS, and S-CSCF. Another reflection is that before selecting a relevant I-CSCF, P-CSCF takes contact with the DNS server. Usually, a static load balancing is designed within the zone file through Service records (SRV records) in order to choose a suitable I-CSCF in contrast to a dynamic load balancing that is determined by the load of the server.

Taking into account those aspects, performance impact on the vI-CSCF1-related virtualized resource will be significant.
8.4. Results discussion

Simulation results were taken within two virtualized homologous contexts. The first situation concerned one signaling service chain and the second one incorporated two signaling service chains.

In effect, after exceeding predefined performance thresholds – after more than 20 simulated subscribers – due to the degradation of the performance of the virtualized resource assigned to v1-CSCF1, the VNFM took the decision to instantiate the subsequent signaling service chain so as to prove that it is significant to render signaling services, including the signaling session establishment, available by using part of the ETSI NFV functional blocks in association with the requisite eTOM core business processes and furthermore to maintain good resource performance in the case of increasing requests from service subscribers.

In respect of the delivery of signaling services, the mechanism of SFC has been carried out in a static way as an introductory to dynamic SFC, which is planned to be deployed when completing the implementation of the entire ETSI NFV MANO framework in association with eTOM processes in the near future.

Resource performance measurements were fulfilled with regard to the v1-CSCF1-related virtualized resource before and after scaling up the signaling services by instantiating a second service chain, including v1-CSCF2. The motivation behind the duplication of the v1-CSCF entity is that it is the most implicated within the registration operations, but the same considerations could apply to the other virtual IMS entities for increasing the availability of the signaling services.

Vis-à-vis the performance indicators of the virtualized resource assigned to the virtual signaling entity in question, i.e. v1-CSCF1, the memory usage, before and after making the second signaling service chain, lessened to some degree with nearly an average rate of 2%. In addition, the memory variation was smaller compared to the other metrics. After the second signaling service chain being set up, throughput considerably decreased, causing notably decreased CPU usage, which means that the static load balancing, assured by the SRV records inside the zone file of the DNS server, is concluded between the involved interrogating servers, v1-CSCF1 and v1-CSCF2, through two signaling service chains, as opposed to the case where the signaling traffic passes through only one v1-CSCF, i.e. one signaling service chain.

The improved virtualized resource performance indicators validates the availability of the signaling services with the existence of static signaling service chaining within an NFV milieu depending on the involved eTOM's processes.

The measurement charts, related to SIP KPIs, show the evolution of two key metrics, session setup time and register delay after exceeding 20 simulated subscribers.

In most situations, when the number of service subscribers augments, the number of registration as well as session setup requests thoroughly increases. Thus, resource performance could be degraded if there are no precautionary measures to keep the service available.

In view of that, the duplication of the IMS VNFs by the VNFM produced two signaling service paths each with its own IMS VNFs, resulting in enhancement of the virtualized signaling resource performance indicators, and therefore improving the IMS application performance indicators.

According to the simulation results, our proposed, virtualized, orchestrated IMS based mobile network system can retain good performance of the entire virtualized resources hosting the IMS VNFs involved in the delivery of the signaling service by supporting new signaling service chains to better respond to the growing number of service subscribers' requests.

9. Conclusions and perspectives

This article joined our two previous works together and showed the correlation between them, with the object of proposing new contributions in this new context. In effect, our article was divided in two parts, where each part corresponded to a given work, to compose our global contribution. The first part of our contribution was related to the mapping between two reference frameworks, eTOM and the ETSI NFV framework, the most broadly supported by the telecommunication community as key models to provide mobile services in a dynamic way and to align operational and business costs with network usage. However, the second part of our contribution put forward new approaches regarding dynamic mobile service chaining to support E2E network slicing within a virtualized background, and therefore enhancing traffic steering and the performance of the mobile system. Indeed, the relationship between the two parts of our contribution was founded on the principle that SMO, which is mapped to NGOSS – an ETSI NFV framework’s element –, interacts with the MANO functional block, mainly the NFVO, for the activation of SFC mechanisms, and the ETSI NFV MANO’s components, which are mapped to part of the eTOM level 1 model – RMO –, in turn, contribute through SDN controllers to the application of the SFC mechanisms in each of the 5G operator’s technology domains.
Basically, this work was a contribution to the evolution of 4G/LTE towards the 5G technology with reference to virtualization, business process, and SFC considerations.

The IMS was used within a virtualized environment as a use case in this study. The related measurements were made for static signaling service chain provisioning in two different contexts, with the help of an implemented VNFM for managing the lifecycle of the involved IMS VNFs composing the signaling service chains. As a result, enhancements were made to virtualized signaling resource performance indicators as well as IMS application performance indicators that included registration delay and session setup time.

In our upcoming research, we plan to corroborate by new experiments some or all of the new improvements reported in this article through the implementation of our dynamic SFC proposal. Moreover, in addition to the tested RPM core process, we intend to implement the SQM process for SLA and QoS considerations in close connection with the dynamic SFC approach.

Declarations

Author contribution statement

Y. Seraoui: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

B. Raouyane, M. Belmekki: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

M. Bellafkih: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Competing interest statement

The authors declare no conflict of interest.

Additonal information

No additional information is available for this paper.

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