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Towards information modeling for a QoS-aware support in the lifecycle of virtual networks

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***Abstract*—Information network modeling is nowadays a popular area of research. Especially, the introduction of virtualization technologies is changing the lifecycle of systems. Virtualization techniques allow distinguishing different levels: applications, networks, and equipment. The design of new virtual networks must consider the requirements of all these levels in a complementary fashion. Quality of Service (QoS) is still the one of the main key feature to be integrated.**

In this paper, we focus on the virtualized environments where we define a generic concept, called the VirtualElement. Indeed, we are interested in the representation of information enabling the automation of deployment, monitoring and management tasks for virtual networks. For this purpose we characterize the VirtualElement by constrains representing its functional and non-functional behavior. We apply our model at different phases of lifecycle of virtual networks by defining the service profiling. We propose a translation of the virtual network into an OVF file.

Keywords—virtual network, QoS modeling, virtual network service

I. INTRODUCTION

Nowadays, our digital society is a pool of uses and technologies that evolve very rapidly. Communication services and networks play an important role in our daily lives. The digital environment becomes a complex element, on the one hand due to the heterogeneity of the network environment (different and usable 3G, 4G, ADSL, etc.) and the new constraints (mobility, ubiquity and accessibility of services). Operators and suppliers must therefore increasingly take service offerings into account in their strategies, in order to satisfy demands according to new consumption patterns and uses. These challenges refer to QoS specification and guarantee, rapid introduction of new services and control of new solutions. Being able to adapt to new uses and quickly and efficiently deploy new network services is a major challenge in ensuring flexible implementation of on-demand services.

Currently, the introduction of virtualization at different levels (application, network, equipment) represents one of the mechanisms used to achieve these objectives of flexibility. The lifecycle of services is seen in this way to evolve allowing to introduce more dynamic treatments. In order to build virtual E2E (end-to-end) solutions where different operators deploy and manage their services, a generic QoS information model would provide a unified and platform-independent design approach. Integrate the QoS representation at each phase of the service lifecycle would allow the development of dynamic and continous provisioning, monitoring and management of shared resources (services, network and computing).

We are interesting in modeling the expected behavior of E2E solution, with a focus on virtual networks (VN). Currently, VN is considered as part of the infrastructure (i.e., with an equipment point of view). Being able to characterize the expected network service, as complementary information, should facilitate the dynamic adaptation of future network solutions. Such an information model will allow if necessary (according to changes in SLA, user mobility, etc.) the rapid substitution of virtual components through a dynamic virtual deployment. A very important challenge is related to maintaining the quality of service (QoS) in a dynamically changing environment, where network must conserve a reactive behavior.

We focus in this paper in the modeling of QoS information for virtualized environments. We begin with the study of current information models in section II. Two viewpoints are considered: virtualized elements and QoS representations. In one hand, we have found that, in general, information models do not address all phases of lifecycle. In the other, there is not a QoS representation for E2E service description.

To answer previous open issues, we define a generic concept, named the VirtualElement (section III). To introduce the QoS representation we characterize the VirtualElement by the constrains representing functional and non-functional behavior (Section III). VirtualElement enables us to represent virtualized components at any level of architecture. We concentrate our attention at network level, and we show the instantiation of generic model. Finnally, we apply our model at different phases of lifecycle of services by defining the service profiling (Section IV).

Our model being platform-independent, it can be translated by using diferent target languages. We propose a translation of service network description, expressed with our model, into an OVF file (section V), and the possibility of automation for VNs deployment.

II. RELATED WORKS

A. Standards representation in network area

In regards to network management standardization, important efforts have been made by DMTF (Distributed Management Task Force), TMF (TeleManagement Forum), IETF (The Internet Engineering Task Force) and 3GPP (3rd Generation Partnership Project) in the last 15 years. These groups propose different models (CIM, SID, and MIB) to

represent managed elements in different domains (applications, networks, devices, etc.) [1,2]. CIM (Common Information Model) defines an abstract object-oriented model to describe entities, their composition, and relationships concerning the tasks management issues. MIB (Management Information Base) is used to describe the current network load, latency, and other parameters. Concerning the autonomic approaches, we can mention the standardized model for network control-knowledge: the IETF PCIM (policy control information model) [3]. A first example of explicit network-related modeling can be found in the CIM Network model [4]. Reference [5] presents an overview of different technologies for network management.

B. *Virtualization related information Models*

To describe virtual E2E solutions it is necessary a generic information model, allowing the control of the provisioning of resources at deployment phase; but also the monitoring and the management of shared resources at exploitation phase. An interested survey about available modeling approaches apply to a host-based network resources provisioning is presented by [6].

Current concept of cloudified networks is based over NFV (Network Function Virtualization). NFV defines virtualized network functions that can be deployed. The deployment model is based on the definition of templates that contains the specific needs and attributed to the network service [7].

The virtualized environment: [8] includes a model for some virtualization platforms based on an extension of CIM model. Likewise, DMTF- CIM, OVF, and VMware-CIM deal with the representation of virtual systems and virtual resources by using CIM extensions. Reference [9] presents a comparison of the mentioned extension for CIM model and its implementations and proposes a generic model called VNE (*Virtual Network Environment*) based on CIM. The VNE model is one of the first to introduce facilities to automatically deploy VNEs. The initial objective of VNE is to introduce an abstraction for creation and deployment of VNEs using different virtualization platforms, that is the automatic configuration of requested components for different infrastructures [10]. Another interesting contribution in a similar context is presented in [11] and [12] with the NOVI information model. NOVI proposes the representation of shared resources for federating virtual infrastructures. Nevertheless, these models do not give yet the QoS representations, neither an E2E network service description.

C. *QoS-aware related Models*

1) *Standarization based in CIM model extension*

In the context of QoS some extensions have been proposed based over standard CIM core model of DMTF: CIM metric model and QoS Policy Information Model (QPIM). CIM metrics model proposes the definition of new classes associated with the BaseMetrics submodel allowing the specification and instantiation of new classes enabling dynamically define new metrics during the runtime of a distributed system [13]. This extension enables monitoring service by using information from OSI application layer, where network layer is not considered. A second extension of CIM metric is given by [14]. This work proposes new classes to define the metric notion and to be used by the QoS monitoring function. The proposed management architecture introduces the notion of calculation / measuring metrics enabling the representation and instrumentation of metrics reflecting the performance and the dynamic characteristics of network resources and services.

QoS Policy Information Model [15] was proposed by IETF to extend the concepts of the PCIM core model and to define a framework of classes and relationships dedicated to model network QoS Policies. In particular this extension focuses in the Differentiated and Integrated service QoS enforcement enabling to configure and manage devices that are IntServ- and DiffServ-compliant.

2) *QoS Languages and ontologies*

Several research works has been done in QoS-aware Application Programming Interface (API) design and QoS specification language development in the last 15 years. In the context of multimedia applications most of the research has focused primarily on deriving appropriate QoS parameters for devices resources, other introduce partial mapping rules with only quantitative translations of certain parameter value into another. An interested review about QoS languages is given by [16].

A complete survey on service quality description is presented by [17]. In this work authors propose the consideration of different phases in the lifecycle of a service (Advertisement, Matchmaking, Negotiation, Monitoring/assessment and Adaptation) to study and classify different concepts about QoS modeling and description. The authors distinguish several comparison criteria based on the formalism used for the model representation (UML, DTD, XML, ontologies); languages and ontologies are thus disassociated. The expression of metric model is also analyzed to express the richness of the QoS modeling. OWL-Q has high complexity, which is the most expressive QoS and metric model, but the QoS description not completely covers service lifecycle.

We believe the idea to associate the QoS description according with the phases of lifecycle of services is key. We propose a distinction of QoS description based over the QoS metric and value to be applied for each phase. QoS description characterizes the behavior of virtual elements with the objective of describe a service viewpoint, but also automation the monitoring and management tasks. From our point of view, the information representing the expected service viewpoint should accompany the lifecycle through a finer modeling of the functional and non-functional aspects of components. For this purpose we present in the following sections our QoS-aware information model.

III. QOS-AWARE INFORMATION MODEL DESCRIPTION

The QoS model, described in this section, is intended to be a generic solution, which can be applied to any element of architecture regardless of the level considered—equipment, network or application. How we focus in virtualized environments, each level consists of a set of virtual elements having functional and non-functional requirements—those representing the QoS. In this fashion, VirtualElement notion can be applied to represent the application, network or equipment service components.

A. The Virtual Element Model

From a conceptual point of view, the proposed basic model defines the notion of *VirtualElement*. A *VirtualElement* is characterized by constraints. Fig. 1 shows the Virtual Element model.

In virtualized environment these virtual elements can be found at different levels (e.g., virtual service element at application level or virtual network element at netwok level). Thus, any virtual element at N-Level will be described through the constraints to be applied at the N-level.

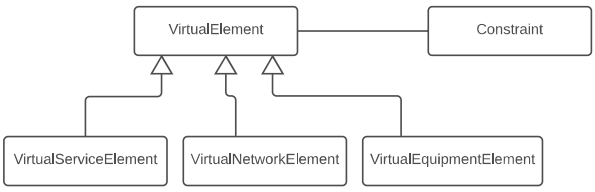


Fig. 1. VirtualElement Model

In the following of this paper we will focus in the modeling of virtual elements at Network level and their constraints: the VirtualNetworkElement model and the Constraint model.

B. Constraint Model

We propose the Constraints model to join the model of VirtualElement and express their declension (model variation) for the phases of desing, deployment and operational. Attach the notion of constraint from the conceptual point of view seems interesting to enable characterized the expected behavior of VN. The notion of constraint makes it possible to characterize the virtual element from the non-functional (QoS) and functional points of view.

Non-functional constraints are called *QoSConstraint* in the model and they are specified through *QoSParameter*. On the other hand, functional constraints can refer to the other constraints, for example to consider the placement issues of virtual network elements, API for configuration, etc. Fig. 2 shows the notion of constraint and their declension into *FunctionalConstraints* and *QoSConstraints* representations.

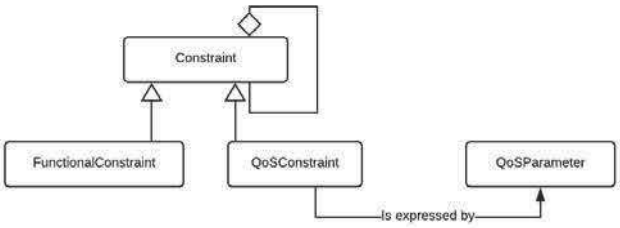


Fig. 2. Constraint Model

C. QoS Metric Model

We associate the QoS representation with four generic criteria, necessary and sufficient, to describe the behavior of any service. *QoSMetric* defines these criteria. Table I gives the definition of four types of QoS Metrics. Our model being extensible other metrics can be represented. A *QoSParameter* evaluates a type of *QoSMetric* (e.g., delay, capacity, availability, integrity) by a *QoSValue*. Fig. 3 shows the relationship between *QoSParameter*, *QoSMetric* and *QoSValue* in the *QoSConstraint* model. We have presented in precedent works [18], [19], [20] the utilization of four basic types of QoS metric and according the QoS information model proposed by [21], [22]. Fig. 4 shows an example of instantiation for the *QoSConstraint* model.

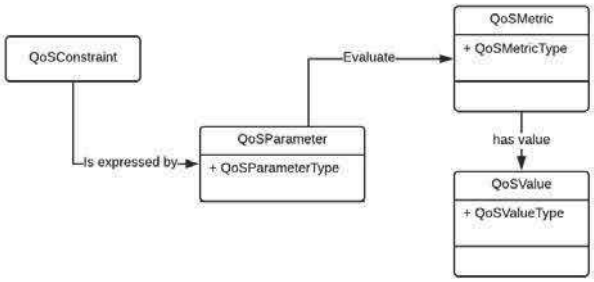


Fig. 3. QoSConstraint model: QoSMetric representation

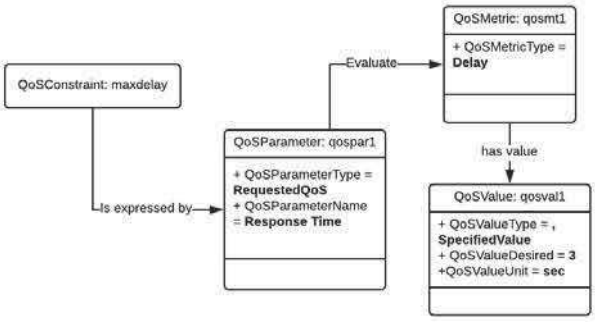


Fig. 4. Example of instantiation of QoSConstraint Model

TABLE I. QOSMETRIC DESCRIPTION

Type of QoS Metric	*Description*
Availability	duration needed for a virtual element to answer an service request without failure
Capacity	processing capacity of a virtual element during a unit of time
Delay	duration used by a virtual element to fulfill its functions
Reliability	compliance rate of the rendered service compared to the demanded one

The *QoSConstraint* notion is expressed by the *QoSParameter*. QoS parameter type is the attribut which enables us to express the association between the QoS metric and its QoS value for each phase of the lifecycle.

D. Viewpoints representation

To support an E2E QoS provision, lifecycle must represented complementay point of views (e.g, customer and provider.). For each level consider (application, network, equipment) we introduce user and provider viewpoints with our approache. Table II shows the association of QoS parameters type and both viewpoints (user and provider).

As mentioned in the article [22] the lifecylce of virtualized environment evolves. Different and new phases appear: strategic, design, deployment (virtual deployment and placement), operational.

The strategy phase concerns the conception of services in accordance with the supplier bussines model and the technologies to be used. Offered QoS caracterizes the service at this phase.

The design phase concerns the conception of an E2E service according to the request of the user. At network level, and for a VN for example, this is represented by the network service chain (set of NFVs) which is the network service support. RequestedQoS expressing the user requirements, the Offered QoS the offers of service.

The deployment phase represents the build of the VN associated to the functional and non-functional constraints. To take into account the virtualization process into the current lifecycle we have proposed to decouple in two the current network deployment process [23]: the first one is the process of VN virtual deployment (network service delivery level) that takes into account the applicative flows, and the second one is the placement process at the physical network infrastructure.

We associate the VN virtual deployment phase with the building of virtual network service as the composition of a potential VN whose virtual nodes (VM with instantiated VNF) and virtual links answer a specific requested QoS. For each VN a dedicated virtual control plane is programmed. The virtual deployment concerns the relation between offered QoS / demanded QoS. In a second time, the placement process maps the VN into an infrastructure. By using the negotiated QoS, the service provider expresses the adaptation of its offered QoS with the current resources of infrastructure (demanded QoS).

Operational phase represents the execution of a virtual element. At this phase, the operational QoS enables us to define the QoS values to be monitored. Operational QoS gives the provider viewpoint with the achieved offer of service.

Table III proposes some examples of QoS parameters for the four types of QoS Metrics at Network level.

TABLE II. QOS PARAMETER TYPE AND VIEWPOINTS

Lifecycle	**QoS parameters type and viewpoints**	
	user viewpoint	***service provider viewpoint***
Strategy		Offered QoS
Design	Requested QoS	Offered QoS
Virtual Deployment	Demanded QoS	Offered QoS
Placement		Negotiated QoS
Operational		Operational QoS

TABLE III. QOS METRIC VIEWPOINTS AT NETWORK LEVEL

Type of QoS Metric	**Examples of QoS parameters at Network level**	
	user viewpoint QoSparameter	***service provider viewpoint QoSparameter***
Availability	Availability rate	CAC (Call Admission Control)
Capacity	Application rate	Bandwidth
Delay	Response time	Latency, gigue, propagation rate
Reliability	Messages loss rate	Binary error rate, packet loss rate

According to the lifecycle, the *QoSValue* takes different types of values to identify parameters in the request (design phase) and the expected parameter to be offered /demanded /negotiated (at virtual deployment and placement phases) and monitored (at operational phase). We identify three types of QoS values: specified, threshold and current values. These values are used according the considered lifecycle phase, as it is explained in section V. Table IV describes the different types of QoS Values proposed.

TABLE IV. TYPE OF QOS VALUES

Specified value	***Threshold value***	***Current Value***
From an user perspective the conception value indicates the requested value associate to the demand. From the Service provider it represents the conceptuel value associate to the offered service.	It is the limits values not to be exceeded by a virtual element in order to ensure a normal behavior.	It is the real current value of a QoS parameter. It is used to supervise the behavior of the virtual element. This value would be compared with the threshold values to control the non-violation of the service capacities.

IV. SERVICE PROFILING MODEL

Monitoring and Management tasks need pertinent information to check the current stage of virtual elements and the constraints associated with each lifecycle phase.

We define distinct profiles to associate our QoS modeling in order to maintain QoS measurements according to lifecycle phases. These profiles represent user and provider points of view associated with the phases of lifecycle such as is showed in Fig. 5.

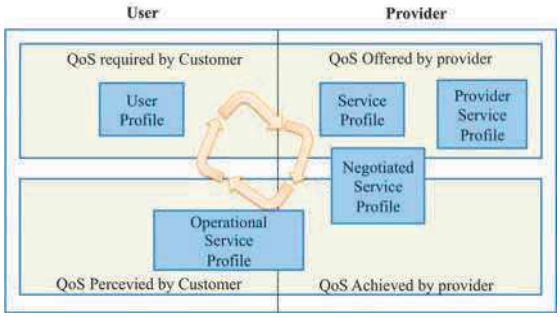


Fig. 5. Profiles and points of view

Each profile specifies the QoS parameters type and the QoS values type appropriates to each phase as is showed by the Fig. 6.

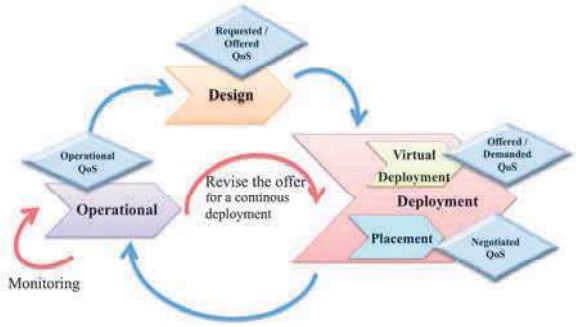


Fig. 6. QoS and service lifecycle: towards a continous deployment

Table V gives a general description of associated QoS parameters type and QoS values type. QoS model is included into the service description.

We define the following profiles:

Service Profile represents in the strategy phase the services offered by a provider.

User Profile and *Service Profile* are used in the design

phase to confront the QoS requested with the QoS offered.

TABLE V. PROFILING QOS MODEL

Service Lifecycle		QoS Model	
	Profiles	*QoS Parameters Type*	*QoS Values Type*
Strategy	Service Profile	Offered QoS	Specified value
Design	User Profile	Requested QoS	Specified value Threshold value
	Service Profile	Offered QoS	Specified value Threshold value
Virtual Deployment	Provider Service Profile	Offered QoS	Specified value
		Demanded QoS	Threshold value
Placement	Negotiated Service Profile	Negotiated QoS	Threshold value
Operational	Operational Service Profile	Operational QoS	Current value

We consider that the service offered by a VN must support the transport of data flow according with the exigencies associated to the application. For this purpose we associate non-functional (QoS) and functional constraints at network level for virtual deployment phase. These constraints enable us to specify the expected behavior of the network service to be deployed. The QoS offered by the service provider at N-level is based over the demanded QoS make to the provider at N-1 level. At virtual deployment phase, the relation between the QoS offered and the QoS demanded is contained in the *Provider Service Profile*. The offered QoS is based over specified values and the demanded QoS is based over Threshold value to be negotiated with the N-1 provider.

A network orchestrator determines the constraints of the execution environment and creates the *Negotiated Service Profile* with the threshold values of each QoS metric type to be measured. These values show the limited capacity beyond which service behavior becomes abnormal (e.g., the limit CPU of the VM in which the network service is deployed). These values will be used to compare with the current QoS values at operational phase.

At operational phase the current values of each QoS parameter are dynamically determined (e.g., free disk space, current load network, requests number in the queue, etc.). These values are contained and updated in the *Operational Service Profile*.

Applying our process, the idea is to be able at operational phase to automatize the return to deployment stage to revise the offer if it is necessary (Fig. 6). From the moment where our model expresses the variables with the thresholds values to be measured, the platform itself will be able to monitor these thresholds and trigger the mechanisms necessary for the treatment of the overflow of its thresholds. Thus, by monitoring and modeling the constraints associated with the VN deployed, monitoring will trigger at operational phase the alerts concerning the exceeding thresholds and return to the deployment stage to adapt the service offered.

V. QOS MODEL TRANSLATION OVER OVF

We have proposed an extension of OVF language to represent the expected behavior of VN in [24]. A new section called <VirtualNetworkSection> has been proposed to describe the VN to be deployed. We describe, in OVF file, QoS and functional constraints, and we applied them to virtual nodes, virtual links and virtual E2E network service such as proposed by [17].

Furthermore, we offered a generic fashion model in (independent platform or language) and the crucial concepts to be applied for the description of VN considering QoS and functional constraints. The idea is to enhance the automation of monitoring and management tasks. Thus, the application of our generic model can be translated into the OVF file to improve the placement stage.

For example, the “maxdelay” constraint defined at network level can be viewed as the expected VN E2E time giving an appropriate response to user request’. For the deployment of VN the E2E time is a constraint to be respected and characterize the behavior to be assured by virtual nodes and virtual links. This information enables to give a guide for the choice of physical nodes and links to map the virtual elements (virtual nodes and links) based on their expected respective treatment times and the transmission delays. Each of the constraints associated to each virtual element should be translated in the OVF sub-sections as proposed in [22]. Fig.7 shows an example of specialization to represent a *VirtualLink* element.

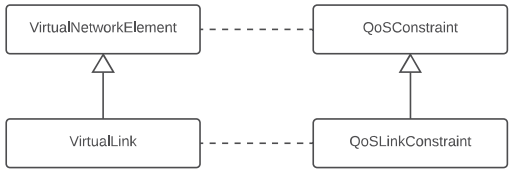


Fig. 7. Specialization of QoS model

For example the network service expected to support a convenable QoS (in the case of a telephonic communication) for VoIP application flow must respect the following delay: from 150 to 300 ms. The E2E delay must be less than 700 ms. Thus, the VN to be deployed can be described by using this threshold values of QoS delay (QoS Metric Type). According to the choise of technology of service provider the behavior of network service can be described with different constraints for these delays. Fig. 8 gives an example for these parameters.

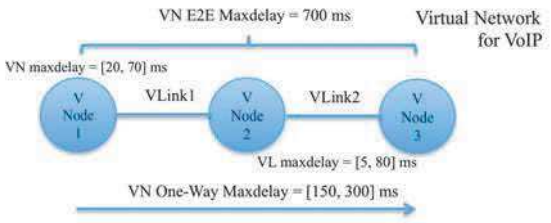


Fig. 8. Example of VN QoS constraints for VoIP

We can find the information given by our QoS model in Fig.9. Fig. 10 gives an example of the proposed Virtual Link section representation with OVF. The QoSLinkConstraints section describes a set of QoS constraints associated to the expected link behavior.

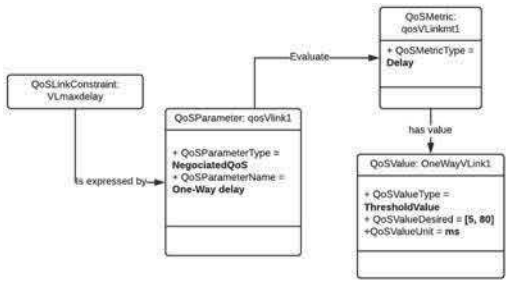


Fig. 9. QoS model instatiation to the virtual link constrains

The next step of our work will addres the experimentation in ordre to evaluate our approache and implement the proposed information model.

```
<VirtualLinkSection ovf:VirtualLinkName="VLink 1">
    <VirtualNodeEdge> VNN1  </VirtualNodeEdge>
    <VirtualNodeEdge> VNN 2 </VirtualNodeEdge>
    <PLinkConstraints>
      <TransitionNodeNumber> 1 </TransitionNodeNumber>
    </PLinkConstraints>
    <QoSLinkConstraints>
      <LinkAvailability>
        <Parameter> Link Availability rate</Parameter>
         <Value>[80,90] %</Value>
      </LinkAvailability>
      <MaxLinkDelay>
        <Parameter> One-Way Delay </Parameter>
        <Value> [5,80] ms</Value>
      </MaxLinkDelay>
      <LinkReliability>
        <Parameter>Bit error rate</Parameter>
        <Value> [0,2] % </Value>
      </LinkReliability>
      <LinkCapacity>
        <Parameter> Bandwidth </Parameter>
        <Value> [64,128] Kbps </Value>
      </LinkCapacity>
    </QoSLinkConstraints>
  </VirtualLinkSection>
```

Fig. 10. Example Virtual Network constraints for VoIP over OVF

V. CONCLUSIONS AND FUTURE WORK

We are interested in characterizing the behavior of virtual networks. This characterization through the specification of its functional and non-functional constraints. We have presented in this paper our QoS generic model that can be applied to different levels of service (application, network, equipment). The use of this model makes it possible to set up mechanisms to automate monitoring and management.

The QoS information model will allow the architect of VN to establish the structure that best meets the demand. It will thus be able to consider both functional and non-functional requirements (QoS) of virtual elements constitutives of VN. QoS information includes profiles with service lifecycle to enhance the automation of monitoring and management tasks. Futhermore, two point of views (user and supplier) enable the represention of negotiated information. QoS is represented for each profile.

Currently, we are working on an proof of concept to integrate of our model in the process of monitoring.

REFERENCES

[1] CIM: https://www.dmtf.org/standards/cim

[2] SID: https://www.tmforum.org/information-framework-sid/

[3] B. Moore, et al. Policy Core Information Model, V 1 Specification. RFC 3060, IBM, LongBoard Inc, Cisco Systems, 2001.

[4] Distributed Management Task Force, (2003) "CIM Network Model", White Paper DSP0152, http://www.dmtf.org/

[5] Samaan N. and Karmouch A.. "Towards autonomic network management: an analysis of current and future research directions". Communications Surveys and Tutorials, IEEE, 11(3), pp 22-36, 2009.

[6] Kontoudis D. and Fouliras P. "A Survey of Models for Computer Networks Management". International Journal of Computer Networks & Communications, Vol.6, No.3, May 2014.

[7] http://openbaton.github.io/documentation/vnf-descriptor/

[8] CIM System Virtualization Model: https://www.dmtf.org/

[9] Fuertes W., López de Vergara J. E., Meneses, F. and Galán F. "A Generic Model for the Management of Virtual Network Environments". Network Operations and Management Symposium (NOMS), 2010 IEEE. 19-23 April 2010.

[10] Galán F., Lopez de Vergara at al., "A Model-driven Configuration Management Methodology for Testbed Infrastructures". IEEE/IFIP Network Operations & Management Symposium (NOMS). April 7-11 2008.

[11] J. van der Ham, C. Papagianni et al., "Challenges of an information model for federating virtualized infrastructures", 5th International DMTF Academic Alliance Workshop on Systems and Virtualization Management: Standards and the Cloud (SVM) IEEE, pp. 1-6, Oct. 2011.

[12] J. van der Ham, J. Stéger et al., "The NOVI information models", Future Generation Computer Systems, vol. 42, pp. 64-73, 2015.

[13] Alexander Keller, Oliver Benke, et al., "The elM Metrics Model: Introducing Flexible Data Collection and Aggregation for Performance Management in CIM". IEEE Transactions on Network and Service Management, 59-71, 1(2), Dec. 2004.

[14] A. Toueir, J. Broisin, M. Sibilla. "Toward Configurable Performance Monitoring. Introduction to Mathematical Support for Metric Representation and Instrumentation of the CIM Metric Model". 2011 5th International DMTF Academic Alliance Workshop on Systems and Virtualization Management: Standards and the Cloud (SVM), Paris, 2011, pp. 1-6.

[15] https://tools.ietf.org/html/draft-ietf-policy-qos-info-model-00

[16] Jingwen Jin and K. Nahrstedt, "QoS specification languages for distributed multimedia applications: a survey and taxonomy", in *IEEE MultiMedia*, vol. 11, no. 3, pp. 74-87, July-Sept. 2004.

[17] Kyriakos Kritikos, Barbara Pernici, Pierluigi Plebani, Cinzia Cappiello, Marco Comuzzi, Salima Benrernou, Ivona Brandic, Attila Kertész, Michael Parkin, and Manuel Carro. 2013. "A survey on service quality description". ACM Comput. Surv. 46, 1, Article 1 (July 2013), 58 pages.

[18] Ines Ayadi, Noemie Simoni, Gladys Diaz. "NaaS: QoS-aware Cloud Networking services". The 12th IEEE International Symposium on Network Computing and Applications. 22-24 August, 2013. Cambridge, MA, USA.

[19] Ines Ayadi, Gladys Diaz, and Noemie Simoni, "QoS-based Network Virtualization to Future Networks: An approach based on network constraints," in Network of the Future (NOF), 2013 Fourth International Conference on the. IEEE, Pohang, 2013, pp. 1-.5

[20] Ines Ayadi, Noemie Simoni, and Gladys Diaz, "Qos-aware component for cloud computing," in ICAS 2013, The Ninth International Conference on Autonomic and Autonomous Systems, 2013, pp. 24–29.

[21] ETSI TR 102 805-3 V1.1.1 (2010-04). "Part 3: QoS Informational Structure". On-line ETSI technical report. Available from http://www.etsi.org/standards [Accessed october 2018]

[22] ETSI TR 102 805-1 V1.1.1 (2009-11), "Part 1: User's E2E QoS". Analysis of the NGN. On-line ETSI technical report. Available from http://www.etsi.org/standards [Accessed october 2018]

[23] Gladys Diaz, Amina Boubendir, and Noëmie Simoni. "Virtual Deployment of Virtual Networks in Network as a Service". In Qiang Duan and Shangguang Wang, editors, Network as a Service for Next Generation Internet, chapter 4. The Institution of Engineering and Technology (The IET), Michael Faraday House, Six Hills Way, Stevenage, SG1 2AY, United Kingdom, 2017.

[24] Gladys Diaz and Noëmie Simoni, "Network service description for virtual network deployment: A constraints based OVF extension proposal", 2016 12th International Conference on Network and Service Management (CNSM), Montreal, QC, 2016, pp. 363-366.