A Cloud Infrastructure to Manage Future Internet: The Virtual Network Operation Center

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Abstract

A Network Operations Center (NOC) is a place from which operators and administrators supervise, monitor and maintain a converged telecommunications networks. The NOC is the focal point for network troubleshooting, software distribution and updating, router and domain name management, performance monitoring, and coordination with affiliated networks. This paper analyzes and proposes a set of innovations for current NOC infrastructure when the NOC is virtualized, using IaaS[1] and PaaS[2] cloud-aware facilities. The scenario described will show how the setting up and operation of the V-NOC should be enabled by emerging technologies for mobile and fixed network business and related technologies.

Keywords: cloud computing, virtualization, network management, next generation networks, Service Oriented Architecture (SOA), Service Oriented Infrastructure (SOI).

[1] Infrastructure as a Service.
[2] Platform as a Service.

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1 Introduction

With the rapid development of cloud technologies and their popular applications, leading to the more and more exacting problems of complex computations and massive data process, arguments for high performance processing devices are becoming increasingly vehement. Nowadays, the number of Intranet formed of many computer clusters is quickly increasing, while cheap personal computers are distributed everywhere, with a low rate of resource usage however. Cloud computing [1, 2] techniques as well as pervasive computation schemes may become the suitable and cost effective approaches to take concrete advantage of the underutilized resources.

The current evolution pushes the redesign of the Network Management architecture to a complex cloud-based purposive infrastructure. Virtualized multiple-agent technology [3, 4] represents an exciting new perspective of analyzing, designing and building complex network management systems. The autonomous, cooperative as well as purposive infrastructure [3] with intelligent features of an agent make explicit that the agent-based system becomes a promising software solution in virtualized cloud computing environments [5].

Within the next generation Network Management System (NMS), network resource are structured via XaaS [6] (IaaS, SaaS, and so on) [14]. All entities and resources involved in the cloud are viewed as services. The SOA [6] accelerates the convergence of agents and cloud. One of the challenging issues in service-oriented cloud using agent-based systems is how to facilitate the service composition with reference to the dynamic feature of the cloud environment. Virtualization orientation is an increasingly recognized paradigm for agent modeling and development.

In this paper, we present an innovative approach for modeling, designing, and managing agent mediated cloud services for TMN [7] application framework. The Virtual Network Operation Center model is introduced for modeling and designing various service agents in a concrete telecommunication scenario. Based on the virtualization approach and cloud-based multi-agent system, a new infrastructure is proposed to enable various network management service functions such as service advertisement, service discovery, service negotiation, and service delivery functions in service-oriented cloud environment. Within the cloud modeling approach, service agents are proposed for the management of the distributed resources, discovery and selection of computing services, etc. The service agents are also used to enable the autonomous behavior of the system, i.e. to adapt to users' computation needs and dynamic resource environments. This paper is organized as follows: Section 2 describes the background and related works about cloud computing and virtualization in a network management scenario. Section 3 introduces the virtual network operation center architecture. It also illustrates the basic requirements of the proposed architecture. Section 4 presents the V-NOC workflow. Finally, a conclusion and the future work are discussed in Section 5.

2 Background and Related Works

According to the V-NOC architecture there are five components (Fault, Configuration, Accounting, Performance and Security management – FCAPS [8]) involved in network management and three components used for service management (Monitoring, Control, Reporting).

The Virtual Network Operations Center (V-NOC) covers all components with a combination of open source tools or instruments that are presented in detail in the following section.

Fault management has to do with network problems discovery and correction. Potential problems are identified, and steps are taken to prevent them from occurring or recurring. This way, the network is kept operational and downtime is minimized. The correction of discovered problems is not automatic, but rather follows a path of procedures and communication between NMS, Helpdesk and the Operator.

Configuration management is responsible for network operation control. Hardware and programming changes, including the addition of new equipment and programs, modification of existing systems and removal of obsolete systems and programs, are coordinated. An inventory of equipment and programs is kept and updated regularly.

Accounting management is devoted to distributing resources optimally and fairly among network subscribers. This makes the most effective use of the systems available, minimizing the cost of operation. This level is also responsible for ensuring that users are billed appropriately.

Performance management is involved with managing the overall performance of the network. Throughput is maximized, bottlenecks and other potential problems are identified. A major part of the effort is to identify which improvements will yield the greatest overall performance enhancement.

At the *Security management* level, the network is protected against offenders and denial-of-service attack (DoS attack), unauthorized users, and physical or electronic sabotage. Confidentiality of users' information is maintained where necessary or warranted. The security systems also allow network administrators to control what each individual authorized user can (and cannot) do with the network equipment.

Monitoring of services involves gathering data about the network services. The following services are monitored: status of interfaces on border routers, status of BGP sessions and the size of the routing table, CPU utilization on routers, MPLS status.

Control refers to manipulation of devices. No automatic manipulation is planned for the first burst of planned operations; rather, all such intervention will be accomplished by human interaction.

Reporting refers to documenting abnormal events and circulation of these documents. It will be materialized by the Helpdesk and the TTS (Trouble Tickets System).

Providing hybrid, agent-based operational cloud-like services architecture is still challenging. A number of initiatives and funded projects for applying cloud based virtualized agents have appeared in recent years. RESERVOIR [9, 10] focuses on technologies that enable to build cooperating computing clouds in order to connect computing clouds to create an even bigger cloud. The Service Oriented Infrastructure (SOI), the resource sharing across organizations/geographies and the use of virtual machines as the basic unit of work, are the key issues of the project.

The idea of GEYSERS on the other hand [11] is the convergence of IT and Telco infrastructure service provisioning, control and management to deploy new cloud scenarios to reach a new level of critical mass. This convergence could support greater flexibility and efficiency in the way IT departments operate and coordinate the provisioning of all of these resources across the cloud, but also how they enact outsourcing of IT capability maintaining essential cloud characteristics: protocol transparency, redundancy options, space and power efficiency. This project proposes a virtual infrastructure layer to handle most of the infrastructure virtualized resources and represent a kind of mediator, virtual infrastructure providers, between the owner of the infrastructures and virtual Infrastructure operators.

The rationale behind the proposed paper is to use a mixed cloud architecture (IT and Network) to support a Virtual Operation Center that could be organized, configured and deployed in a dynamic way, reducing the OPEX and CAPEX of the overall telecommunication infrastructure.

3 The V-NOC Architecture

This section describes the architecture of the V-NOC taking into account current requirements and possible future extensions. The architecture design was mainly driven by the following basic *requirements*:

- *Scalability*. The principal reason for having a distributed infrastructure instead of a centralized one is the higher scalability of decentralized solutions. The V-NOC architecture has to be able to support lots of users in the near future, sharing their knowledge and data, currently only accessible via the local desktops of the NOC. Whereas a centralized solution is only able to support a limited number of users, scalability is a major decentralization design requirement even though it is sometimes in conflict with other requirements for the architecture.
- *Fault-tolerance*. A decentralized system consisting of unreliable loosely coupled nodes (e.g., user's desktops and laptops) have to be able to deal with failures such as network churn or node failures. The architecture has to take this into account, up to a certain degree, the system availability without any loss of service quality.
- *Flexibility.* The V-NOC system has to be able to support future extensions by new technologies and Telco service distribution, such as provider/consumer/prosumer paradigms. A flexible architecture is required to be able to integrate those extensions and offers new functionalities through existing APIs. The V-NOC is independent from the underlined multi-vendor technology and from the specific O&M system available normally at layer level or deployed nodes level. More in general the network management layer applied to this virtualization of resources shall therefore allow configuring the dynamic downgrade or upgrade of available infrastructure resources.

Apart from new technologies, the infrastructure also has to take into account domain specific requirements variation, i.e., users have to be able to tailor the V-NOC system to their needs by providing application-specific handlers.

In addition to the requirements shown above, basic overall purposes of the V-NOC architecture are:

- To provide a V-NOC to third part entities (network providers, operators, vendors etc.) in order to maximize the network management business (e.g. outsourcing) and optimize the resource usage.

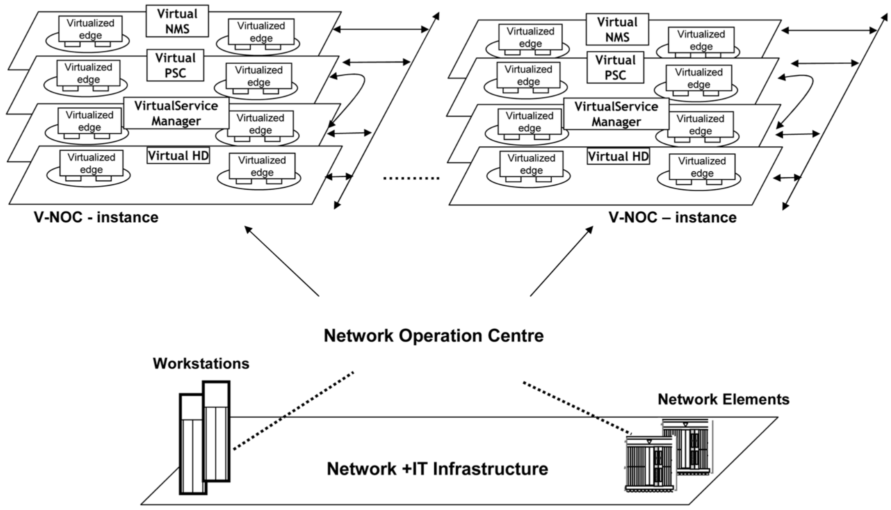

Figure 1 The V-NOC architecture.

- To provide an (all-in-one) immersive environment with familiar NOC structures such as Network Elements, distributed storage systems, power equipment, and displays.
- To provide a multi-user virtual world where users can effectively collaborate on elements of the NOC together.
- To provide a centralized graphical tool useful to manage network resources as a real NOC, but which can be also used as a modeling and simulation tool (e.g. requirements monitoring and analysis) in order to make better use of network and storage resources, discussing measurements and consolidate monitoring.

The V-NOC is organized as an IaaS scheme, as presented in Figure 1. In the V-NOC concept the network operations and services management are provided by different entities in a distributed paradigm. Each instance of the V-NOC is composed of the following components:

- *Virtual Network Management System* (V-NMS): a small group of network managers formed by access port managers that have the administrative control of the overall Network Elements connected to the V-NOC, guaranteeing proper functioning. NMS provides network management and user support within their area of authority.
- *Virtual Help Desk*: This entity is entitles to monitor connectivity problems and to handle the trouble tickets System.

- *Virtual Service Manager*: These are a set of virtual entities which design, specify and orchestrate the deployment of advanced services on the V-NOC infrastructure (networking and storage services).
- *Virtual Project Steering Committee* (PSC): It is not considered part of the V-NOC, however it interacts with the access port managers and it makes decisions on strategic aspects of the project, and the deployed services.

4 The V-NOC Workflow

The V-NOC workflow will be organized in five different phases:

- Phase 1: The V-NOC is managed virtually. Basic components of the V-NOC are accessible in ubiquitous way.
- Phase 2: Part of the V-NOC is the Virtual Network Management System. It is composed of enhanced graphical users interfaces in order to plan, provision and monitor (in real-time) the physical changes within the Infrastructure Provider's network.
- Phase 3: New virtual services are offered using the Virtual Service Manager. These services are used to design, specify and orchestrate the deployment of advanced services on the V-NOC infrastructure.
- Phase 4: When a problem occurs it is possible to interact with the Virtual Help Desk system, in order to solve connectivity problems and handles the trouble tickets System.
- Phase 5: The Virtual PSC is available to makes decisions on strategic aspects of the project and the corresponding deployed services.

5 Conclusions and Future Work

In this paper, we have described the evolution of the Network Operation Centre (NOC) architecture [19] by using virtualization over the cloud. We have discussed a Virtual Network Operation Centre (V-NOC) that provides the runtime machinery to easily manage next generation networks, using a distributed approach.

Its integration into the global cross-platform NMS has been made possible via support for execution of virtualized jobs through cloud interface using a broker middleware (open-nebula). We plan to extend the V-NOC to a wide variety of services: (1) The support of additional functionalities via the API including inter-thread communication is planned. (2) We are

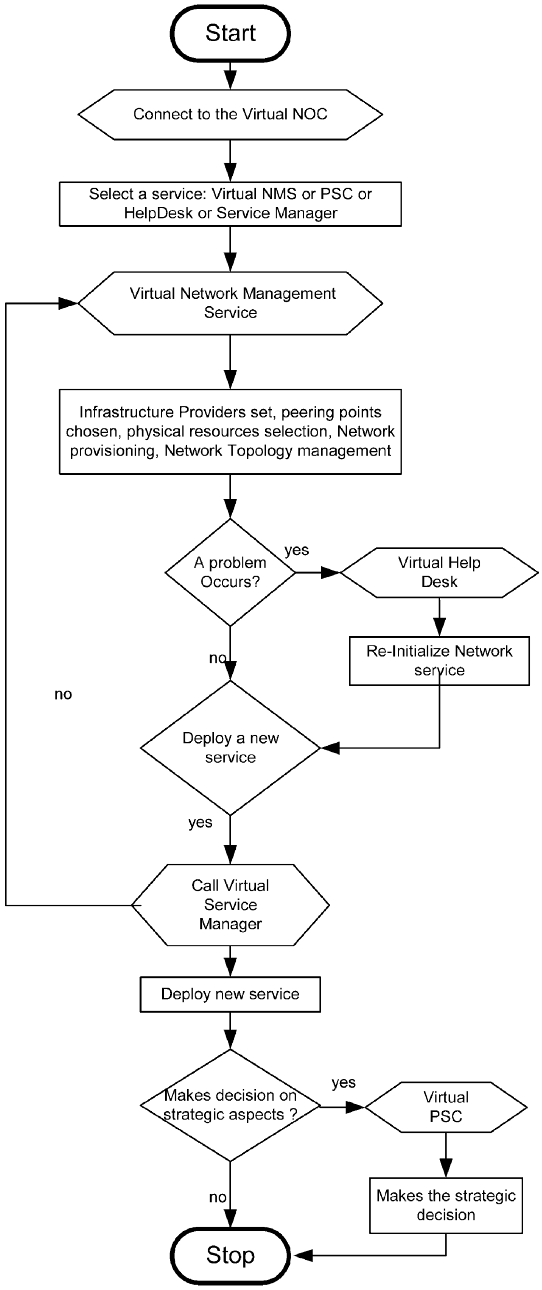

Figure 2 The V-NOC workflow.

working on support for multi-clustering with Peer-to-Peer communication between Network Managers. (3) We plan to support utility-based resource allocation policies driven by economic, quality of services, and service-level agreements. (4) Since Internet has been largely deployed and utilised around the globe several business models have been adopted to yield revenues to all actors involved in the value chain. A consolidated one is based on gold services associated with "free" basic service offers. Good examples are YouTube, megaupload, megavideo, Skype and recently announced Google on net QoS.

Therefore, on top of the best effort quality, the internet is converging to a quality managed cloud that shall need both high capacity generalised infrastructure and innovative generalised OSS/BSS (V-NOC) solutions also exploiting APIs to the service providers like GEYSERS concept.

We are also investigating strategies for adherence to Web Service Resource Framework (WSRF) and Representational State Transfer (REST) standards by extending the current V-NOC interface. This is likely to be achieved by its integration with open-nebula [12] low-level cloud middleware implementations that conform to OCCI standards such as OGF [13]. Finally, we plan to provide data cloud capabilities to enable resource providers to share their data resources in addition to computational resources.

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Biographies

Pasquale Donadio is a system engineer working for Alcatel-Lucent Italia. He received the automation engineering degree from the University of Naples Federico II, where his thesis work encompassed the modeling and simulation of innovative multimedia languages based on XML. He began his career at IPM, where he worked on the design of Internet security systems based on smartcards. Then he joined the Alcatel Italia OND (Optical Network Division) and worked on network management design and development, first as a top-level designer and later as system architect. Since his graduation he has been continuing his research activity acting in a part-time position in several Frame Program 7 (FP7) funded programs, as task leader and wp leader (ETICS, GEYSERS, ECONET, OneLAB2, E-photon/ONe+). His current research interests include network management based on distributed systems (Grid&Cloud computing), energy aware networks and tridimensional graphical user interfaces for network management and control. He has authored/co-authored about 20 patents.

Antonio Cimmino graduated in electronic engineering in Napoli (I). He is trainer at the Italian Air force in telecommunications and air-navigation systems. In 1991 he joined Alcatel Italia, working in the radio mobile research department, primarily involved in mobile research activities: system definition and network architecture on Mobile Broadband System project (MBS/60 GHz), UMTS – Monet, OBANET and Moicane (FP5). Recently, he has been involved in co-ordination of FP6/FP7 research projects (WEIRD, OneLab 1&2, ePhoton+, Nobel 2, GEYSERS and ECONET) for the IST area.

Ramjee Prasad (R) is a distinguished educator and researcher in the field of wireless information and multimedia communications. Since June 1999, Professor Prasad has been with Aalborg University (Denmark), where currently he is Director of Center for Teleinfrastruktur (CTIF, www.ctif.aau.dk), and holds the chair of wireless information and multimedia communications. He is coordinator of European Commission Sixth Framework Integrated Project MAGNET (My personal Adaptive Global NET) Beyond. He was involved in the European ACTS project FRAMES (Future Radio Wideband Multiple Access Systems) as a Delft University of Technology (the Netherlands) project leader. He is a project leader of several international, industrially funded projects. He has published over 500 technical papers, contributed to several books, and has authored, coauthored, and edited over 30 books. He has supervised over 50 PhDs and 15 PhDs are at the moment working with him. He has served as a member of the advisory and program committees of several IEEE international conferences. In addition, Professor Prasad is the coordinating editor and editor-in-chief of the Springer International Journal on *Wireless Personal Communications* and a member of the editorial board of other international journals. Professor Prasad is also the founding chairman of the European Center of Excellence in Telecommunications, known as HERMES, and now he is the Honorary Chair. He has received several international awards; the latest being the "Telenor Nordic 2005 Research Prize". He is a fellow of IET, a fellow of IETE, a senior member of IEEE, a member of The Netherlands Electronics and Radio Society (NERG), and a member of IDA (Engineering Society in Denmark). Professor Prasad is advisor to several multinational companies. In November 2010, Ramjee Prasad received knighthood from the Queen of Denmark, the title conferred on him is Riddere af Dannebrog.