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REZUMAT

TEZĂ DE DOCTORAT

CONTRIBUTIONS TO SEAMLESS CONNECTIVITY IN CLOUD-BASED COMMUNICATIONS SYSTEMS

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1 Introduction

Mobility has become the catalyst for human activity and also for communication systems. In order to provide the demanded services and keep up with the rapid evolution of the infrastructure, legacy provider concepts are replaced with new ones such as Cloud Computing. The need of redefining the infrastructure comes from the fact that little or no regard is paid to the underlying infrastructure by the modern applications. That is also encouraged by the fact that telecommunications networks in the recent years have seen an evolutionary change towards all-IP mechanisms. Furthermore, the legacy boundaries between IT infrastructure and telecommunications infrastructure are also starting to collapse.

Another game changing aspect in recent communications is increasingly more of the network functions are available as pure software functions. Furthermore, the abstraction of the network made it more accessible in term of controlling the channel through signaling, thus the interest in specialized tools and algorithms that tackle with the network at signaling level. With that taken in consideration it can be stated that the paradigm has changed, terminal mobility being addressed in terms of pre-call and mid-call mobility, presence servers instead of location areas, visitor or home location registers. Essentially these terms are referring to techniques allowing changing a network attachment point without losing connectivity (pre-call mobility) or continuity (mid-call mobility). In the context of cloud computing these concepts are easily integrated due to the software defined infrastructure.

Present network services are built over proprietary appliances and different network devices that have a specific purpose. Therefore, it can be said that the network is experiencing a stiffening regarding operation of service additions and network upgrades. Addressing this issue is the virtualization concept which approach is to decouple the software networking processing and applications from their supported hardware thus allowing network services to be implemented as software. Therefore, the ETSI industry Specification Group proposed the concept of Network Function Virtualization (NFV) to define the process through which the network functions of previously proprietary dedicated devices are performed as a software provided service. Moreover, such an approach provides flexible provisioning of software-based network functionalities on top of an ideally shared physical infrastructure.

A concurrent concept to NFV which has revolutionized networking is Software Defined Networking (SDN). The straightforward integration of new abstractions into the network infrastructure facilitates the integration of SDN with NFV to achieve even more complex topologies and at the same time keep them easy manageable. While NFV provides the infrastructure, when applying SDN concepts in such a topology the challenges of dynamic resource management and intelligent service orchestration are more accessible. Through this symbiosis a virtual dynamic environment service is created for every service chain, thus any dedicated hardware upgrade or intensive labor for an upgrade is avoided.

Furthermore, this virtualization concept encourages automating the current manually intensive network configuration, provisioning, and management. Thus, the time and operation complexity are significantly reduced and manual errors are dramatically decreased, which in turn offers better scalability. Various tools such as Ansible, Chef and Puppet, have been developed and are enabling the dynamicity of the developed infrastructures through a high level of automation and abstraction. These solutions provide easy management and cheaper services in the local area network, enterprise networks, data center, and even for Internet service provider networks.

Although NFV, SDN and Cloud concepts are not that old, they matured rapidly and the age of the Internet of Things (IoT) is forthcoming. This new paradigm will give objects and even generated contents to the ability to communicate with other mediums. In this new environment every object will generate data, however it will not remain raw as is today but will be customized to the users based on their needs and even converge with other data. Although the concept of IoT is simple it has the capability to change the entire paradigm of legacy technology. The basic concept behind it is based on embedded network interfaces into objects which enable communications between them and provide various services for the users. Ergo, a unique identifier such as an Internet Protocol (IP) will be attributed to each device so that they can communicate in the current Internet through the IoT networking environment. In contrast to the era before, IoT empowers the users permitting them to obtain data directly from local network rather than only from the provider. Therefore, this capability leverages the usage of IoT to provide an innovative service to industry, academia, and even personal use.

In the world of IoT, domains such as ubiquitous and context-aware computing are gaining importance. The interaction between the new defined objects will conclusively generate amounts of data like never before, thus implying the usage of a different approach regarding data and infrastructure management. Here cloud computing comes in play, however resource management, service creation, service management, service discovery, data storage, and power management for IoT environment require much a better infrastructure and a more sophisticated mechanism even than the cloud could provide. Therefore, concepts like Cloud of Things (CoT) were proposed. Sensor network systems, like most embedded systems, needs to be tightly coupled with their applications. Moreover, the recent advances have helped reduce the complexity of implementing wireless sensing and actuation systems.

Ubiquitous computing (ubicomp) is another modish concept in which information processing has been thoroughly integrated into everyday objects and activities. This is also known as edge computing, concept that eases mobility because the otherwise service provider infrastructure is now available through NFV and SDN. While the NFV infrastructure provides the necessary level of dynamicity and re-configurability a Software Defined Networking Controller is the one needed for a global view of the infrastructure. With such a perspective insight over the network new complex routing mechanisms like context-based can be defined with regard to application specifics and access technology.

The applications when combining the presented concepts and technologies are endless. However, the focus in this thesis is on communications system which in contrast to new paradigms has to ensure on one hand compatibility with legacy technology, and on the other bring innovations that will intrigue the user. While the SDN concept which is responsible for decoupling the network control (Routing Process) from the forwarding functions (Data Plane) and it is intensely used throughout the following presented implementations it is not the scope of the thesis. The merger of concepts which separately are innovative regarding communications but only together can provide the primary desired outcome which is seamless connectivity. The concept is pursued from a local environment to a global and ubiquitous one, thus implying the necessity of NFV, SDN, Cloud Computing, Automation mechanisms, Context-based routing, and high abstraction models all together, in order to create an reusable and adaptable concept infrastructure for whatever access technology the dawn of tomorrow brings.

1.1 Seamless connectivity

In the current world of IT one of the most prevalent and intricate challenges is getting "specific information to specific users at a specific time". Materializing this concept implies seamless connectivity between people, software brokers and various communications systems. Such connections are essential in order to support the vivid communities in which the exchange of data and information is at a regular basis.

Ubiquitous computing is being considered in the recent years as one of the most attractive areas of research. Thus, both the academic and industry sectors are conducting various researches in this area. The main establishment of ubiquitous computing is that all of the environment components should be connected to the network. That is the reason why seamless connectivity is such an imperative component in modern communications systems. Implementing a handoff mechanism management scheme between heterogeneous networks devices should be performed taking in consideration the characteristics of each interface. However, until recently approaches only presumed that the seamless connectivity is provided with no regard toward how is it performed. In software defined infrastructure the handoff operation is no longer based on network factors, such as signal and latency but rather considering context information, e.g., application requirements.

Currently the wireless connectivity is still divided in three basic categories primary based on coverage and mobility requirements: Wireless Wide Area Network (WWAN, such as cellular systems covering the wide area of coverage), Wireless Local Area Network (WLAN, covering the local area) and Wireless Personal Area Network (WPAN, such as Home Radio Frequency, Bluetooth etc. covering small office or home office) [Jha02]. Another category that has been later been introduced is Metropolitan area network (MAN, such as inner-network connectivity in a city). As the user mobility is high the interaction with all of the types of wireless technologies can take place in a very short period of time or mostly at the same time Table 1 :

Range	Application	Standards
Within reach of a person	IoT (at home)	Bluetooth, Z Wave, NFC
Local area network	Internet connection (at home, at work)	802.11a, 802.11b/g/n, 802.11ac
Metropolitan area network	Communication backup (at home, in town)	IEEE 802.16 (WiMAX)
Wide area network	Mobile communication (at home, worldwide)	GSM, 3G, 4G, 5G/LTE, Satellite

Table 1.1 Wireless connectivity categories

Unfortunately, these four standards developed isolated and were not designed to communicate with each other. However, the present communication context in which a user has a single device that supports all of the wireless schemes pushes towards the need of a merger. Moreover, the user has to continually search and find types of available wireless access channels and manually instruct the applications to use it. Therefore, the need of a mechanism that regardless of the device or access technology capabilities can provide seamless connectivity is imperative. All of the issues previously discussed meet under an "umbrella" the cloud, the environment in which this thesis proposes a solution.

1.2 Cloud-based infrastructures

Computing power as a “utility” is something that the scientists and the IT industry were searching for a few decades. The principle is rather similar to plugging an appliance into a power supply socket, the end user not taking care how the power is generated or how it gets to that outlet. This principle hides the power generators and the huge distribution grid. When the principle is extended to IT, this concept means delivering useful functions while hiding how their internals parts work. Furthermore, this business model also permits the implementation of a “pay-as-you-go” scheme which makes it even more appealing for the end consumers.

In one of the very first definitions of Cloud Computing, the National Institute of Standards and Technology NIST defines it as a model of service delivery and access where dynamically scalable and virtualized resources are provided as a service over the Internet. Buyya et al. [Buy09] have defined it as follows: “Cloud is a parallel and distributed computing system consisting of a collection of inter-connected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements (SLA) established through negotiation between the service provider and consumers.” The concept reached its maturity and standardization by focusing around some essential characteristics as defined in [Mel11]:

- **On-demand self-service**: Users of clouds can “unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider”.
- **Availability of “infinite” computing resources**: Cloud users do not have to plan the provision computing resources in advance, they have the potential to access computing resources by simply making a demand.
- **Rapid elasticity and adaptability**: Computing resources can be provisioned in an elastic and rapid way by allowing users to buy computing services at any time at various granularities and be able to up and downscale those services according to their needs.
- **Elimination of up-front commitment**: This allows companies to start small and to successively increase hardware and software resources only when needed.
- **Short-term pay for use**: Users are able to pay for their use of cloud services on a short-time basis.
- **Network access**: Computer services are accessed over the network and through standard mechanisms thus allowing users to connect several devices to the cloud (e.g. laptops, mobile phones).
- **Pooling of resources**: Providers’ cloud services are pooled to serve multiple customers using a multitenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand.
- **Measured service and adaptability**: Cloud computing systems are able to react on-time to changes in the amount of computing resources requested and thus automatically control and leverage resources.

Cloud computing can be defined either by the abstraction level of the capability provided and service model of providers, or based on the deployment location. For the first case cloud computing services are divided into several service layers [OECD14]: Software as a Service (SaaS); Platform as a Service (PaaS), Infrastructure as a Service (IaaS), Security as a Service (SECaaS), Metal as a Service (MaaS) etc. The first three are considered to be the basic of Cloud Computing services. The latter perspective divides the cloud into four location based models as [OECD14]: (1) private; (2) public; (3) hybrid; and (4) community clouds.

1.3 Motivation of the thesis

The incentive of this thesis was represented by the groundwork performed in two contributions: First was my Master's degree thesis in which the aspect of seamless connectivity in Wi-Fi networks for a Voice over IP (VoIP) session is addressed. While the concept of mobility and seamless connectivity operates well in the specially designed systems like cellular telephony networks where users move freely within the coverage area of a given network without service interruption in the IP based infrastructures the concept cannot be applied. The novelty of that thesis was that the session continuity was ensured during an Access Point (AP) handover by addressing the process dynamically at the application layer of the proposed system. Both the pre-call and mid-call mobility were tested resulting in successful presence services information to the clients for the first and a seamless change of the destination for the voice packets whenever a client changed its connection point for the latter. The second starting point came from the work previously performed within UC Labs and presented in [Uli14]. While the paper aims to prove that by using an OpenFlow-based testbed that a real gearbox-like routing algorithm selection in runtime is feasible, it also presents the idea of software-defined networking. By introducing a Software-Defined Networking Controller (Beacon) the network could be controlled in a decoupled and abstract manner.

Combining the two approaches lead to new developments and obstacles regarding unifying communications and ensuring seamless connectivity between access technologies. Thus it was decided to further develop a testbed integrating other SDN controllers such as Pyretic, OpenDaylight and Cisco APIC-EM and leverage new concepts like Network Function Virtualization (NFV) and context routing based on network metrics, One Way Delay (OWD) and Active Transfer Rate (ATR), and application specifics, signaling messages or data traffic. The scope was to provide seamless connectivity at a wider scale, i.e. for cloud communications systems. The developments were implemented in an OpenStack orchestrated environment with applications regarding two research (still ongoing) projects, as follows.

The first project is called CHIST-ERA "DIONASYS - Declarative and Interoperable Overlay Networks, Applications to Systems of Systems". It started in January 2015 and includes four institutions: University of Neuchâtel (Switzerland), University of Bordeaux (France), Lancaster University (UK) and Technical University of Cluj-Napoca (Romania). The goal is "to make the programming of complex and heterogeneous Systems-of-Systems simpler and more straightforward by allowing a higher level of abstraction and allowing advanced features such as automatic adaptation, automatic interoperation, and support of programmable networks for these tasks". A novel OWD estimation tool and the OpenStack orchestrated testbed previously discussed were developed as part of the work in this project. The active measurement of the latency does not require node synchronization and it is based on cyclic-path delay method in cloud. The originality of the implementation is related to the breaking of the well-known flooding rules.

Secondly, a national project "URBIVEL-Advanced Technologies for Intelligent Urban Electric Vehicles" (started in October 2016) offered the opportunity to investigate a new use case for seamless connectivity. This is due to the mobility of vehicles and the need to provide permanent connectivity between all the participants (i.e. cars) to the infrastructure. Furthermore, by involving sensor networks the project "pushes" the doctoral studies towards the Internet of Things (IoT).

The results of this thesis were validated by several publications at the following conferences: IEEE LANMAN 2016 and 2017, IEEE ISETC 2014 and 2016, IEEE RoEduNet 2015, 2016 and 2017, IEEE COMM 2014 and 2016, and IEEE SOFTCOM 2017. Two articles were published in ACTA TECHNICA NAPOCENSIS, Electronics and Telecommunications.

1.4 Structure of the thesis

This thesis is organized as follows:

Chapter 2 "Uninterrupted Unified Communications Sessions in Wireless Networks" presents the implementation of a Mobility Component at the Application Layer, in a Wi-Fi network which ensures seamless connectivity for a VoIP session during an Access Point handoff. The solutions deals with both pre-call and mid-call mobility and enhances the standard VoIP session by implementing an AES algorithm working in Cipher Block Chaining mode, thus offering encryption.

Chapter 3 "Automatic Deployment of Infrastructure and Services for a Private Cloud Orchestrated by OpenStack" focuses on automatic deployment of OpenStack and on solving issues regarding virtualizing previous physical testbeds. The automation was performed on two levels both for the infrastructure and the software suite using Chef. Furthermore it was demonstrated that in the virtualized network environment available RAM on the hosting machine is a critical aspect.

Chapter 4 "Automatic Management of Applications in Private Cloud Environments" is dedicated to the automatic management of applications in a virtualized testbed orchestrated by OpenStack. The SPLAY open-source framework, based on Lua, was chosen for the implementation. The automation developed in this contribution allows the application layer to keep up with the dynamicity of the overlay infrastructure.

Chapter 5 "Context-Aware Routing for Signaling in NFV" approaches modern communications systems with new concepts such as NFV and SDN. An implementation of a context-aware decision making system was defined in the form of a context-aware routing algorithm for a cloud environment. The algorithm was tested in an adaptable overlay network infrastructure for a geo-distributed private cloud.

Chapter 6 "Seamless Connectivity for Intra/inter-cloud Applications" describes the use case of seamless connectivity in IoT where ubiquity is the term that defines the environment. Independency form low level infrastructure changes was implemented through a high-level abstraction model defined as Holons. An implementation regarding mobility between different access technologies (3G/4G – WiFi – Ethernet) of a Mobile Wireless Sensor Network Gateway between different access technologies (3G/4G – WiFi – Ethernet) emphasizes scalability and ubiquity, key requirements of the CHIST-ERA "DIONASYS" and URBIVEL projects.

Chapter 7 "Contributions to Seamless Connectivity in Cloud-Based Communication Systems" presents a summary of the five contributions presented in the previous chapters. It also includes some final remarks, awards, and a list of personal publications.

1.5 Conclusions

Seamless connectivity has not only become more desired but is a stringent need in the context of modern communication systems. The heterogeneous environment of IoT provides the best use case for such concepts. The request can be met by combining virtualization and abstraction models under a centralized management. Furthermore, any current mechanism must ensure compatibility between legacy systems and future communications developments, thus a software defined infrastructure is the key.

The solution proposed in this PhD thesis aims at providing reusable network adaptability mechanisms for facing the dynamicity of new demands in Future Internet. The integration in a cloud environment makes it easy deployable and highly scalable. Therefore, the concept was designed to be less vulnerable to the underlying cloud infrastructure through a high level of abstraction definition. Moreover, the proposed system provides a complete solution with regards to application quality of service and user experience based on network performance parameters for in both traditional and cloud-based networks.

2 Contributions to Seamless Connectivity in Cloud-Based Communications Systems

2.1 Contributions summary

This section presents a synthesis of the contributions which were discussed in the previous chapters.

1. **Uninterrupted Unified Communications Sessions in Wireless Networks**
2. **Automatic Deployment of Infrastructure and Services for a Private Cloud Orchestrated by OpenStack**
3. **Automatic Management of Applications in Private Cloud**
4. **Context-aware Routing for Signaling in NFV**
5. **Seamless Connectivity for Intra/Inter-Cloud Applications**

1. Uninterrupted Unified Communications Sessions in Wireless Networks

This contribution presents the incentive of the thesis, mobility, also considered to be a catalyst for modern communications systems. In contrast with cellular telephony networks terminal mobility over IP based networks is addressed in terms of pre-call and mid-call mobility and presence servers instead of location areas, visitor or home location registers. The concept of seamless connectivity in respect to the previous mentioned is addressed for a VoIP call placed over Wi-Fi were the Access Point (AP) is changed mid-call. For that an implementation was made at the application level of the smart mobile devices in the system. Pre-call mobility is implemented using a presence server that acts as a DNS for the moving users. During the call a UDP based protocol called TeamSpeak2 was used, that lead to the need of having a buffer for packets lost during AP changing, after experiments it was concluded that 512 bytes were sufficient for the buffer. Mid-call mobility was resolved by preserving the application socket for the VoIP session when the attachment point is changed and dynamically changing the IP address before encapsulating. The security issue of any wireless communication system was not left aside the system implementing an Advanced Encryption Standard (AES) algorithm working in Cipher Block Chaining (CBC) mode, thus offering superior safety to the specific application connections. However the implementation eventuated the need for a more scalable and application independent system in the context of IoT. This poses new challenges in terms of infrastructure performance which were addressed by means of optimization using Objective Functions-Delay for the signaling. From the results it was concluded that for a ubiquitous communication environment parameters such as infrastructure architecture and performance must be considered in order to create an application aware system which will allow seamless connectivity.

Contributions can be found in:	Chapter 2
Publications:	[Luc14], [Com15], [Luc15]

2. Automatic Deployment of Infrastructure and Services for a Private Cloud Orchestrated by OpenStack

This contribution objective is the automation of the deployment of a private cloud infrastructure and services which performed manually are no trivial task. Although there are several automation tools available they are mostly focused on specific packages and configurations thus the need for a particular and more configurable one. The proposed solution brings together three very powerful software packages in order to provide a full cloud deployment, i.e. Chef, Vagrant and VirtualBox. The particularity of the implementation is that both the underlying infrastructure and the post installation configuration of the services are performed. In comparison to a manual installation the time required decreased from dozen of minutes to no more than 2 minutes for the deployment of a new cloud node and its corresponding virtual network infrastructure in full configuration. The rapid infrastructure deployment facilitated various configurations to be tested. One of the most significant results is the fact that the performance of the virtual network in terms of One-Way Delay (OWD) and Active Transfer Rate (ATR) was proven to be in correlation with the amount of RAM memory on the network nodes. For a multi-node deployment of OpenStack on a computer with a house-end performance processor it was concluded that a minimum of 32 GB of RAM is needed to get similar performances for the Network Function Virtualization (NFV) to a physical NIC. Overall performance evaluation in terms of the aforementioned parameters depicted that a Software Define Network (SDN) testbed leveraging NFV in the cloud renders better performances when configured accordingly than a physical one. Furthermore the share costs of a complex testbed are significantly reduced when adopting such an approach. The success of the infrastructure encouraged pushing forward towards more complex software defined infrastructures and scenarios using APIC-EM SDN.

Contributions can be found in: Chapter 3
Publications: [Luc16a], [Luc16b], [Dio16b], [Luc16d], [Ghe17]

3. Automatic Management of Applications in Private Cloud

The paramount focus of this contribution falls upon the implementation and automatic management of applications that leverage the NFV possibilities of the cloud. Network programmability was one of the main objectives, thus an SDN application was chosen for deployment. A previous physical implementation of an SDN testbed provided a solid benchmark for analyzing performances when migrated in a cloud environment. Being that the environment in the NFV context is more dynamic than in the physical world the automatic management of any application is mandatory. The mentioned fact pushed for the developing and of automatic control of a cloud network using Lua scripting language and the features of SPLAY automatic software deployment. It was proved that SPLAY could help in having an automatic control of a testbed by providing easy management of applications and their respective configurations in a dynamic and seamless manner. Furthermore the automation of custom developed applications was implemented in a Pyretic SDN controller platform written using the high-level policies. Pyretic was chosen because of its capability of abstracting and coextending algorithms. Two additional functionalities, dynamic shortest path calculation and real-time topology visualization, were integrated using developed Python modules, likewise an IP Device Tracking custom module was developed in APIC-EM SDN controller testbed. The results provided a baseline for a possible inter-cloud deployment of configuration scripts.

Contributions can be found in: Chapter 4
Publications: [Luc16a], [Luc16b], [Dio16b], [Luc16d], [Lup16], [Pad16], [Ghe17]

4. Context-Aware Routing for Signaling in NFV

In this contribution a deep analysis of the traffic flow for a NFV network was performed. It was concluded that the software controlled routing of underlying networking infrastructure could be performed context-aware based on signaling and QoS parameters. The zestful environment pushed for the deployment of an automatic and dynamic monitoring tool with a modified Management Information Base. Thus a modified MIB for a SNMP based monitoring tool which included OWD and ATR was developed and implemented in a cloud based network. A reasoning based one (IF-THEN rule) algorithm was proposed and implemented for context-aware routing in which service markers were defined for different access technologies, network parameters and applications. Experiments involved defining rules for allowing independency of an AMQP service a VoIP SIP based application and a ZooKeeper database in a cloud based environment were carried out. This work can be further developed to generate more complex algorithms that will ensure routing in a context-aware approach for unconventional and ubiquitous environments such as the world of IoT.

Contributions can be found in: Chapter 5
Publications: [Luc17a], [Luc16c], [Luc17b], [Luc16e],[Com15], [Car17], [Tau17]

5. Seamless Connectivity for Intra/ Inter-Cloud Applications

The high-end developments from the thesis are presented in this contribution. First an implementation of the previously developed algorithm for seamless connectivity based on context-routing in the world of Intra/Inter-Cloud applications which represent the focus of the CHIST-ERA "DIONASYS" project. An application required in the project was ZooKeeper, a strongly consistent replicated store, which performances were improved by controlling a geo-distributed network infrastructure from the edge through context-routing based on active measurements. Furthermore this contribution also validates the fact that seamless connectivity is a present requirement in cloud-based communication systems. Secondly leveraging work previously done within UC Labs and current developments a test-bed in in the context of a cloud connected WSN was build. The key of the system was implemented on a Raspberry Pi model 3 that acted as a MWSNG and as a compute node in the cloud infrastructure. The latter provides the needed easy to access and centralized management interface for applications deployed in a distributed and mobile environment. Seamless connectivity was ensured by dynamically context-routing of active flows from the WSN to the cloud backend simultaneously over different access technologies. Moreover, the implemented architectures have been mapped to a high abstraction model which enables the further development without any setback from developing infrastructure components.

Contributions can be found in: Chapter 6
Publications: [Car17], [Tau17], [Luc17b], [Dio17], [Luc17a], [Iva16], [Luc16e]

2.2 Final remarks

The main goal of this thesis was to design and implement a seamless connectivity model in cloud-based communications systems. However, during the doctoral stage, the contributions were adjusted according to the requirements of the CHIST-ERA “DIONASYS and “URBIVEL” projects, to which we adhered from 2015 and, respectively, 2016. This pushed to the development presented in the last contribution related to seamless connectivity in an IoT environment. Moreover, the idea of abstracting the underlying infrastructure in order to provide application stability in case of service disruption was enhanced from the original goal by leveraging overlay networks and the higher level of abstraction. The achievements of this PhD are already partially deployed within CHIST-ERA “DIONASYS”. However, there are several components which are still under development and will be implemented in the “URBIVEL” project.

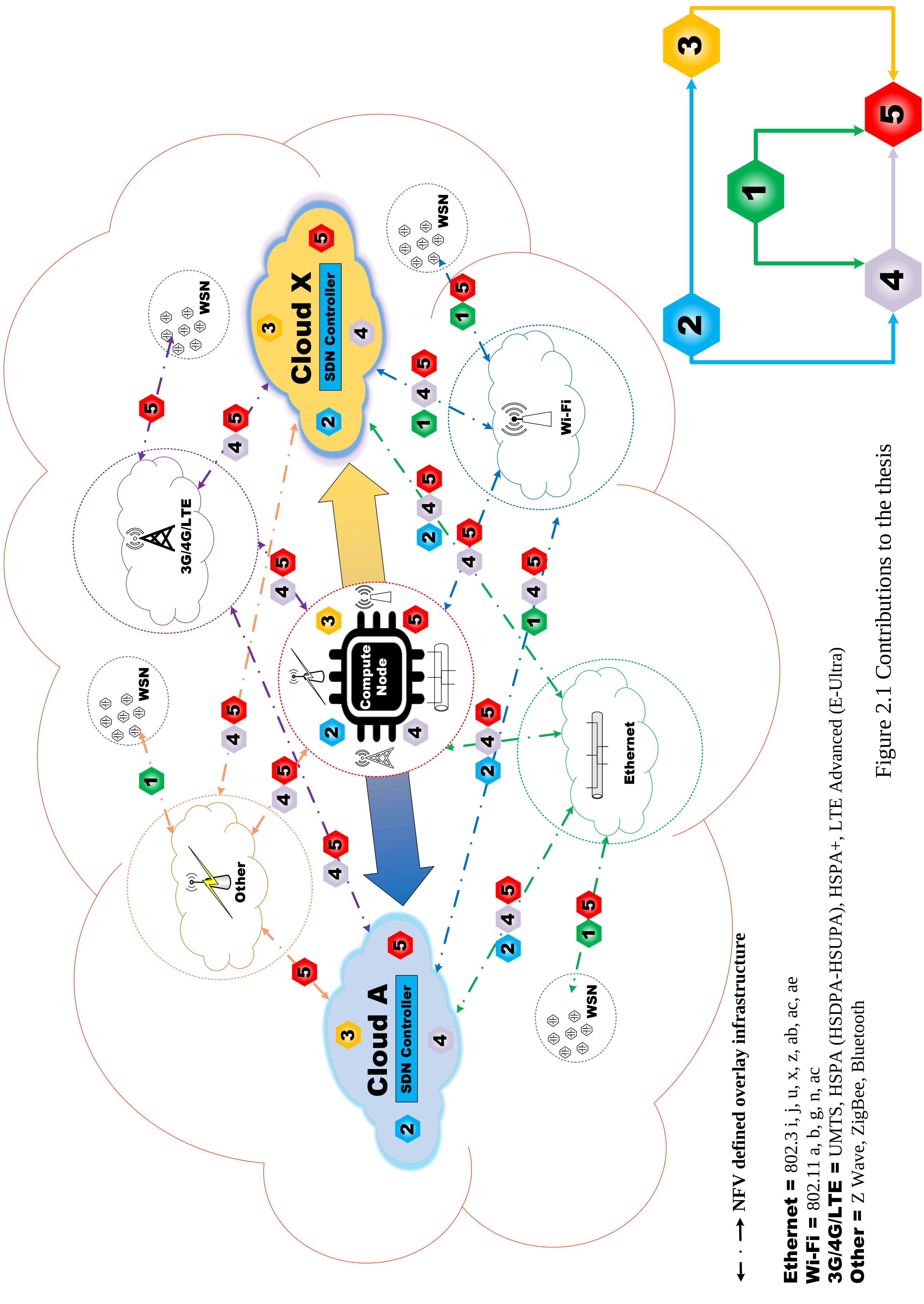

Figure 2.1 Contributions to the thesis

2.3 Awards

Advisor for the papers awarded the First Prize in the "Students Scientific Communication Session in Electronics and Telecommunications", organized by the Faculty of Electronics, Telecommunications and Information Technology, Technical University of Cluj-Napoca, Romania, May 2016 and May 2017.

2.4 Personal publications

2.4.1 Indexed database journals

[Tau17]	A. Taut, I.A. Ivanciu, **E. Luchian**, and V. Dobrota, "Active Measurement of the Latency in Cloud-Based Networks", ACTA TECHNICA NAPOCENSIS, Electronics and Telecommunications, ISSN 1221-6542, Vol.58, No.1, 2017, pp.22-30
[Luc16a]	**E. Luchian**, I.A. Ivanciu, A.B. Rus, G. Lazar, and V. Dobrota, "Migration of an SDN-Based Testbed into a Private Cloud: An OpenStack Approach", *ACTA TECHNICA NAPOCENSIS, Electronics and Telecommunications*, ISSN 1221-6542, Vol.57, No.1, 2016, pp. 1-10

2.4.2 ISI Proceedings conferences

[Luc14]	**E. Luchian**, R. Terebes and M. Cremene. "Design and implementation of a mobile VoIP system on Android." Proceedings of the 11th International Symposium on Electronics and Telecommunications ISETC 2014, Timisoara, Romania, November 14-15, 2015, pp. 157-161, Electronic ISBN: 978-1-4799-7267-8, DOI: 10.1109/ISETC.2014.7010772
[Com15]	A. Comsa, I.A. Ivanciu, **E. Luchian**, V. Dobrota, and K. Steenhaut, "End-to-End Delay Minimization in an Application-Aware Routing for Wireless Sensor Networks", *14th RoEduNet Conference: Networking in Education and Research NER'2015*, Agency ARNIEC/RoEduNet and University of Craiova, Craiova, Romania, September 24-26, 2015, pp.80-84, Print ISBN: 978-1-4673-8179-6, DOI: 10.1109/RoEduNet.2015.7311832
[Pad16]	M. Padurariu, B. Rosca, I.A. Ivanciu, **E. Luchian**, A.B. Rus, and V. Dobrota, "Automatic Control of an OpenFlow-Based Network Using Lua Scripts and SPLAY", *11th International Conference on Communications COMM 2016*, Military Technical Academy, "Politehnica" University of Bucharest, "Electronica 2000" Foundation and IEEE Romania Section, Bucharest, Romania, June 9-11, 2016, pp. 299-302, DOI: 10.1109/ICComm.2016.7528286
[Luc16b]	**E. Luchian**, C. Filip, A.B. Rus, I.A. Ivanciu, and V. Dobrota, "Automation of the Infrastructure and Services for an OpenStack Deployment using Chef Tool ", *15th RoEduNet Conference: Networking in Education and Research*, University Politehnica Bucharest, September 7-9, 2016, pp. 1-5

[Luc16c]	**E. Luchian**, P. Docolin, and V. Dobrota, "Advanced Monitoring of the OpenStack NFV Infrastructure: A Nagios Approach Using SNMP", *Proceedings of the 12th International Symposium on Electronics and Telecommunications ISETC 2016, Timisoara, Romania, October 27-28, 2016*, pp. 51-54, Electronic ISBN: 978-1-5090-3748-3, DOI: 10.1109/ISETC.2016.7781055
[Lup16]	F.L. Lupaescu, I.A. Ivanciu, **E. Luchian**, and V. Dobrota, "A Firewall Application for Performance Evaluation of the Pyretic Controller in Software-Defined Networks", *15th RoEduNet Conference: Networking in Education and Research*, University Politehnica Bucharest, September 7-9, 2016, pp. 17-21
[Iva16]	I.A. Ivanciu, **E. Luchian**, E. Riviere, and V. Dobrota, "OpenStack-based Clouds as Holons: A Functional Perspective", *22nd IEEE International Symposium on Local and Metropolitan Area Networks LANMAN 2016*, Rome, Italy, June 13-15, 2016, Electronic ISSN: 1944-0375, DOI: 10.1109/LANMAN.2016.7548849
[Car17]	R. Carvajal Gomez, **E. Luchian**, I.A. Ivanciu, A. Taut, V. Dobrota, and E. Riviere, "On the Impact of Indirect WAN Routing on Geo-Replicated Storage", *23rd IEEE International Symposium on Local and Metropolitan Area Networks LANMAN 2017*, Osaka, Japan, 12-14 June 2017, pp. 1-6, Electronic ISSN: 1944-0375, DOI: 10.1109/LANMAN.2017.7972171
[Luc17b]	**E. Luchian**, A. Taut, I.A. Ivanciu, G. Lazar, V. Dobrota, "Mobile Wireless Sensor Network Gateway: A Raspberry Pi implementation with a VPN backend to OpenStack", *Proceedings of the 25th International Conference on Software, Telecommunications and Computer Networks IEEE SOFTCOM 2017*, Split, Croatia, September 21-23, 2017, pp. 271-275, Electronic ISBN: 978-953-290-078-1, USB ISBN: 978-953-290-074-3, Electronic ISSN: 1847-358X, DOI: 10.23919/SOFTCOM.2017.8115561

2.4.3 Indexed Database Proceedings Conferences

[Ghe17]	C.M. Gheorghe, C.M. Iurian, **E. Luchian**, I.A. Ivanciu, and V. Dobrota, "Applications of the Cisco APIC-EM Software-Defined Networking Controller for a Virtualized Testbed", 16th RoEduNet Conference: Networking in Education and Research,"Petru Maior" University of Targu-Mures, Romania, September 21-23, 2017

2.4.4 Technical Project Reports

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2.4.5 PhD Scientific Research Reports

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[Luc16d]	**E. Luchian**, "Private Cloud Solutions: Access and Services", Ph.D. Scientific Research Report 2 (unpublished), Technical University of Cluj-Napoca, Romania, March 2016
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2.5 List of Projects

1	C. Martis (coordinator), V. Dobrota, I.A. Ivanciu, **E. Luchian** (included in list of members), ID P_40_333 " URBIVEL - Advanced Technologies for Intelligent Urban Electric Vehicles", 2016-2018
2	V. Dobrota (coordinator for TUCN), A.B. Rus, I.A. Ivanciu, G. Lazar, **E. Luchian** (members) et al., „CHIST-ERA DIONASYS "Declarative and Interoperable Overlay Networks, Applications to Systems of Systems", 2015-2018