PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Ugo Giordano

XXIX Cycle

Training and Research Activities Report – Second Year

Tutor: Prof. Stefano Russo

1. Information

PhD Student: Ugo Giordano
MS title: Computer Engineering – University of Naples Federico II
PhD cycle: XXIX – ITEE – University of Naples Federico II
Fellowship: Projects "SVEVIA" and "DISPLAY" of the "COSMIC" public-private laboratory (PON02_00669)
Tutor: Prof. Stefano Russo

2. Study and Training activities

a. Courses

Lecture/Activity	Type	Professor	Date	h	CFU
Project Management per la Ricerca	Ad hoc module	Guido Capaldo	20/03/15	15	**3**
Models, methods and software for Optimization	Ad hoc module	Antonio Sforza/Claudio Sterle	23-25/03-04/15	18	**4**
English Language Course	Ad hoc module	Geraint Thomas	-	-	**6**
Total					**13**

b. Seminars and other

Lecture/Activity	Type	Lecturer	Date	h	CFU
Reliability of electronic power devices and modules	Seminar	Alberto Castellazzi	24-26/03/15	6	**1.2**
The Memories of Tomorrow: Technology, Design, Test, and Dependability	Seminar	Elena Ioana Vatajelu	24/04/15	3	**0.6**
Design and writing scientific manuscripts for publication in English language scholarly journals, and related topics	Seminar	Barnet Parker	15-17/06/15	12	**3**
Beyond the data: how to achieve actionable insights with machine learning	Seminar	Matteo Santoro	10/11/15	2	**0.3**
Winter School: Securing Critical Infrastructures	Doctoral School	-	17-24/01/16	36	**7.2**
Adversarial Testing of Protocol Implementations	Seminar	Cristina Nita Notaru	23/02/16	2	**0.4**
Programmable network conjunction	Seminar	Roberto Bifulco	26/02/16	2	**0.4**
Total					**13.1**

3. Research activity

Title: Performance evaluation of software-based network technologies

Description and study:

3.1. NFV and SDN: toward the softwarization of future networks

Traditionally, the network control systems and services within a telecommunications industry have been based, in most of the cases, on physical proprietary devices with a strong integration between the physical component (hardware) and application logic (software) that implements the specific network functionality. This has lead to have a specific hardware component for each network function.
In addition, service components have strict chaining and/or ordering that must be reflected in the network topology and in the localization of service elements, such that a physical intervention is needed in order to deploy a new service or to update an existing one.

All these aspects, coupled with the proliferation of heterogeneous technologies, non-replaceable proprietary solution, stringent protocol adherence and high quality service requirements, have lead to a high operational complexity together with high **CPAEX** (Capital Expenses) and **OPEX** (Operational Expenses) for Telecommunication Service Providers (TSPs) [1,2].
Network function virtualization (NFV), **software-defined networking** (SDN) and **network virtualization** (NV) have been proposed as a way to address these challenges by leveraging IT virtualization technologies to deploy and manage networking services on standard COTS (Commercial Off-The-Shelf) server, while providing great operational flexibility [3, 4, 5]. This in turn will bring significant changes in the way that network applications are delivered to service providers.
The main idea of NFV and SDN are as follows:

- **SDN**: separates the network's control and forwarding planes and provides a centralized view of the distributed network for more efficient orchestration and automation of network services.
- **NFV**: by decoupling Network Functions (NFs), such as DNS, firewalls, etc., from proprietary hardware appliances, so they can run in software. NFV has the potential to lead to significant reduction in CAPEX and OPEX and accelerate service innovation and provisioning.

These emerging networking technologies, that are attracting significant attention from both academia and industry, mainly aim to reduce costs and time-to-market, improve manageability, and provide more advanced services [6].
However, a lot of challenges need to be addressed in order to move existing network functions into the virtualization infrastructure. To this aim, telecom operators are currently developing proof-of-concept [7] to prove the feasibility of the adoption of such innovative technologies.

3.2. Performance evaluation of NFV technologies under overload conditions

Over decades, the telecom service providers have spent a lot of effort on building telecom networks that are incredibly reliable. That is the premise behind **carrier-grade** networks [8, 9, 10], that are capable to guarantee a "**six-nines**" reliability. This means the network is guaranteed to be up 99.9999 percent of the time, implying a downtime of no more than few seconds per year.
On the other hand, with the introduction of NFV, the telecom networks will be build on top of standard off-the-shelf server which are in turn designed for IT services and enterprise application having availability requirements of the order of "**two-nines**" (availability of 99%) to "**three-nines**" (availability of 99.9%).
So, since carrier-grade networks' reliability requirements are stricter than traditional IT, TSPs need to continue to meet those requirements as they move to NFV. In particular, the network performance requirements play a crucial rule for achieving carrier-grade reliability. They specify that a network

must achieve high throughput but at the same time ensure very low latency for critical real time applications, also under high **overload** conditions.
In ICT systems an overload condition occurs when at given time the submitted load is larger than the system can run at that time. This may cause performance degradations, such as high response times, or, even worse, service failures. The overload conditions can occur for many reasons, such as: flash crowd (e.g. the occurrence of popular event), component failures, poor capacity planning and so forth.
The TSPs have spent a lot of effort to face such phenomena over the years, given the high impact it can have on the the quality of the network services provided. Indeed, if the overload traffic is out of control, the overloaded network will lose high-priority requests or subsequent messages of a request, and will not guarantee the SLA (e.g. service success rate, etc.), even causing avalanche, complete failure or cascade failures due to retires or traffic handover.
However, the overload control solution adopted by the TSPs are not sufficient for the NFV context, given the significant difference from traditional network equipment.
At same time, the traditional mechanisms adopted in the virtualization and cloud computing environments to face overload condition, such as virtual machine scaling and/or migration [16-20], peak periods forecasting [11-15], are not suitable for the NFV as they require too much time (in the order of minutes) to effectively face an overload condition.

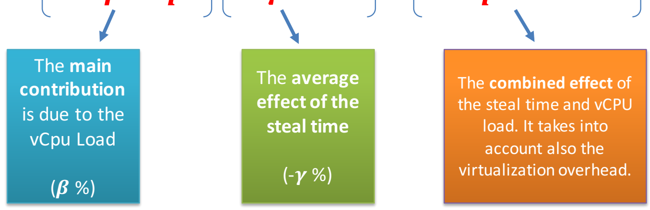
During my second year I collaborate with Huawei Technologies Co. Ltd., within an industrial research project with the aim to propose efficient methodologies and tools to detect and mitigate overload conditions of Network Function Virtualization systems.
In particular, within my research group, first I have studied how the overload phenomena affect the performance of NFV-oriented technologies. Towards this goal, by considering a virtualized IP Multimedia Subsystem [22] (the Clearwater IMS Project) as a testbed, we have conducted the following activities:

- **Performance analysis of a virtualized IP Multimedia Subsystem:** we need to understand what are the most critical overload conditions that can affect reliability of a VNF infrastructure. To this aim we have tested the Clearwater IMS [21], an existing VNF architecture, by taking into account a wide range of possible overload scenarios. Specifically, we have covered scenarios whit different overload conditions: 1) unexpected increase of load; 2) Poor capacity planning; 3) Resource contention; 4) Hardware faults and 5) Software problems.
  Moreover, we have also studied how the overload affect the performance at different VNF infrastructure layer: 1) Overload at **node level**, with a single machine providing a specific network function; 2) Overload at **network level**, with the whole system, using VNFs, to provide a service (e.g., IMS); 3) Overload at **Infrastructure level**, with the Virtual Network Infrastructure providing physical resources to the virtual network functions.

- **Identification of Key Performance Indicators for VNF reliability:** we need to identify not only measurements that are representative of the VNF performance but also those that can help us to distinguish between normal operational condition and overload condition.

- **Definition of a more accurate Indicator for an overload condition:** we have found that the most significant measurement (i.e. the virtual CPU utilization) for the overload detection can be inaccurate under specific situation, such as physical CPU contention (due to resource over-commitment). Therefore, we have developed, by means of a regression analysis, a model for discriminating between overload conditions due to high workload and those due to physical resource contention. The model reported below estimates the real CPU footprint of a virtual machine (i.e. a VNF), using measurements from the Guest Operating System and the NFV infrastructure.

$$\overline{rcpu} = (\alpha + \beta\, vcpu)(-\ \gamma\, steal) - (\delta\, vcpu\ * steal)$$



The $\overline{rCPU}$ represents the estimated version of the $rCPU$ (i.e. the real CPU footprint of a VNF), and then the difference $\overline{rCPU} - rCPU$ represents the error of such a model. According to this model, the man contribution to estimate the real CPU footprint is due to the $vCPU$ measurement (it contributes with 90% of its value), that is the CPU consumption collected inside a virtual machine; the second higher contribution is due to the $steal$ time (-30%), that is the time during with a virtual CPU is not idle and waits to be scheduled on a physical CPU (i.e. the time that a vCPU process waits in the **run-queue** of the hypervisor); finally the combined effect of $steal$ time and $vCPU$ represents a correlation factor that contribute with the -1% to the $rCPU$ estimation.

- **Design and validation of a novel algorithm to detect and mitigate overload conditions:** we will conduct a proof-of-concept validation of an algorithm, based on the defined measurements, to detect and react to an overload conditions on commercial NFV products.

We are developing a closed-loop architecture for NFV overload control based on virtual CPU and real estimated CPU measurements. The key results of such research activities will be included in a **patent proposal**. Therefore, for confidentiality reason on our collaboration with Huawei, further details are not shown/discussed here.

4. Products

a. Publications

Conference Paper

G.Carrozza, M.Cinque, U.Giordano, R.Pietrantuono, S.Russo,
Prioritizing Correction of Static Analysis Infringements for Cost-Effective Code Sanitization, Proc. IEEE/ACM 2nd International Workshop on *Software Engineering Research and Industrial Practice* (SER&IP), 37th "*IEEE International Conference on Software Engineering*",
Florence, Italy, May 17, 2015, pp. 25-31
DOI: 10.1109/SERIP.2015.13D, ISBN: 9781467370851,
IEEE

5. Conference and Seminars

a. Conference

Winter School: "Securing *Critical Infrastructures*", Cortina d'Ampezzo, from January 17th to 24th, 2016.

6. Activity abroad

For the activities of the next year, I will join the **Alcatel Lucent** research group at **Bell Laboratories** (NJ) with a 1-year Fellowship financed by Bell Labs.
Topics that will be covered are related to different facets of resiliency of advanced networking and control technologies (SDN/NFV) in the context of development of distributed Network Operating System, such as:

- Run-time injections for continuous testing in carrier-grade SDN operating systems
- System-level failure detectors and distributed failover techniques for fast recovery in carrier-grade SDN
- Running user-level network stacks to reduce latency in a carrier-grade SDNs operating system

7. Tutorship

I have been teaching assistant for the course of Real-time Systems a course of the Master's degree in Computer Engineering, Department of Electrical Engineering and Information Technologies at University of Naples Federico II, academic year 2015/2016.

8. CS summary

	Credits year 1									Credits year 2									Credits year 3	
		1	2	3	4	5	6				1	2	3	4	5	6				
	Estimated	bimonthly	bimonthly	bimonthly	bimonthly	bimonthly	bimonthly	Summary	Check	Estimated	bimonthly	bimonthly	bimonthly	bimonthly	bimonthly	bimonthly	Summary	Check	Estimated	Check
Modules	24	0	0	6	0	3	15	24	20-40	13	7	6	0	0	0	0	13	10-20	0	0-10
Seminars	6	0	0	3	0	2.7	2	7.7	5-10	8	1.8	3	0	0	0.3	8	13.1	5-10	0	0-10
Research	35	8	8	2	9	8	2	37	10-35	45	5	7	7	8	9	9	45	30-45	60	40-60
	65	8	8	11	9	13.7	19	68.7		66	13.8	16	7	8	9.3	16.2	70.3		70	

9. Bibliography

[1] Chen, Clark. "C-RAN: the Road Towards Green Radio Access Network." White paper (2011).

[2] Wu, Jun, et al. "Cloud radio access network (C-RAN): a primer." Network, IEEE 29.1 (2015): 35-41.

[3] Han, Bo, et al. "Network function virtualization: Challenges and opportunities for innovations." Communications Magazine, IEEE 53.2 (2015): 90-97.

[4] Operators, Network. "Network Functions Virtualization, An Introduction, Benefits, Enablers, Challenges and Call for Action." SDN and OpenFlow SDN and OpenFlow World Congress. 2012.

[5] ISG, NFV. Network Functions Virtualisation (NFV)-Network Operator Perspectives on Industry Progress,". ETSI, Tech. Rep, 2013.

[6] Manzalini, A., et al. "Manifesto of edge ICT fabric." 2013 17th International Conference on Intelligence in Next Generation Networks (ICIN).

[7] ETSI ISG for NFV, "NFV Proofs of Concept "http://www.etsi.org/technologies-clusters/technologies/nfv/nfv-poc"; accessed 28 Feb. 2016.

[8] Greene, Wedge, and Barbara Lancaster. "Carrier-Grade: Five Nines, the Myth and the Reality." Pipeline magazine (2007).

[9] Staessens, Dimitri, et al. "Software defined networking: Meeting carrier grade requirements." Local & Metropolitan Area Networks (LANMAN), 2011 18th IEEE Workshop on. IEEE, 2011.

[10] Han, Bo, et al. "Network function virtualization: Challenges and opportunities for innovations." Communications Magazine, IEEE 53.2 (2015): 90-97.

[11] N. Bobroff, A. Kochut, and K. Beaty. Dynamic placement of virtual machines for managing sla violations. *In Integrated Network Management, 2007. IM '07. 10th IFIP/IEEE International Symposium on*, pages 119–128, May 2007.

[12] A. Quiroz, Hyunjoo Kim, M. Parashar, N. Gnanasambandam, and N. Sharma. Towards autonomic workload provisioning for enterprise grids and clouds. In *Grid Computing, 2009 10th IEEE/ACM International Conference on*, pages 50–57, Oct 2009.

[13] Xiaoqiao Meng, Canturk Isci, Jeffrey Kephart, Li Zhang, Eric Bouillet, and Dimitrios Pendarakis. Efficient resource provisioning in compute clouds via vm multiplexing. In *Proceedings of the 7th International Conference on Autonomic Computing*, ICAC '10, pages 11–20, New York, NY, USA, 2010. ACM.

[14] Sheng Di, Derrick Kondo, and Walfredo Cirne. Google hostload prediction based on bayesian model with optimized feature combination. Journal of Parallel and Distributed Computing, 74(1):1820–1832, 2014.

[15] A. Beloglazov and R. Buyya. Managing overloaded hosts for dynamic consolidation of virtual machines in cloud data centers under quality of service constraints. Parallel and Distributed Systems, IEEE Transactions on, 24(7):1366–1379, July 2013.

[16] Ye Huang, Nik Bessis, Peter Norrington, Pierre Kuonen, and Beat Hirsbrunner. Exploring decentralized dynamic scheduling for grids and clouds using the community-aware scheduling algorithm. Future Gener. Comput. Syst., 29(1):402–415, January 2013.

[17] Evangelia Kalyvianaki, Themistoklis Charalambous, Marco Fiscato, and Peter Piet- zuch. Overload management in data stream processing systems with latency guaran- tees. In 7th IEEE International Workshop on Feedback Computing (Feedback Com- puting'12), 2012.

[18] S. Sotiriadis, N. Bessis, P. Kuonen, and N. Antonopoulos. The inter-cloud meta- scheduling (icms) framework. In Advanced Information Networking and Applications (AINA), 2013 IEEE 27th International Conference on, pages 64–73, March 2013.

[19] Long Wang, R.A. Hosn, and Chunqiang Tang. Remediating overload in over-subscribed computing environments. In *Cloud Computing (CLOUD), 2012 IEEE 5th International Conference on*, pages 860–867, June 2012.

[20] L. Tomas and J. Tordsson. An autonomic approach to risk-aware data center overbooking. *Cloud Computing, IEEE Transactions on*, 2(3):292–305, July 2014.

[21] Cao, Lianjie, et al. "NFV-VITAL: A Framework for Characterizing the Performance of Virtual Network Functions."

[22] Project Clearwater. Project Clearwater - IMS in the Cloud. http://www.projectclearwater.org.