PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Stefano Rosiello

XXXI Cycle

Training and Research Activities Report – Third Year

Tutor: prof. Domenico Cotroneo

1. Information

PhD candidate: Stefano Rosiello
MS title: Computer Engineering – Univ. of Naples Federico II
PhD cycle: XXXI (year III)
Fellowship type: Phd student grant
Tutor: prof. Domenico Cotroneo

This report is on the training and activities of Stefano Rosiello during his third year of the PhD course "Information Technologies and Electrical Engineering" (ITEE), XXXI cycle, at University of Naples Federico II.

Stefano received his Master's degree cum laude in Computer Engineering in 2015 from the University of Naples Federico II, working on reliability evaluation for Network Function Virtualization infrastructures.

Stefano works within the DIETI DESSERT (Dependable System and Software Engineering Research Team) group, under the supervision of prof. Domenico Cotroneo. His main research activity focuses on overload control in carrier-grade network function virtualization and cloud infrastructures. His research interests also include experimental reliability evaluation, dependability benchmarking and fault-injection testing.

2. Study and Training activities

In his third year, Stefano attended the following courses and seminars:

Seminars

(1) "**Graph Queries: Generation, Evaluation and Learning**",
Prof. Angela Bonifati, 18/12/2017 (0.4 CFU)

(2) "**Logic-Based Languages and Systems for Big Data Applications**",
Prof. Carlo Zaniolo, 13-15/03/2018 (0.8 CFU)

(3) "**Model-based API Testing of Apache Zookeper**",
Dr. Cyrille Artho, 19/03/2018 (0.4 CFU)

(4) "**IBM-Q: Building the first universal quantum computers for business and science**",
Dr. Federico Mattei, Dr.ssa Najla Said, 16/05/2018 (0.4 CFU)

(5) Tutorial, "**Past, Present and Future of Software Reliability Assurance**"
Dr. Rashid Mijumin (Nokia, Ireland), Dr. Kazuhira Okumoto, 15/10/2018, ISSRE 2018, Memphis (0.8 CFU)

(6) Tutorial, "**Exploiting Operational Profile Data for Continuous Dependability Assessment in DevOps**"
Dr. Alberto Avritzer (Esulabsolutions, Inc., USA), Dr. André Van Hoorn (University of Stuttgart, Germany), 17/10/2018, ISSRE 2018, Memphis (0.8 CFU)

(7) Tutorial "**Towards Development of Secure Mobile Software**",
Dr. Hossain Shahriar (Kennesaw State University,USA), 18/10/2018, ISSRE 2018, Memphis (0.8 CFU)

CS Summary

	Credits year 1								Credits year 2								Credits year 3									
		1	2	3	4	5	6			1	2	3	4	5	6			1	2	3	4	5	6			
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Total	Check
Modules	20	0	7	0	3	0	9	**19**	10	0	9	2	0	0	0	**11**	0	0	0	0	0	0	0	**0**	**30**	**30-70**
Seminars	5	0	0.8	0.8	1.2	0	0.5	**3.3**	5	1.8	0	2.6	0	0	1.4	**5.8**	5	0.4	0	1.2	0.4	0	2.4	**4.4**	**14**	**10-30**
Research	35	10	2	9	6	10	1	**38**	40	8	1	5	10	10	9	**43**	55	9.6	10	8.8	9.6	10	7.6	**56**	**137**	**80-140**
	60	10	9.8	9.8	10	10	11	**60**	55	9.8	10	9.6	10	10	10	**60**	60	10	10	10	10	10	10	**60**	**180**	**180**

3. Research activity

Title: Autonomic Overload Management for Large-Scale Virtualized Network Functions

Description and study

(1) Motivation

The explosion of data traffic in telecommunication networks has been impressive in the last few years. The networks of today connect computers, phones, cars, TV and IoT devices and provide us billion of different services, such as VoIP and instant messaging, gaming and VR, maps, IPTV and video-streaming up to Ultra HD definition. Moreover, pervasive services provided by the giants of the Internet as Google, Apple, Facebook, Amazon, and Netflix are increasing the competition among Telecom operators: customers are constantly pushing for more innovative services and expect them to be provided with a high quality of experience, in their offices, in their homes as well as in mobility through their smartphones and other smart devices.

As result, if in the past telecommunication networks where challenged by exceptional events like a new year or a natural catastrophe (such as an earthquake), nowadays mass events are more frequents: we can think of a viral post on the social networks, the release of a new version of a popular app or an update of the Operating System, a new episode of a TV series, the live streaming of a sport match. The above are only a few examples of challenges for today networks and they cannot be considered exceptional events anymore.

In this context, traditional network architectures, which are complex and hard to scale and to manage, become a real bottleneck for the innovation due to higher maintenance costs and unacceptable higher roll-out times for new services. To keep up with the demand and staying profitable, Telcos are embracing the Network Function Virtualization (NFV) paradigm by shifting from hardware network appliances to virtual network functions, implemented in software. NFV aims to leverage standard IT virtualization technology to consolidate network functions in industry-standard high volume servers, switches, and storage; and to take advantage of orchestration and monitoring solutions used for cloud computing [1-2]

Being a cloud-based solution, NFV inevitably inherits the threats coming from this domains. A major cause of cloud service failures is represented by overload conditions [3] which occur when the incoming traffic exceeds the available capacity (e.g., by tens, or even hundreds of times). However, overloads are not only due to traffic spikes (e.g., due to mass events): an important class of problems in this area is represented by faults that restrict the capacity causing overload, such as faults that can occur in commodity hardware and software components [4-7], physical resource contention inside the cloud infrastructure [8-9] and, even more frequently, misconfigurations due to human intervention.

Despite the above threats, the NFV solutions are expected to support extremely large scale architectures, providing high performance and high dependability. Indeed, telecom regulation imposes carrier-grade requirements in term of high packet processing and availability (99.999\% or even higher).

For this reason, the main consortia behind NFV, including the ETSI and OPNFV, pointed out the need for solutions capable of:

- optimizing the performance at very large scale without human intervention in response to both service configuration and workload variations [10];

- detecting the occurrences of network problems and mitigating their symptoms within few seconds [11-12];

The problem of managing the overload conditions touches both these aspects: First, the overload management is responsible to dynamically optimize the resource usage (such as Compute, Memory, Network), in order to prevent both the exhaustion and the under-utilization of physical infrastructure resources, in response to workload changes. Second, it is responsible to guarantee an acceptable QoS by masking or mitigating the effects of faults affecting the service capacity. Moreover, an overload management solution needs to reconfigure itself without human intervention in response to changes in both service workload and scale.

Therefore, an effective overload management framework for NFV should be an autonomic solution, in order to react timely to bottlenecks undermining the performance and the availability of the network services. My research faces the problem of autonomic overload management for virtual network functions.

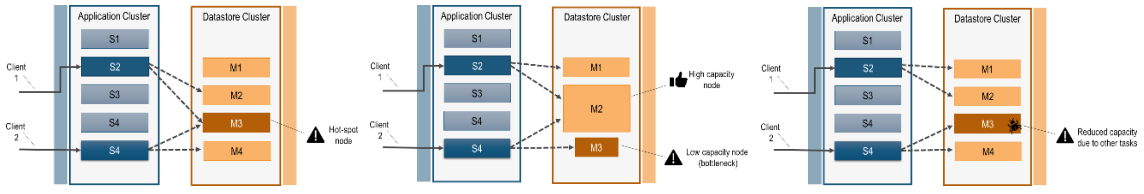
Research Activities

During these three years, Stefano collaborated 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.

His research activity includes the analysis of the performance failures in software-based network function systems, approaches to detect performance anomalies in these systems, and solutions to mitigate the effect of such anomalies. Details of the third-year activities as follows:

Analysis of performance failures. In the first part of the third year, Stefano studied the performance failures of stateful multi-tier virtual network functions. Indeed, VNF software is evolving by shifting the state in highly distributed datastores (such as Cassandra, Memcached) to achieve massive scalability. The new multi-tier architecture for the VNF software adds new data dependencies between application and storage nodes and, thus, poses new threats that may affect the capacity (and the reliability) of NFV services, such as:

- Unbalanced accesses caused by “Hot-spot” resources (Figure 1 (a))
- Unbalanced capacity in storage nodes (Figure 1 (b))
- Reduced capacity due to sporadic (or periodic) background tasks (Figure 1 (c))



(a) (b) (c)

Figure 1: Overload threats in stateful multitier architectures

Overload control. The benchmark phase pinpointed that in all the considered scenarios, the main effect is the overload of some system component which leads to a QoS degradation, in terms of both availability or responsiveness. For this reason, during the second part of the year, he focused on researching effective overload control strategies that are applicable to NFV. He developed an admission control algorithm which is able to quickly react (in few seconds) to the above performance anomalies by using a set of heuristics to dynamically estimate the capacity variations of the system, by looking combining the information about the

current workload (e.g., service request rate) and the current resource consumption (e.g., CPU usage). The experimental evaluation of the algorithm on the IMS testbed revealed that even during serious overload conditions (such as ten times bigger than the capacity), the system is able to provide at least the 95% of the maximum throughput and, at the same time, it ensures an acceptable QoS for the accepted sessions.

An overload control framework. With his research group, Stefano developed and evaluated a framework, namely DRACO, for protecting modern multi-tier stateful architectures from the threats of the overload happening in large-scale deployments. The framework, the overload control algorithm, and the results about the experimental evaluation on the IMS have been included in a research paper submitted to ACM Transaction on Computer Systems international journal.

Other activities.

During the year, he got involved in the organization *of 15th European Dependable Computing Conference that will held in Naples 17-20 September 2019,* as Local Organization Chair and Web Chair.

In October, he also participated to the 29th IEEE International Symposium on Software Reliability Engineering (ISSRE 2018) in Memphis, USA, gaining insightful feedbacks on his work from both industrial and academic worlds.

In the last period of his third year, he started the put in writing of the PhD thesis and focused completely on it till the end of the PhD year.

4. Products

International Journal

(P1) D. Cotroneo, R. Natella, **S. Rosiello** – "NFV Throttle: An Overload Control Framework for Network Function Virtualization" – IEEE Transaction on Network and Service Management, Spec. Issue on "Advances in Management of Softwarized Networks", September 2017, DOI: http://dx.doi.org/10.1109/TNSM.2017.2752173, ISSN: 1932-4537, IEEE Computer Society Press

(P2) D. Cotroneo, R. Natella, **S. Rosiello** – "Overload Control for Virtual Network Functions under CPU Contention" – Future Generation Computer Systems, Elsevier (**under-review**)

(P3) D. Cotroneo, R. Natella, **S. Rosiello** – "DRACO: Distributed Resource-aware Admission Control for Large Scale, Multi-tier systems" – ACM Transactions on Computer Systems, ACM (**under-review**)

(P4) D. Cotroneo, A.K. Iannillo, R.Natella, **S. Rosiello**, "Software Fault Injection for the Android Mobile OS", IEEE Computers Magazine (**under-review**)

International Conferences

(P5) D. Cotroneo, R. Natella, **S. Rosiello** – "A Fault Correlation Approach to Detect Performance Anomalies in Virtual Network Function Chains", IEEE 28th International Symposium on Software Reliability Engineering (ISSRE), October 24th, 2017, Toulouse, France

(P6) D. Cotroneo, A. K. Iannillo, R. Natella, **S. Rosiello**, "*AndroFIT: Software Fault Injection for the Android Mobile OS*", ACM 40th International Conference on Software Engineering – Software Engineering in Practice (ICSE2018 SEIP), ACM, 2018 (***under-review***)

5. Conferences and Seminars

At the end of his second year, Stefano participated to the 28th IEEE International Symposium on Software Reliability Engineering (ISSRE 2017) in Toulouse, France, where he presented a conference paper in the main research track. The conference paper is entitled "A Fault Correlation Approach to Detect Performance Anomalies in Virtual Network Function Chains".

At the end of his third year (14-19 October 2018), Stefano participates to the 29th IEEE International Symposium on Software Reliability Engineering (ISSRE 2018) in Memphis, USA, gaining insightful feedbacks on his work from both industrial and academic worlds.

6. Activity abroad

No activity abroad has been carried out during his second year.

7. Tutorship

Also this year, Stefano has been teaching assistant for the Ms.Sc. course “Impianti di Elaborazione” (prof. Domenico Cotroneo), 10 hours.

Moreover, he has been co-advisor for the following MSc thesis:

- “Performance analysis of an NFV-*oriented IMS infrastructure”,* Giovanni Di Fiore, 2016
- “Overload Detection in cluster-based storage systems”, Simona Posca, 2017
- “Overload Detection in Large-Scale Cluster Servers”, Roberta De Viti, 2017
- “Capacity Management in sistemi multi-tier altamente scalabili”, Domenico Schiano, 2018
- “Fault-tolerance analysis of distributed storage middleware”, Noemi Gemito, 2018

References

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[2] OpenStack Foundation Report, “Accelerating NFV Delivery with OpenStack,” 2016.

[3] E. Bauer and R. Adams, *Reliability and Availability of Cloud Computing*, 1st ed. Wiley-IEEE Press, 2012.

[4] D. Cotroneo, L. De Simone, A. K. Iannillo, A. Lanzaro, R. Natella, J. Fan, and W. Ping, “Network function virtualization: Challenges and directions for reliability assurance,” in *Software Reliability Engineering Workshops (ISSREW), 2014 IEEE International Symposium on*. IEEE, 2014, pp. 37–42.

[5] D. Cotroneo, L. De Simone, A. K. Iannillo, A. Lanzaro, and R.Natella, “Dependability evaluation and benchmarking of Network Function Virtualization Infrastructures,” in *Network Softwarization (NetSoft), 2015 1st IEEE Conference on*, 015, pp. 1–9.

[6] T. Niwa, M. Miyazawa, M. Hayashi, and R. Stadler, “Universal fault detection for NFV using SOM-based clustering,” in *Network Operations andManagement Symposium(APNOMS), 2015 17th Asia-Pacific*. IEEE, 2015, pp. 315–320.

[7] C. Sauvanaud, K. Lazri, M. Kaaniche, and K. Kanoun, “Anomaly Detection and Root Cause Localization in Virtual Network Functions,” in *Software Reliability Engineering (ISSRE), 2016 IEEE 27th Conference on*. IEEE, 2016, pp. 196–206.

[8] L. Wang, R. A. Hosn, and C. Tang, "Remediating Overload in Over-Subscribed Computing Environments," in *Cloud Computing (CLOUD), 2012 IEEE 5th International Conference on*, 2012, pp. 860–867.

[9] S. A. Baset, L. Wang, and C. Tang, "Towards an Understanding of Oversubscription in Cloud," in *Hot Topics inManagement of Internet, Cloud, and Enterprise Networks and Services, 2nd USENIXWorkshop on*, 2012.

[10] S. Singh and I. Chana, "Qos-aware autonomic resource management in cloud computing: a systematic review," *ACM Computing Surveys (CSUR)*, vol. 48, no. 3, p. 42, 2016.

[11] ETSI, NFVISG, "ETSI GS NFV-REL 001 V1. 1.1: Network Functions Virtualisation(NFV); Resiliency Requirements," 2015.

[12] NFV Doctor: Fault management and maintenance. [Online]. Available: http://artifacts.opnfv.org/doctor/docs/development_requirements/