PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Fabio Palumbo

XXXIII Cycle

Training and Research Activities Report – Second Year

Tutor: Prof. Antonio Pescapè

Add the following items according to the meeting we had today.

Concerning the structure of the document, use the Section number as is. Use the sub-contents indicated with a letter only as a suggestion for your content (a free form text is preferable)

1. **Information**

   I am Fabio Palumbo; I received a M. Sc. Degree in Computer Engineering at the University of Napoli Federico II in July 2017. I am a PhD student attending the XXXIII Cycle of the ITEE PhD program at the Department of Information Technology and Electrical Engineering of the University of Napoli Federico II. I have a "PON Dottorati innovativi" fellowship, and my tutor is Prof. Antonio Pescapè. I am currently part of the COMICS research group, studying in the field of computer networks.

2. **Study and Training activities**

   a. Courses

      i. *Data Science and Optimization*, Prof. C. Sterle, 5-7/02/2019, 1.2 Credits.
      ii. *Big Data,* Prof. A. Picariello and Dr. G. Sperlì, 26-27/02/2019, 4-6/03/19, 3 Credits.
      iii. *Strategic Orientation for STEM Research & Writing*, Dr. Chie Shin Fraser, 15-18-22-25/03/2019, 1-8/04/2019, 6 Credits.
      iv. *Internet censorship: enforcement, detection and circumvention*, Prof. G. Aceto, 7-9/05/2019, 2 Credits.

   b. Seminars

      i. *Bitcoin e Blockchain: oltre l'hype*, Proff. N. Mazzocca and G. Ventre (organizers), 18/01/2019, 0.6 Credits.
      ii. *Computational and machine learning methods for complex ecosystems*, Dr. E. Pasolli, 26/02/2019, 0.2 Credits.
      iii. *Matlab and Embedded Systems*, Eng. S. Marrone, 28/03/2019, 0.4 Credits.
      iv. *IEEEXplore Training and Authorship Workshop*, Dr. E. Lukacs, 4/4/2019, 0.5 Credits.
      v. *Neural Networks (part of the Machine Learning module),* Prof. R. Prevete, 13/05/19, 0.4 Credits.
      vi. *Ensemble Methods (part of the Machine Learning module)*, Prof. C. Sansone, 15/05/2019, 0.4 Credits.
      vii. *Recurrent Networks (part of the Machine Learning module)*, Prof. A. Corazza, 17/05/2019, 0.4 Credits.
      viii. *Overview of some basic notions of machine learning (part of the Explainable AI module)*, Prof. R. Prevete, 22/05/2019, 0.4 Credits.
      ix. *Selected current state-of-the-art methods for interpretability (part of the Explainable AI module)*, Prof. R. Prevete, 27/05/2019, 0.4 Credits.
      x. *Sparse dictionary learning for explainable machine learning (part of the Explainable AI module)*, Prof. R. Prevete, 31/05/2019, 0.4 Credits.
      xi. *In network machine learning for networks*, Dr. R. Bifulco, 14/06/2019, 0.4 Credits.

   c. Credit summary:

	Credits year 1								Credits year 2							
	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary
Modules	20	0	3	12	0	0	7,2	**22**	10	1,2	9	2	0	0	0	**12**
Seminars	5	0,3	1,1	0,4	3,2	0	0,4	**5,4**	5	0,8	0,9	2,8	0	0	0	**4,5**
Research	35	9,7	5,9	0	6,8	10	2,4	**35**	45	8	0,1	5,2	10	10	10	**43**
	60	10	10	12	10	10	10	**62**	60	10	10	10	10	10	10	**60**

3. Research activity

My research activity is entitled “Cloud infrastructures for telepathology”; it involves the study of cloud computing infrastructures (from the *networking* perspective) to assess the feasibility of *telepathology* applications. The capability of gaining access to IT resources in a rapid and on-demand fashion, according to a pay-as-you-go model, has made the *cloud computing* a key-enabler for innovative *telemedicine* services. However, some kinds of applications have specific requirements that cannot be satisfied by the current cloud infrastructure. In particular, since the cloud computing involves communication to remote servers, two problems arise: firstly, the core network infrastructure can be *overloaded*, considering the massive *amount of data* that has to flow through it to allow clients to reach the datacenters; secondly, the *latency* resulting from this remote interaction between clients and servers is *increased*. In particular, *low latency* is a key requirement for telepathology applications, which requires the remote transmission of images coming from slides placed under a microscope, and the remote control of such equipment. We refer to this use-case as *remote consultation*. We refer to another important use-case for telepathology as *remote computation*, since it involves the offloading of image processing to help diagnosis. For both these use-cases, guaranteeing a stable, low latency (when controlling the microscope and receiving its output, and/or when receiving the diagnosis) is crucial.

For these, and many other cases outside the field of telemedicine, the *Fog* and *Dew* computing paradigms were introduced. In these new paradigms, the IT resources are deployed not only in the core cloud datacenters, but also at the *edge* of the network, either in the telecom operator *access network* (as in the case of Fog) or even leveraging other *users’ devices* (as in Dew computing). The proximity of resources to end-users allows to alleviate the burden on the core network and at the same time to reduce latency towards users.

In my research activity, I have been focusing on the applicability of fog and cloud infrastructures for telepathology applications. Following the roadmap traced during the first year, the main steps of my second PhD year are outlined as follows:

- **Analysis of the performance of existing cloud providers.** Following the activities of the first year, I have conducted an in-depth characterization of cloud-to-user latency for the two main public cloud providers, namely *Amazon Web Services* (AWS) and *Microsoft Azure*. In particular, during a 14-days experimental campaign, we have collected latency measurements from 25 Vantage Points scattered around the globe towards 4 different datacenters in 4 different regions, for AWS and Azure each. Different probing methods were leveraged with an increased granularity compared to the state-of-the-art. The results obtained and the analysis conducted on this dataset have led to one accepted conference paper, and a journal one is currently in preparation.
- **Design and implementation of a protocol for SDN controller migration.** In the context of cloud and fog computing, a great role is played today by *Software Defined Networks* (SDN), a paradigm that simplifies the management of network equipment by decoupling the control plane and the data plane; forwarding devices (representing the data plane) are programmed through a *logically centralized* controller. The controller therefore becomes a key point of the SDN architecture. For scalability and security reasons, the controller may need to be migrated; for example, if it is under attack, or to move it closer to switches in order to reduce the communication latency. To this aim, we have *designed*, *implemented* and *experimentally evaluated* a protocol for the migration of SDN controllers, named *FLOCK*. It was designed to be independent from the underlying *southbound interface* protocol adopted (e.g. *OpenFlow* or others), and to take into account the switch-controller traffic flowing *during* the migration phase (we refer to this traffic as *dirty-packets* in analogy with the *dirty-pages* of a Virtual Machine migration). The results of this activity have led to one accepted conference paper, awarded as “***Best Fast-Track Paper***” during the NFV-SDN 2019 conference.

- **Assessment of the Quality of Service requirements for medical images transfer, both for teaching and consultation purposes.** The following steps were conducted during my visiting period at the Computer Science Department of Saint Louis University (located in Saint Louis, MO, USA). In collaboration with the Department of Pathology of Saint Louis University, I was able to use a real microscope currently used by pathologists for their research. After a training phase, where I was instructed on how to properly use it, I used two different software solutions for pathology: a proprietary one linked to the specific microscope used during the experimentation, and an open source solution, named *micro-manager*, which can work with different varieties of vendors, but still requires the availability of specific drivers.
  Thanks to this activity, I was able to get a direct look at how a pathology system works, and I assessed its performances and requirements considering some Key Parameter Indicators (KPIs) such as throughput, delay (in terms of images per second), jitter. The evaluation of these KPIs represent an important step prior to focusing on the *network* aspect of a *remote* solution.
- **Development of a prototype for the telepathology system and evaluation.** After assessing the requirements of microscope images transfer, we started the implementation of a prototype for a *telepathology* system, which is based on the *micro-manager* open source solution, but extends it by allowing the *remote control* of the microscope and *visualization* of the slide images. A first prototype was designed and implemented. A preliminary testing phase has shown that the system is *capable* of remotely communicate with the microscope and send different commands. Afterwards, a performance evaluation phase was done in order to compare some of the KPIs with the local setup.

4. Products

a. Publications

i. F. Palumbo, G. Aceto, A. Botta, D. Ciuonzo, V. Persico, A. Pescapé. "*Characterizing Cloud-to-user Latency as perceived by AWS and Azure Users spread over the Globe*", IEEE Global Communications Conference (GLOBECOM), Waikoloa, Hawaii (USA), December 9-13 2019.

ii. C. Contoli, F. Palumbo, F. Esposito, F. Callegati, A. Pescapè. "*Flock: A Live Migration Protocol for SDN Controllers*". IEEE Conference on Network Function Virtualization and Software Defined Networks (NFV-SDN), Dallas, Texas (USA), November 12-14 2019. **Best Fast Track Paper Award.**

iii. (*under review*) A. Pescapè, F. Palumbo, A. Montieri, S. Shamshirband, A. Chronopoulos, M. Fathi. "*Computational Intelligence Intrusion Detection Techniques in Mobile Cloud Computing Environments: Review, Taxonomy, and Open Research Issues*", Journal of Information Security and Applications (JISA), Elsevier.

iv. *In preparation: "Analyzing Latency in Cloud-to-User Networks for Azure and AWS" (journal paper, tentative title)*

v. *In preparation: "A Multi-armed Bandit Approach for LTE-WLAN Aggregation Resource Management" (tentative title)*

5. Conferences and Seminars

I did not attend any conference during my 2nd year.

6. Activity abroad

From July to December 2019 I have been a visiting PhD student at the **Computer Science Department** of **Saint Louis University**, located in Saint Louis (MO), USA. I have worked under the supervision of Dr. Flavio Esposito on telepathology related applications, so far producing 1 accepted paper (awarded as "***Best Fast Track Paper***" at NFV-SDN 2019 conference), and more in preparation.

7. Tutorship

Teaching assistant for the M. Sc. Course "**Analisi e prestazioni di Internet"** and B. Sc Course "**Reti di Calcolatori"** at the University of Napoli Federico II**.**
Teaching assistant for the M. Sc. Course "**Web Technologies**" at Saint Louis University.