Title:	***Artificial Intelligence-based cloud network control***
Position:	CNRS PhD position
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Funding:	***ARTIC project*** funded by French National Research Agency (ANR)
Starting date:	October 1st, 2020
Duration:	36 months (3 years)
Salary:	approx. 1700 €/month net (2 135 €/month brut)

Deadline to apply for: **June 20th, 2020**

To obtain more information, send an e-mail to raparicio@i3s.unice.fr

Supporting documents for the application

1. **Curriculum vitae**
2. **Cover letter**
3. **Transcript of records (marks) up to the Master degree (essential)**
4. *Final internship or final year project report (if available)*
5. **At least, two recommendation letters and a list of the three references to contact**

Description:

By 2021, cloud IP traffic will be the most part of an Internet traffic that complexifies with an increasing devices diversity and traffic dynamicity [1] . A proposal framed at the cloud to face this situation is the Knowledge Defined Networking (KDN) [2] , where Machine Learning (ML) and Artificial Intelligence (AI) are combined with Network Softwarization (SDN/NFV) [3] and network monitoring to collect data, transform them into knowledge (e.g. models) via ML, and take decisions with this knowledge. Under this paradigm, this thesis aims to design a unified AI-based framework able to learn new efficient cloud network control algorithms), addressing scalability and optimality issues of the cloud control [4] . To do that, we intend to apply two promising AI tools: Deep Learning (DL); and, Reinforcement Learning (RL), following the example of [5] .

In this thesis, a Deep Learning Artificial Neural Network (ANN) will be used to transform the original input data representations (in our case, the cloud network state) into a low dimensional space where the network structural information and network properties are maximally preserved, and used them to solve in a more tractable way the optimal control problem. RL will be applied to learn the optimal control by interacting with the Cloud network. The main novelty of our approach is that we state that, for network control problems, the deep ANN should not be implemented using the same deep layer architectures used in computer vision (the so-called convolutional layers), but using a different kind (for example, the so-called graph embedding architectures [6]) better fitted to the graph nature of the network problems.

Then, the thesis will address the cloud network control problems, namely the dynamic allocation of service chains composed by network virtualised functions as stated in [7] . Starting from the case where

the network service is unicast, we will move later to the multicast case, since video delivery, the classical multicast service, is the Internet killer application. Finally, the thesis will conclude with a proof-of-concept of the KDN paradigm by implementing a KDN testbed using a SDN controller (as [8]) in an emulated SDN network.

Pre-requisites if any:

-IT skills:

- Python 3.5 language, Python frameworks (like PyCharm, Jupiter Notebook, Spyder, Conda)
- Deep Learning Libraries (like TensorFlow, Keras)
- Other IT skills such as: networks and system (Unix, typically), knowledge of OOP (like Java), Agile, Git.

Theory:

- Machine learning and data science (namely neural network theory)
- Classical optimization theory (convex optimization, combinatorial optimization)
- Computer network control plane (algorithms and protocols)

Work context:

This thesis is part of the ANR ARTIC project (ARTificial Intelligence-based Cloud network control, cf. http://www.i3s.unice.fr/~raparicio/project/artic/), of which Ramon APARICIO PARDO is the principal investigator. This project will provide the candidate with the funds and resources necessary for their activities (participation in scientific events, equipment, computer, access to computing platforms, etc.)

The thesis will take place in the I3S laboratory, a joint public research laboratory resulting from the collaboration of the CNRS, Univ. Cote d´Azur and INRIA. The I3S laboratory is one of the most important research laboratories in information and communication sciences in the French Riviera and was one of the first to settle in the science and technology park of Sophia Antipolis. It brings together just under 300 people.

The student will work with experts in optimization, machine learning and telecommunications networks from the I3S and INRIA.

References

[1] *Cisco Global Cloud Index (GCI): Forecast and Methodology, 2016–2021,* White paper, Feb. 2018

[2] A. Mestres, A. Rodriguez-Natal, J. Carner, *et al.* Knowledge-defined networking. *ACM SIGCOMM Computer Communication Review*, 2017, vol. 47, no 3, p. 2-10.

[3] D. Kreutz, et al. "Software-defined networking: A comprehensive survey." *Proc. of the IEEE*, vol. 103.1, pp. 14-76, 2015.

[4] H. Feng, J. Llorca, A. M. Tulino, and A. F. Molich, Optimal dynamic cloud network control," in *Communications (ICC), 2016 IEEE International Conference on*. IEEE 2016, pp. 1-7.

[5] E. Khalil, H. Dai, Y. Zhang, B. Dilkina, and L. Song, "Learning combinatorial optimization algorithms over graphs," in *Advances in Neural Information Processing Systems*, 2017, pp. 6351–6361.

[6] W. Hamilton, R. Ying, and J. Leskovec. "Representation Learning on Graphs: Methods and Applications." *arXiv preprint arXiv:1709.05584* (2017).

[7] A. Tomassilli, F. Giroire, N. Huin, S. Pérennes, "Provably Efficient Algorithms for Placement of Service Function Chains with Ordering Constraints," in *Proc. IEEE International Conference on Computer Communications, INFOCOM 2018*, Honolulu, HI, USA, Apr. 2018

[8] OpenDaylight Controller: https://www.opendaylight.org/

[9] TensorFlow Guide, the TensorFlow's official documentation. (https://www.tensorflow.org/guide/)