

Panel: Challenges and Directions in Modeling and Simulation of Computer Networks and Systems

Modeling and Emulation of Computer Networks

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<http://www.tnt-lab.unige.it>

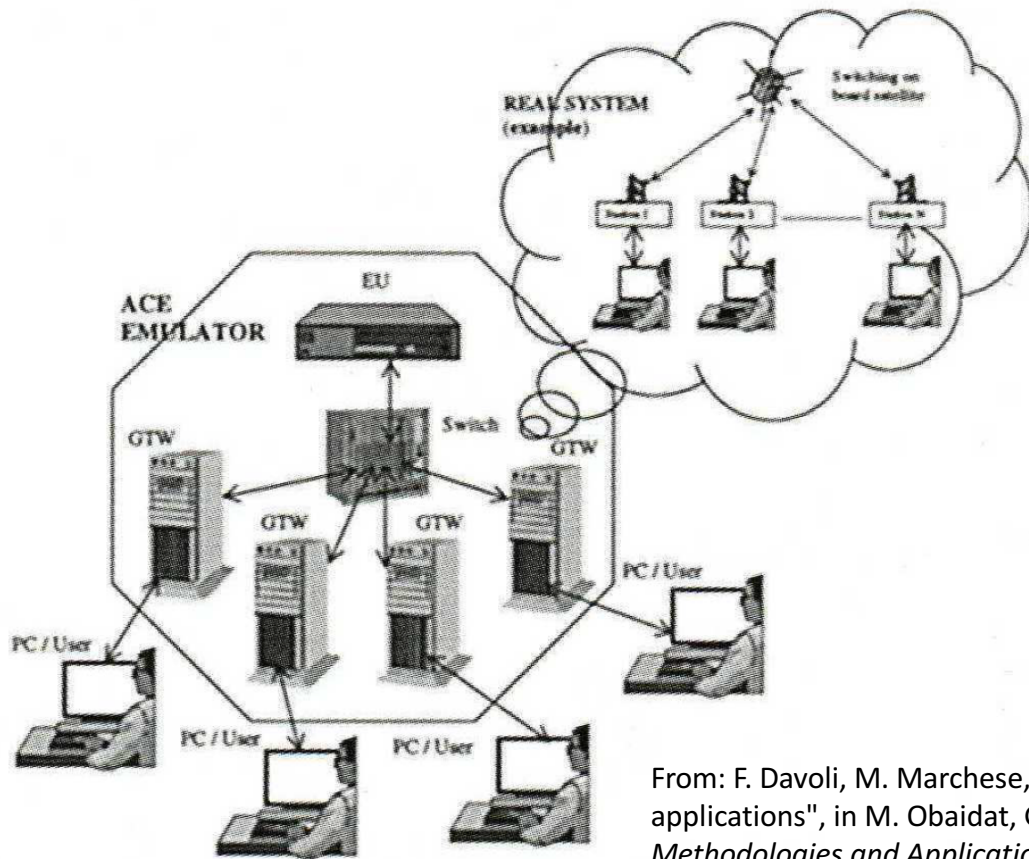
<http://www.cnit.it/en/institutes/s3iti/>



Three relevant methodologies

- Analytical Models
 - Provide insight – need to balance between computational complexity and accuracy
- Simulation/Emulation
 - May be very accurate in modeling system behavior – scalability issues
- Test beds
 - Mimic real systems – scalability issues, demonstration

Simulation / Emulation



From: F. Davoli, M. Marchese, "Satellite system simulation techniques and applications", in M. Obaidat, G. Papadimitriou, Eds., *Applied System Simulation: Methodologies and Applications*, Kluwer Academic Publishers, Norwell, MA, 2003, pp. 155-177.

Also *hybrid techniques* may be used, e.g., kernel re-entering, where the running simulation executes operations related to the network layer by directly injecting packets into the kernel, hence using the native Linux TCP/IP stack (TUN/TAP pseudo interface, as adopted in NCTUns, which allows sending/receiving data from real running applications). "...It is possible to plug-in a real node to the computer where the simulation is going on and use it like a properly emulated node." [L. Caviglione, F. Davoli, "Using P2P overlays to provide QoS in service-oriented wireless networks", *IEEE Wireless Communications Magazine*, vol. 16, no. 4, pp. 32-38, Aug. 2009; L. Caviglione, F. Davoli, P. Maryni, "On the usage of overlays to provide QoS over IEEE 802.11b/g/e pervasive and mobile networks", in M. S. Obaidat, M. Denko, I. Woungang, Eds., *Pervasive Computing and Networking*, John Wiley & Sons, Ltd., UK, 2011, pp. 263-277.]

Evolution of telecommunication networks

- Networks are undergoing a profound evolution, moving from specialized hardware inside the core, edge and access, to an ever-increasing presence of software modules on general-purpose machines. Spawned by datacenter technologies, this *softwarization* process is made possible by the paradigms of
 - Software Defined Networking (SDN)
 - Network Functions Virtualization (NFV)
- Virtualization paradigms in the access networks allow the creation of user *Personal Networks* with *virtualized user objects*.

Evolution of telecommunication networks

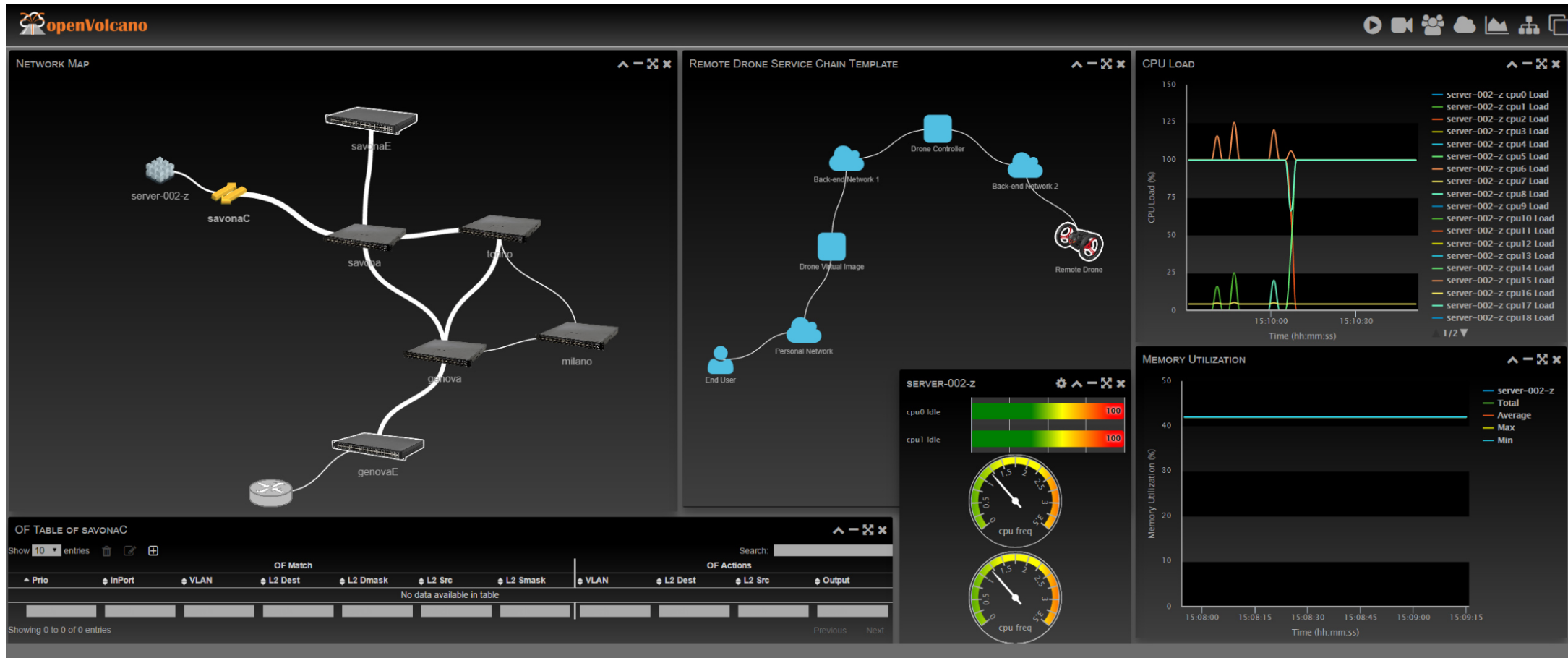
- As a result, emulation of networks at L2/L3 and above has become easier and more attractive.
- Simulation remains an important element (along with real system components that can be put in place – notwithstanding the obvious scalability issues) at the physical and MAC layers, to assess novel techniques as those of 5G wireless networking.

Platforms – The example of openVolcano

- openVolcano (Open Virtualization Operating Layer for Cloud/fog Advanced NetwOrks – <http://openvolcano.org>) is a **comprehensive open-source platform for mobile edge and fog computing services in 5G-ready infrastructures**.
- It allows exposing a number of latest-generation APIs, protocols, and interfaces (e.g., from OpenStack, to OpenFlow, libVirt, and ETSI NFV).
- It allows the creation of complex IaaS and PaaS services with tight delay/performance constraints as "templates", along with their dynamic instantiation at the network edge to single mobile users or user groups.

R. Bruschi, P. Lago, G. Lamanna, C. Lombardo, S. Mangialardi, "OpenVolcano: An Open-Source Software Platform for Fog Computing," *Proc. Workshop on Programmability for Cloud Networks and Applications (PROCON)*, in conjunction with the 28th International Teletraffic Congress (ITC28), Würzburg, Germany, Sept. 2016, pp. 22-27.

Platforms – The example of openVolcano



Toward a tighter integration

- ...among analytical modeling, simulation and emulation on platforms capable of offering testing and performance evaluation of network architectures and protocols, as well as of their control and management frameworks.
- A word of warning: when stochastic variables are being used, do not forget **accuracy assessment** of results!

[K. Pawlikowski, H.-D. J. Jeong, and J.-S. R. Lee, "On Credibility of Simulation Studies of Telecommunication Networks," *IEEE Commun. Mag.*, vol. 40, no. 1, pp. 132–139, Jan. 2002.

N. I. Sarkar and J. A. Gutiérrez, "Revisiting the Issue of the Credibility of Simulation Studies in Telecommunication Networks: Highlighting the Results of a Comprehensive Survey of IEEE Publications," *IEEE Commun. Mag.*, vol. 52, no. 5, pp. 218-224, May 2014.]