Bio-inspired routing algorithms for Software Defined Networking

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Research context and motivation

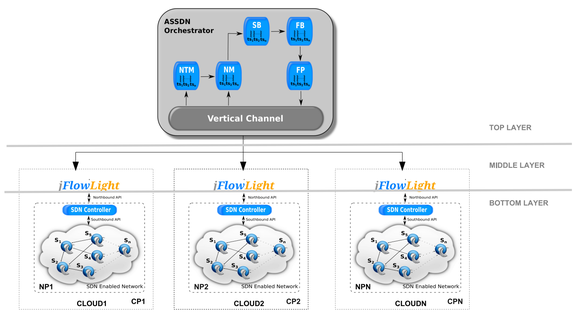
The research activity is focused to extend the concept of an SDN to build robust, reliable and performant networks across geographically-distributed resources owned by different providers, that can be competitive or federated.
The aim is to manage the QoS and investigate if adaptive strategies can be considered in this new context evaluating the pro e cons. This means:

- analyzing the issues related with the brokering and deployment of cloud workflows over different cloud providers
- studying how supply models (competitive or cooperative) influence the QoS and pricing models
- evaluating the weight of performance isolations in these hetregenous environments
- introducing the Software Defined Networking (SDN) to improve the hypervisors control over the network infrastructure

ASSDN

Adaptive Strategy for Software Defined Networking (ASSDN) iis a framework which offers an API to configure the routing and the performance-related network parameters independently both from the specific SDN technology adopted and from the peculiarities and heterogeneities of the network providers.
This allows any cloud provider managing its own control plane functions extending the concept of large-scale Network-as-a-Service. The main features in the design of ASSDN are:

- implementing a flexible control layer on network elements belonging to different administrative domains
- guaranteeing specific levels of **QoS** to end-user
- supporting the development of **adaptive** and **autonomic** routing strategies



- **Network Topology Mapper (NTM)**
- **Network Monitor (NM)**
- **Strategy Builder (SB)**
- **Flow Builder (FB)**
- **Flow Pusher (FP)**

A4SDN

The *Adaptive Alienated Ant Algorithm for Software-Defined Networking* (A4SDN) is a distributed, adaptive, load-balancing algorithm for traffic engineering on Software-Defined Networks. Balancing the traffic is often a complex issue, especially at runtime. The higher are the fluctuations of the traffic, the harder is to react to them in order to achieve a balanced load.

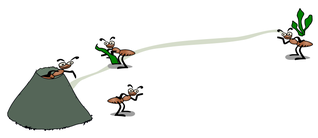
Main Features

- **Based on the Alienated Ant Algorithm (AAA)**
- **Supplies an adaptive and autonomic dynamic routing strategy**
- **Leads to a better exploitation of the network bandwidt enforcing the best effort traffic**
- **Improves the throughput**
- **Reduces the end-to-end delay**
- **Reduces the packet-loss rate**
- **Improves the scalability**
- **Reduces the total cost of the infrastructures**

A4SDN: Alienated Ant Algorithm and Pheromone Evaluation

The *Alienated Ant Algorithm* (AAA) is a stochastic-based, heuristic approach based on a non natural ants' behaviour. The AAA forces the ants in search of food to distribute themselves over all the available paths rather than converge to a single one.
Main characteristics of AAA that makes it different from the ACO-based algorithms:

- **The opposite interpretation of the pheromone:** guarantees the load-balancing capability
- **The sub-path pheromone evaluation:** avoids the scalability and convergence issues

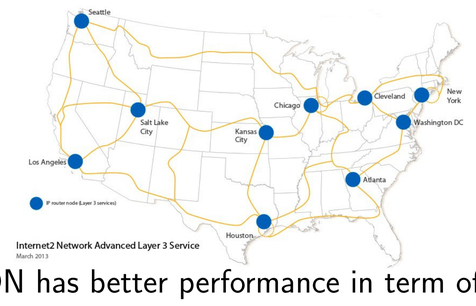


The *Pheromone Evaluation* evaluates, for each switch, the the distribution of traffic forwarded on the output links for the next cycle, based on data collected.
The pheromone P_n is defined as:

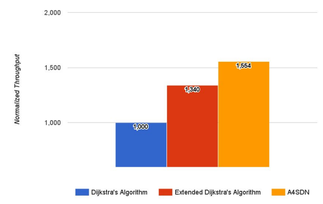
$$P_n = (Rx_n) - (Tx_n + Dx_n) \quad (1)$$

Performance Evaluation

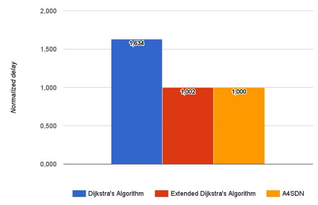
I compared the A4SDN with other two Shortest Path Forwarding (SPF) solutions. Both the classical well-known Dijkstra algorithm and the dynamic application of the Extended Dijkstras algorithm proposed in 2014 by J.R. Jiang, et.al were taken into account.
I evaluated the algorithm on the **Internet2s Advanced Layer 3 Service** *(www.internet2.edu)* and the **Garr-X** *(www.garr.it)* topologies.



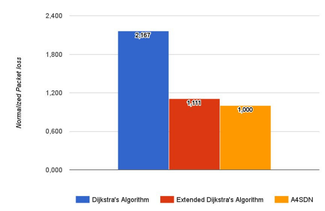
The A4SDN has better performance in term of throughput, delay and packet-loss.



Throughput



Delay



Packet-loss

eA4SDN: Energy-Aware Routing in A4SDN

The *eA4SDN* algorithm is an energy-aware extension of the A4SDN. In eA4SDN I focused our work on an energy aware traffic engineering algorithm for SDN networks, by studying the energy consumption of an SDN and reducing the cost per Megabyte.
The model, which considering of all the operations related with the routing process (not limited only to packet forwarding but including the ones for switches configuration and management), is able to approssimate the consumed energy with an error of less than 8% for the software switch and less than 1% for the hardware switch.
According to that model, the power consumption of a switch, here defined as P_{switch}, is:

$$P_{switch} = P_{base} + P_{config} + P_{control} + P_{OF} \quad (2)$$

where:

- P_{base} is the static power needed to keep the device active;
- P_{config} is the power used by the assigned configuration, i.e. related with the number of active ports or with the configured line speed;
- $P_{control}$ is the power needed to control the network traffic, i.e. the packets involved in the network management (it depends on the packet rate and energy managing consumption);
- P_{OF} is the power consumed by the traffic processed by OpenFlow (e.g. the flow match).

jFLowLight

jFlowLight is an open source SDN-controller client that allows provisioning and control of an SDN deployment. jFlowLight decouples the control from the northbound API provided by SDN-Controllers supporting flows and statistics.

https://github.com/giovannicammarata/jflowlight

Published and Submitted Conference/Journal Papers

- Di Stefano, A., Cammarata, G., Morana, G., & Zito, D. (2015, November). A4SDN-Adaptive Alienated Ant Algorithm for Software-Defined Networking. In *10th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC) (pp. 344-350)*. IEEE.
- Cammarata, G., Di Stefano, A., Morana, G., & Zito, D. (2016, May). Evaluating the performance of A4SDN on various network topologies. In *Parallel and Distributed Processing Symposium Workshops, 2016 IEEE International (pp. 801-808)*. IEEE.
- Cammarata, G., Di Stefano, A., Morana, G., & Zito, D. (2016, June). ASSDN: A Framework for Adaptive Strategies for Software-Defined Networking. In *Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE), 2016 IEEE 25th International Conference on (pp. 101-106)*. IEEE.
- Cammarata, G., Di Stefano, A., Morana, G., & Zito, D. (2017, July). Energy-Aware Routing in A4SDN. In *CISIS 2017: The 11th International Conference on Complex, Intelligent, and Software Intensive Systems (pp. 577-588)*. IEEE.

Attended classes or events

- OpenStack Summit Paris 2014. Openstack Foundation. November 3-7, 2014
- Scuola ReCaS Networking Avanzato per la Ricerca Scientifica. INFN. April 20-30, 2015
- Cisco Live San Diego 2015 (CA). Cisco Systems. June 8-11, 2015

Current progress and future work

I am working on:

- Evaluating the ASSDN approach to a real hybrid, multi-provider cloud scenario;
- Evaluating the capability of a NaaS controller on the network segments belonging to several, independent SDN islands;
- Extending the sensitivity analysis of the A4SDN for understanding the best match between its configuration parameters and the underlying scenario