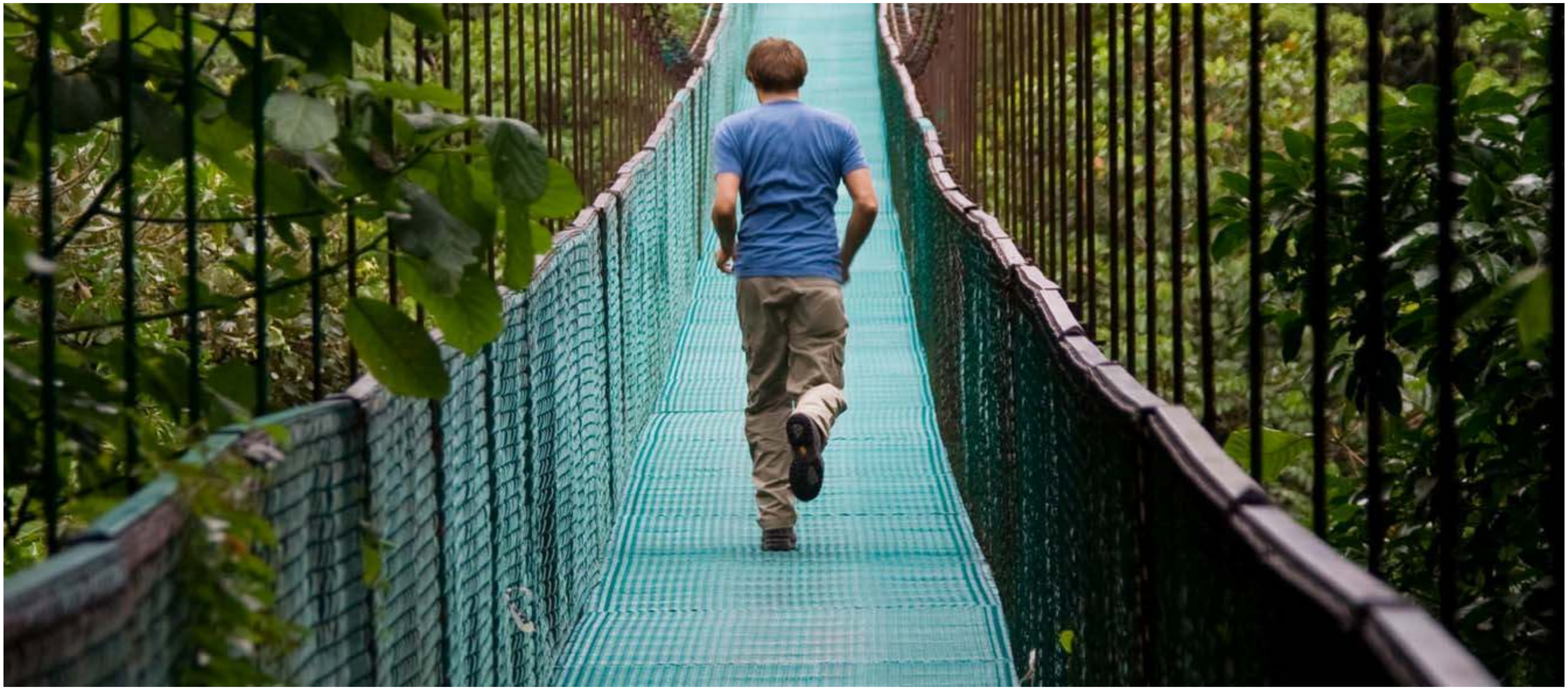


Traffic Steering in Software Defined Networks: Planning and Online Routing

Zizhong Cao, New York University

Murali Kodialam, Bell Labs, Alcatel-Lucent

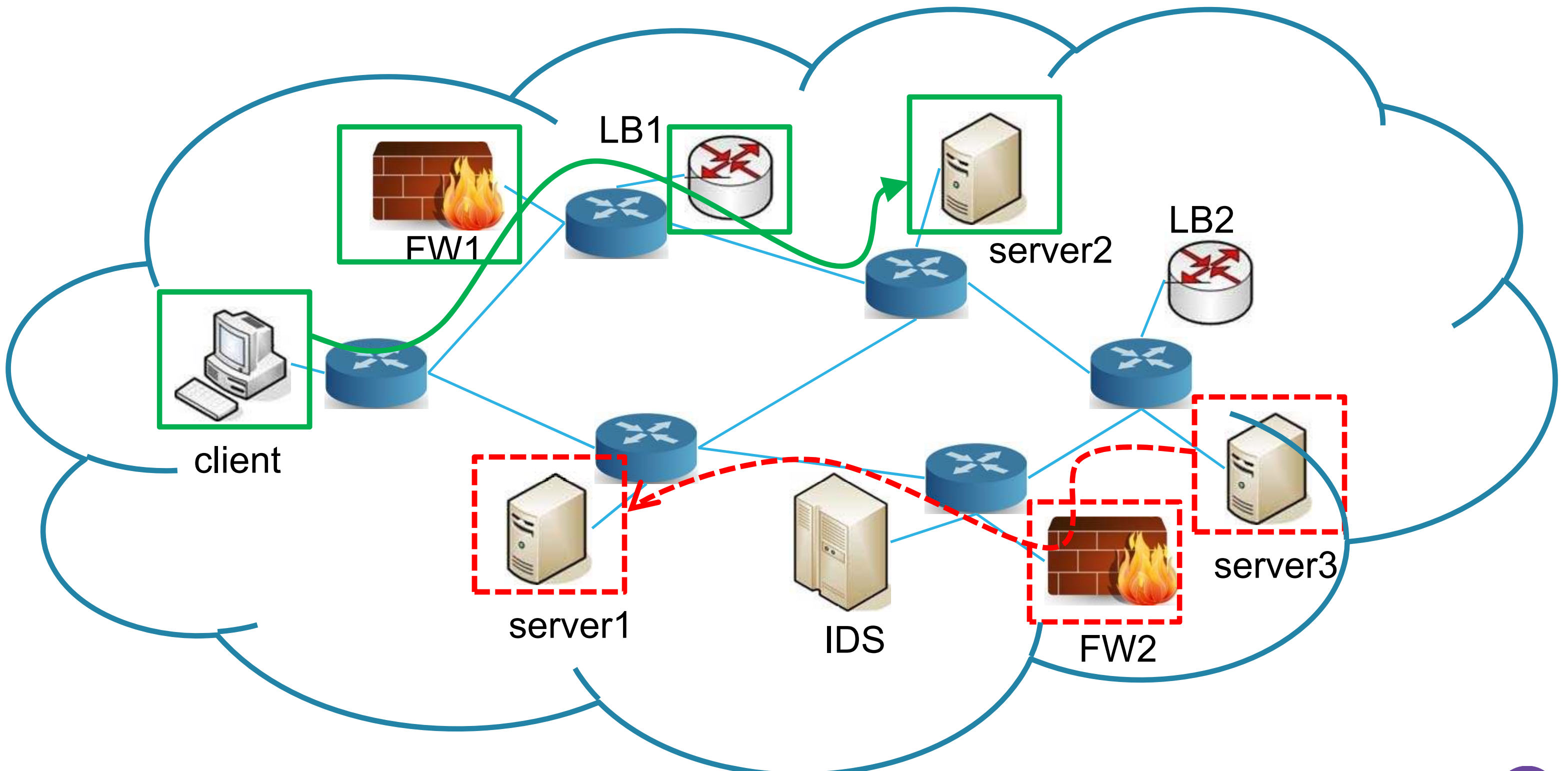
T.V. Lakshman, Bell Labs, Alcatel-Lucent

Outline

1. Introduction to Policy Aware Routing and SDN Framework
2. Problem Statement
3. General Methodology Description
4. SPAR: Sizing Policy Aware Routed Networks
5. COATS: Competitive Online Algorithm for Traffic Steering
6. Simulation Results
7. Conclusions

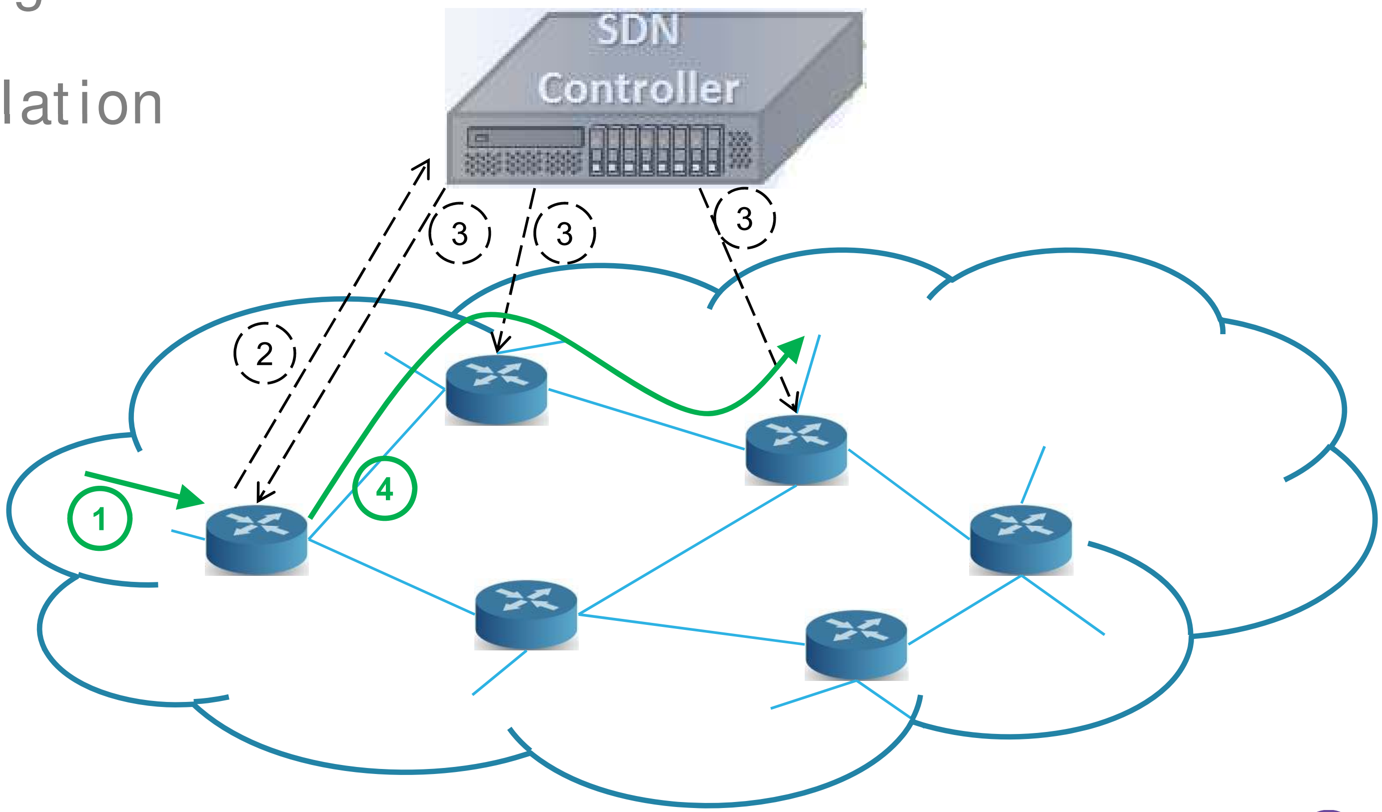
Policy Aware Routing – Middlebox Traversal

- Firewall, load balancer, intrusion and detection system
- Data center and wide area networks



Software Defined Network – Flow Scheduling

- Policy lookup
- Flow steering
- Route installation



Problem Statement

1. Offline network planning problem: Given the location of the middleboxes and projected traffic, determine if there is enough capacity in the network to access the middlebox functions.

FPTAS that achieves
(1-ω) approximate solution

2. Online traffic steering problem: When a flow has to be instantiated in the network, the SDN controller finds a physical path for the current request that permits as many future flows to be instantiated in the network as possible.

log-competitive online algorithm

General Methodology Description

- Linear programming (exponential)

$$\begin{aligned} &\max \lambda \\ \text{s.t.} \quad &\textstyle\sum_{p \in \mathcal{P}_d} x_{dp} \geq \lambda h_d, \ \forall d \\ &\textstyle\sum_d \sum_{p: e \in p} x_{dp} \leq c_e, \ \forall e \\ &x_{dp} \geq 0, \ \forall d, \forall p \end{aligned}$$

$$\begin{aligned} &\min \alpha(\mathcal{L}) = \textstyle\sum_e c_e l_e \\ \text{s.t.} \quad &\textstyle\sum_{e \in p} l_e \geq z_d, \ \forall d, \forall p \in \mathcal{P}_d \\ &\textstyle\sum_d h_d z_d \geq 1 \\ &l_e, z_d \geq 0, \ \forall e, \forall d \end{aligned}$$

- Primal-dual FPTAS (iterative)

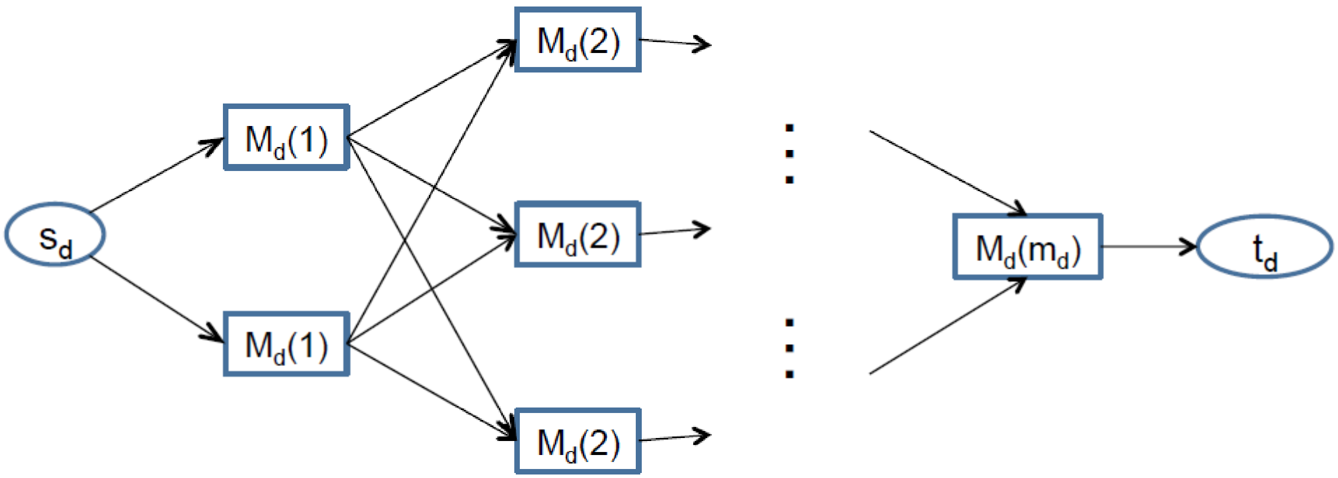
augment shortest path lengths z_d

  - Find the shortest path p for demand d under the current length system l_e;
  - Allocate flow $\Delta f_d := \min\{h'_d, \min_{e \in p_d(\mathcal{L})} \{c_e\}\}$.
  - Augment the length of arcs e on path p by $l_e := l_e(1 + \epsilon \Delta f_d / c_e)$.

intuition: highly congested arcs get larger lengths to avoid being further exploited

SPAR: Sizing Policy Aware Routed Networks

- Policy aware shortest path (segment+APSP+assembly)



- Lazy dual update
  - Perform one pass of APSP for all demands and segments;
  - Delay update until all policy aware shortest paths are found and allocated.

COATS: Competitive Online Algorithm for Traffic Steering

- Tasks with finite durations

$$\max \sum_d \sum_{p\in\mathcal{P}_d} h_d \tau_d x_{dp}$$

s.t.
$$\sum_{p\in\mathcal{P}_d} x_{dp} \le 1\ \forall d$$
$$\sum_{d|t\in[\tau_d^s,\tau_d^f]} \sum_{p|e\in p} n_{ep} h_d x_{dp} \le c_e,\ \forall e, \forall t$$
$$x_{dp} \in \{0,1\}\ \forall d, \forall p$$

$$\min \alpha = \sum_t \sum_e c_e l_{et} + \sum_d z_d$$

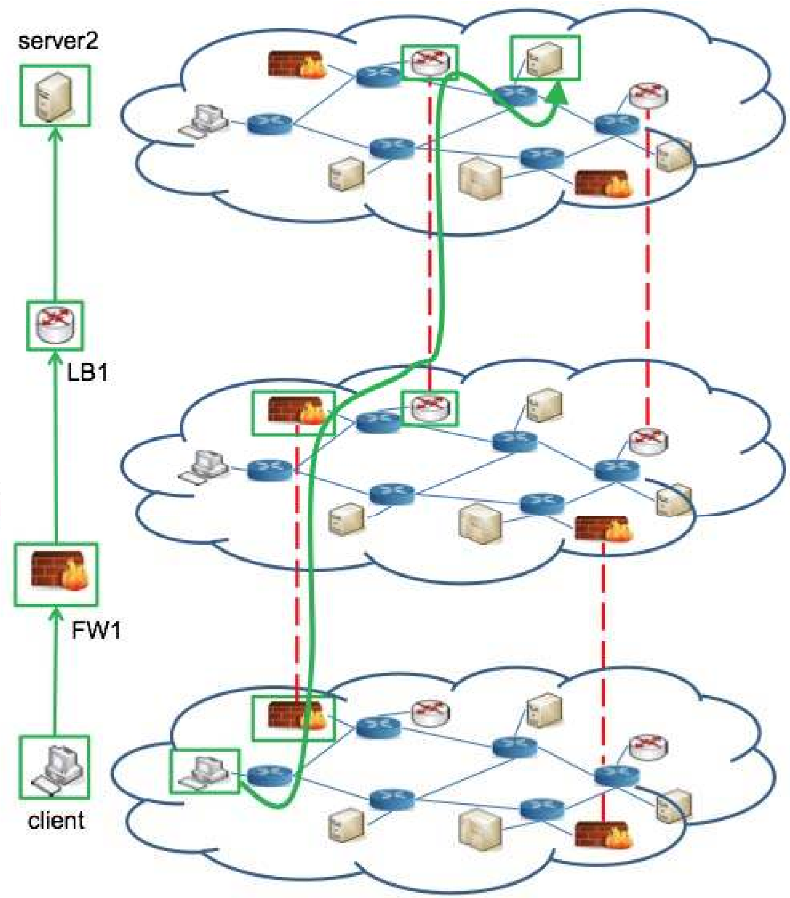
s.t.
$$\sum_{t\in[\tau_d^s,\tau_d^f]} \sum_{e\in p} n_{ep} l_{et}/\tau_d + z_d/h_d\tau_d \ge 1,\ \forall d,$$
$$l_{et} \ge 0,\ \forall t, \forall e$$
$$z_d \ge 0,\ \forall d$$

- Length system settings

$$\hat{l}_e = \sum_{t\in[\tau_d^s,\tau_d^f]} l_{et}/\tau_d$$

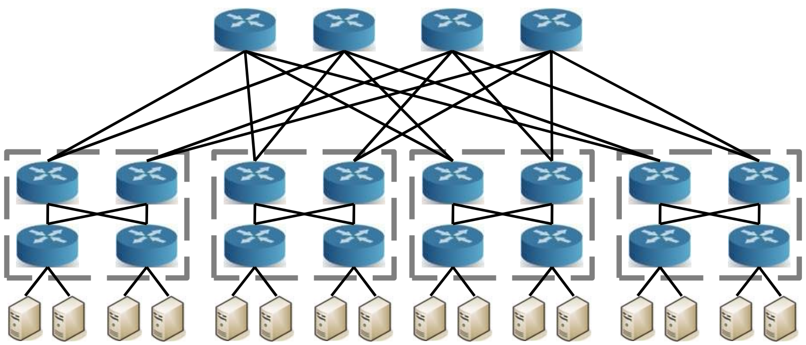
$$l_{et} := l_{et}\left(1 + \frac{n_{ep}h_d}{c_e}\right) + \frac{n_{ep}h_d}{|p|c_e}$$

- Graph Layering Approach

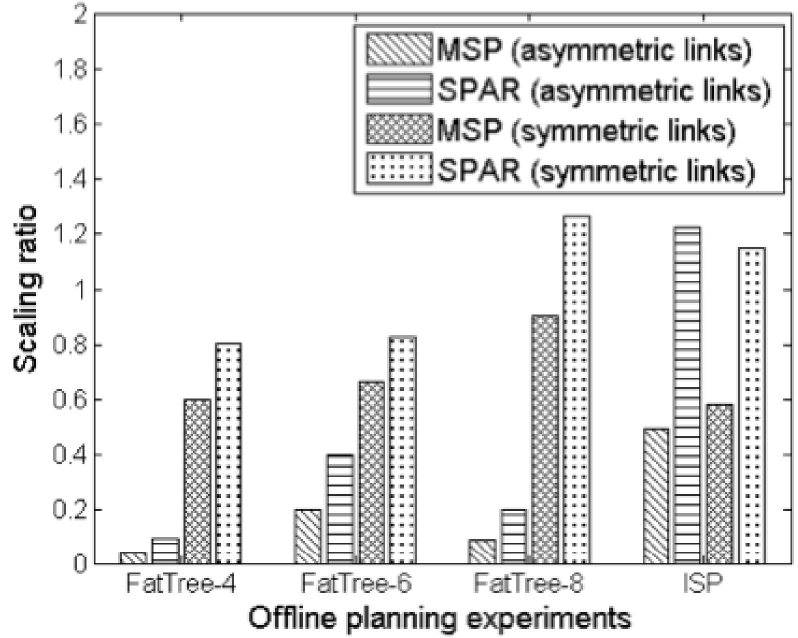


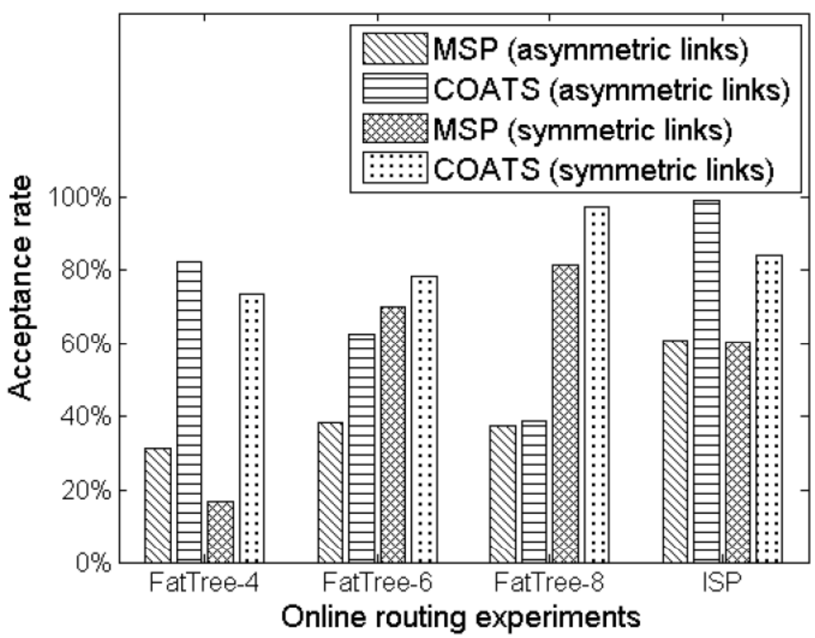
Simulation Results

- Fat Tree + ISP networks



- SPAR & COATS





Conclusions

- We have developed a FPTAS, SPAR, to solve the offline networking problem for policy aware routing. Lazy dual update is of independent interest and can be used for other constrained routing problems.

- We have also developed a log-competitive algorithm, COATS, to solve the online traffic steering problem. Tasks with finite durations are taken into account, as in real systems.

- Simulation results in both data center and ISP networks show that our proposed algorithms work very well.

- Future work: further exploit the challenges in policy aware routing and how they affect network design and management.

Thank you!