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Bringing Energy Aware Routing closer to Reality with SDN Hybrid Networks: SENAtoR

Myriana RIFAI

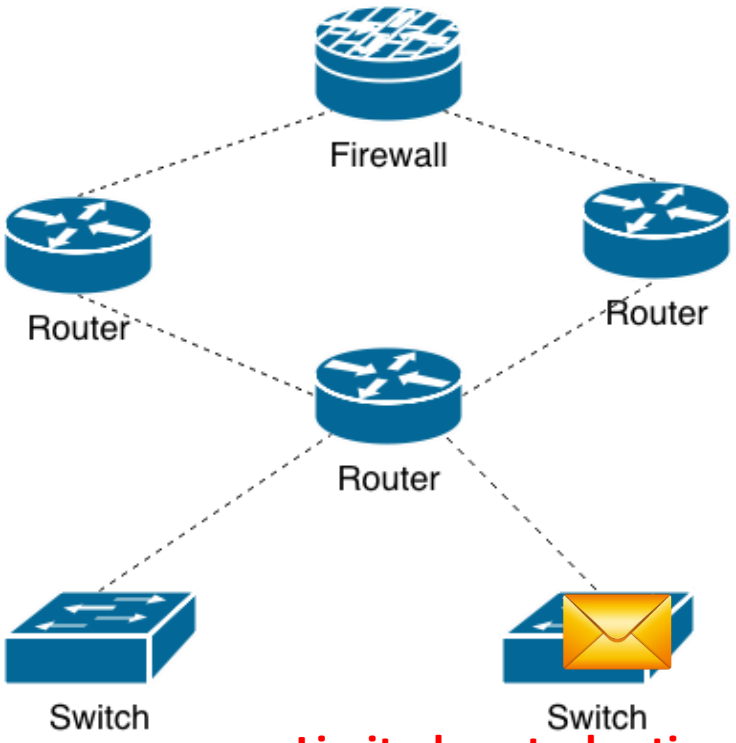
***Work done as a collaboration between SigNet and COATI teams**

What is Software Defined Networks?

Legacy Networks

Distributed System

- Every device has a unique independent control functionality

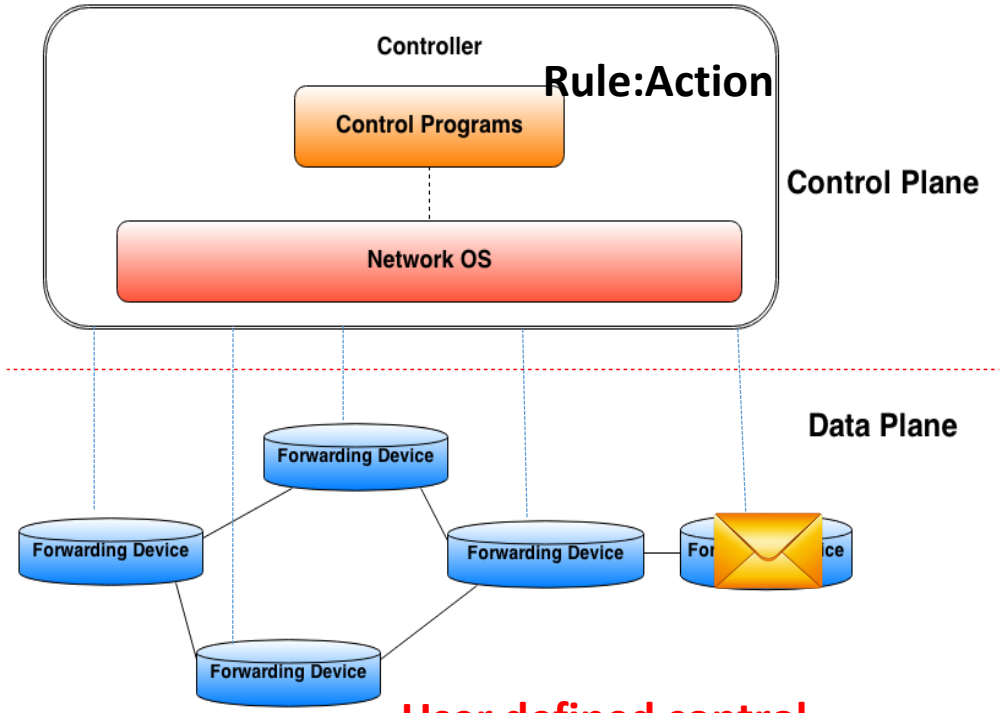


Limited control action

Software Defined Networks

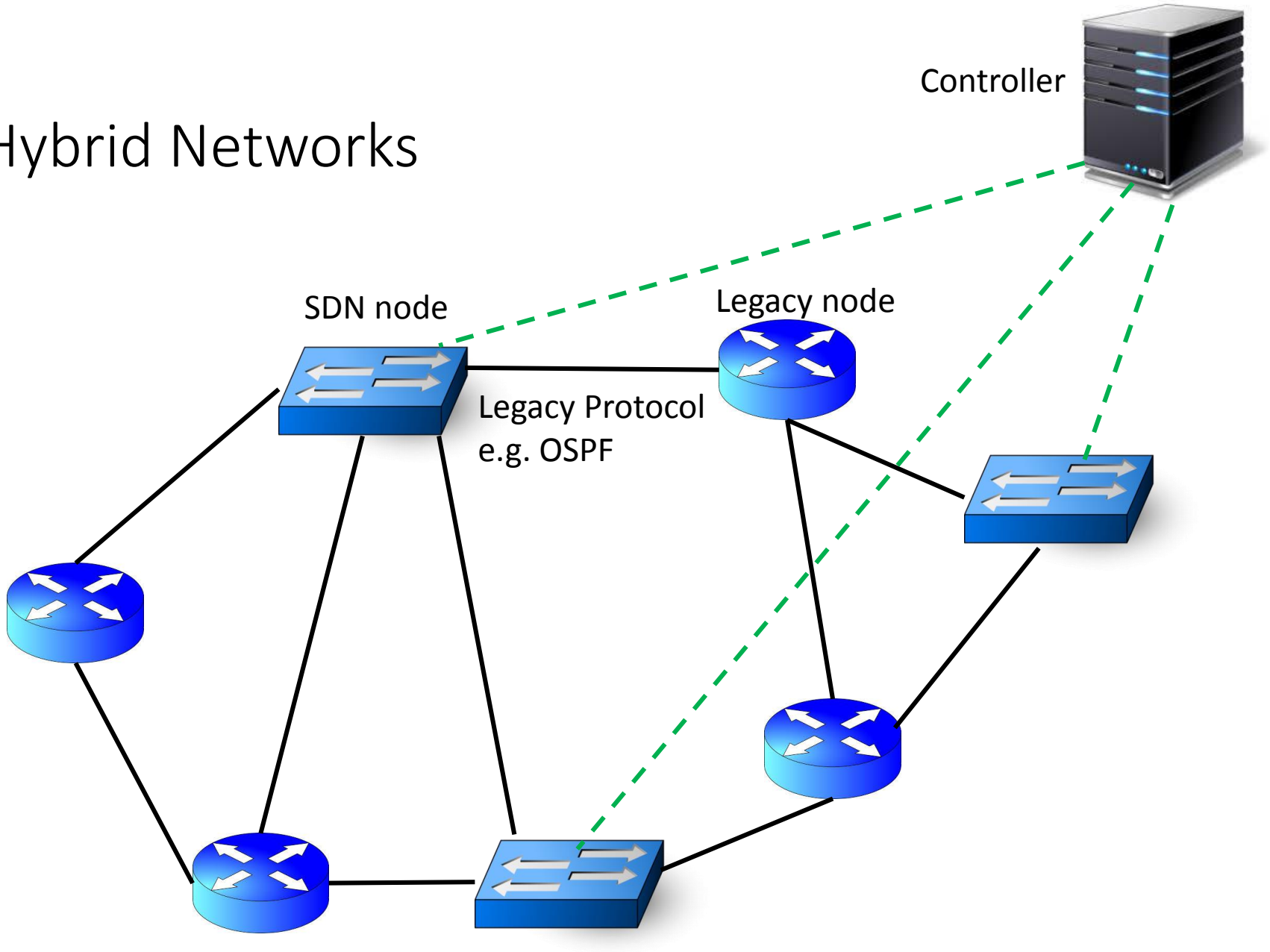
Centralized System

- Control functionality centralized in the controller
- Network Programmability (API)



User defined control

Hybrid Networks



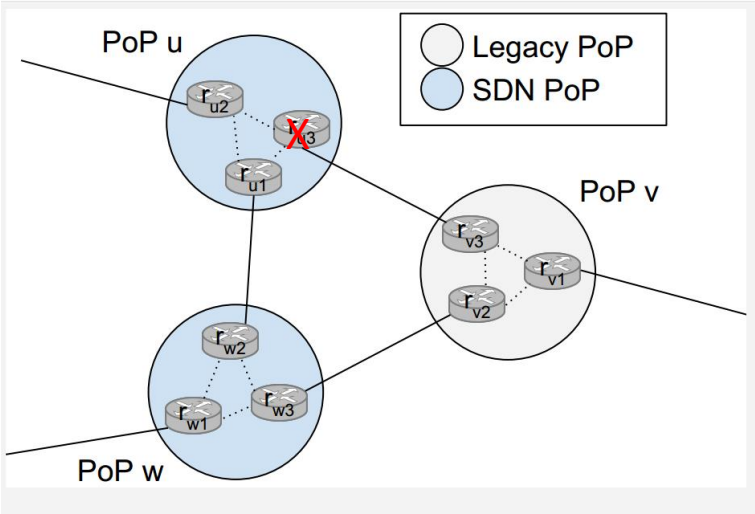
General Outline

- Motivation
- Our Solution: SENAtoR
  - SENAtoR Heuristic
  - Performance Mitigation Mechanisms
- Results
  - Numerical Evaluation
  - Emulation
- Conclusion

Motivation

- Energy aware routing solutions come at the cost of performance degradation:
  - Link failure → network disconnection
  - Traffic peak → increased loss
  - Turning off links or nodes → data loss when turning off links
- Why to leverage SDN nodes ?
  - Detect link failure faster than legacy nodes
  - Programmable
  - Centralized global view of the network

Our Solution: SENAtoR



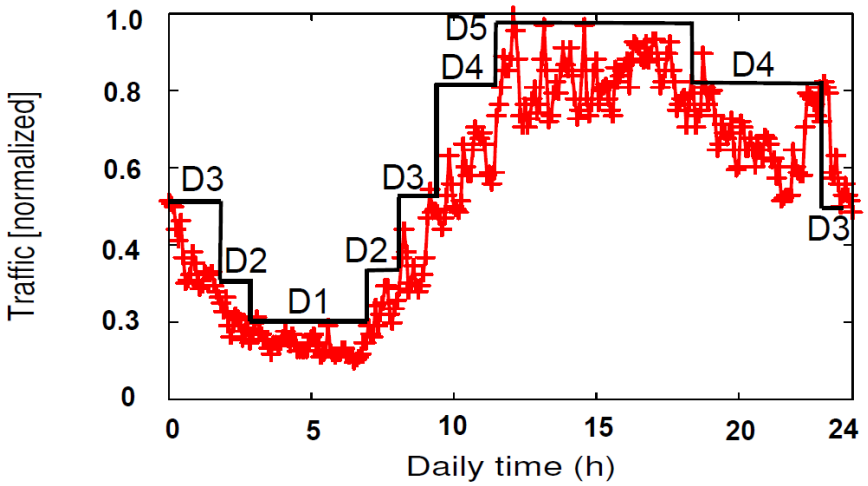
- Hybrid ISP networks
  - SDN + legacy nodes
- Energy aware routing
  - Route the traffic to maximize the number of SDN turned off devices.
  - Use tunnels to reroute the traffic when the legacy node routing table differs from the SDN node routing table
- Performance mitigation mechanisms
  - Smooth SDN link turn off
  - Link failure and traffic peaks detection

SENAtoR Heuristic

Assumption: The traffic matrix in an ISP network follows a curve that can be estimated.

Aim: Maximize the number of links and nodes that can be turned off

1. SDN Nodes Placement
2. Link off Selection



Orange ISP daily traffic matrix.

SENAtoR SDN Node Placement

- Cover the maximum number of links that can be turned off using a budget of k SDN nodes.
- Only SDN neighboring links can be turned off

→ Sort based on the node degree, the first k nodes are selected as SDN nodes

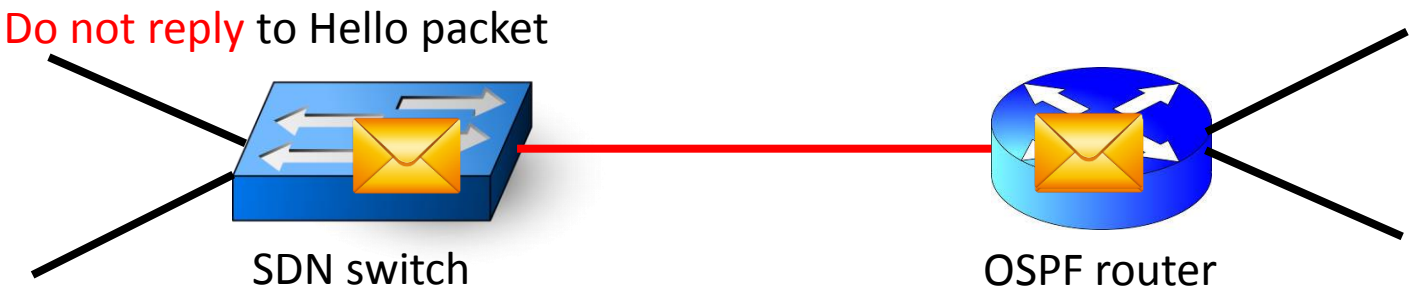
SENAtoR Off Link Selection

- Links with at least one SDN endpoint can be turned off
- Order the links in increasing order of utilization
- Select the lowest used link to turn off
- Try to reroute all of its traffic in the residual graph
  - If all traffic can be rerouted → the link is powered off
  - If not all traffic can be rerouted → the link is set as un-removable
- Stop once all links are categorized as powered off or un-removable

Performance Characteristics

- Smooth link turn off
- Link failure mitigation
- Traffic peak mitigation

Smooth link turn off



- When SENAtoR notifies the SDN switch to turn off link A, the switch stops sending data traffic and control packets on link A but keeps receiving traffic for:

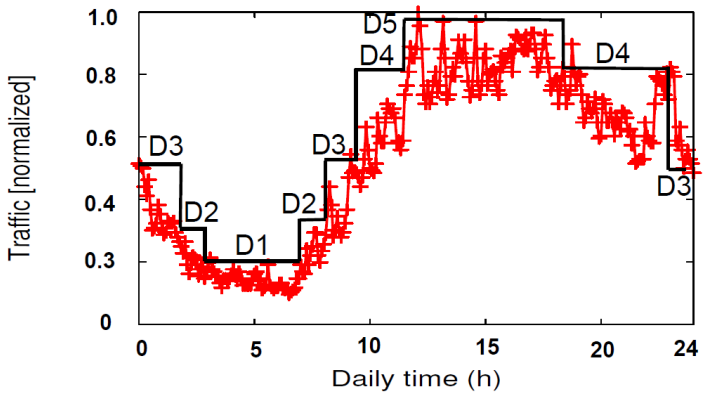
  dead_intereval + reconvergence_time

(i.e. time for legacy nodes to detect link down and reroute the traffic away from this node)

- Hello Packet Exchange
- If the hello packet is not received during a predefined timer e.g. dead_interval → declare link down → reroute

Then the link/node is turned off

Link failure and traffic peak mitigation



- In general in ISP traffic load on the nodes can be estimated.
- Our solution:

  1- Monitor the traffic at SDN nodes

  2- Compare existing traffic $E_i(t)$ with estimated traffic $E_i^{ES}(t)$

  - If : $E_i(t) \geq X * E_i^{ES}(t)$ → traffic peaks are happening X>100%

  - If: $E_i(t) \leq Y * E_i^{ES}(t)$ → possible link failure occurred Y<100%

  3- Turn on any previously turned off link to prevent packet loss

Numerical Evaluation Testing Scenarios

- Atlanta (15 PoP nodes, 22 links) and ta2 (65 PoP nodes and 108 links) topologies from SNDlib
- GRE tunnels used to reroute traffic when the legacy routers have not yet converged to the new topology designed by SENAtoR

Aim: Numerically evaluate the energy saving and additional delay

Numerical Evaluation: Energy Saving

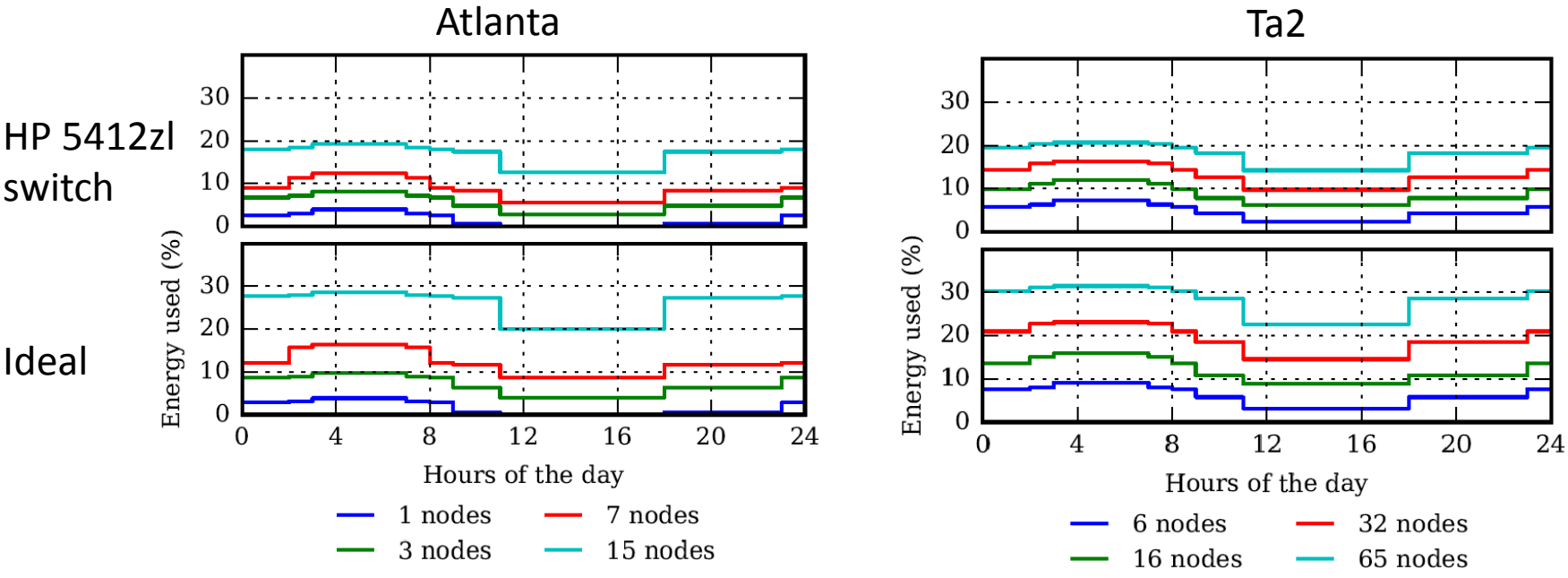
With HP 5412zl SDN switch:

$$P_n(u) = B_u + A_u + \sum_{v \in N^+(u)} P_l(u,v) \qquad P_l(u,v) = x_{uv} * (U_{uv} + \mathcal{F}_{uv} L_{uv})$$

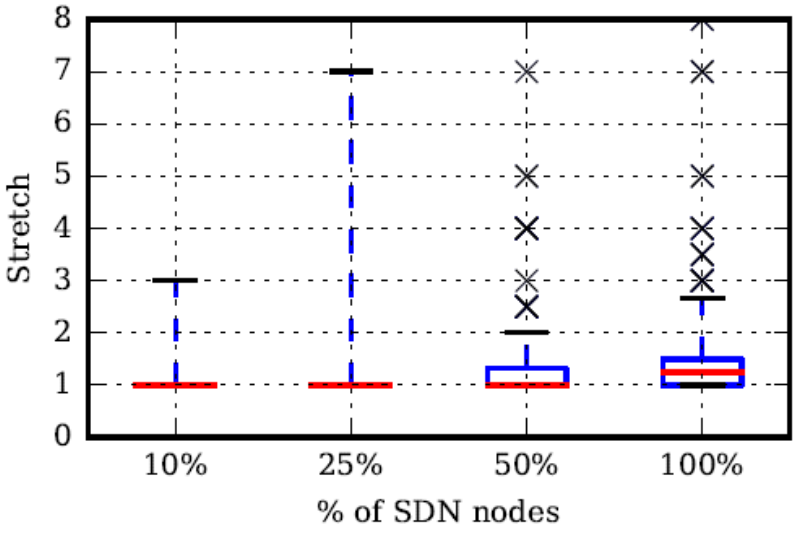
$$B_u = 95\,W \qquad A_u = 55\,W \qquad U_{uv} = 30W \qquad L_{uv} = 10W$$

With ideal model:

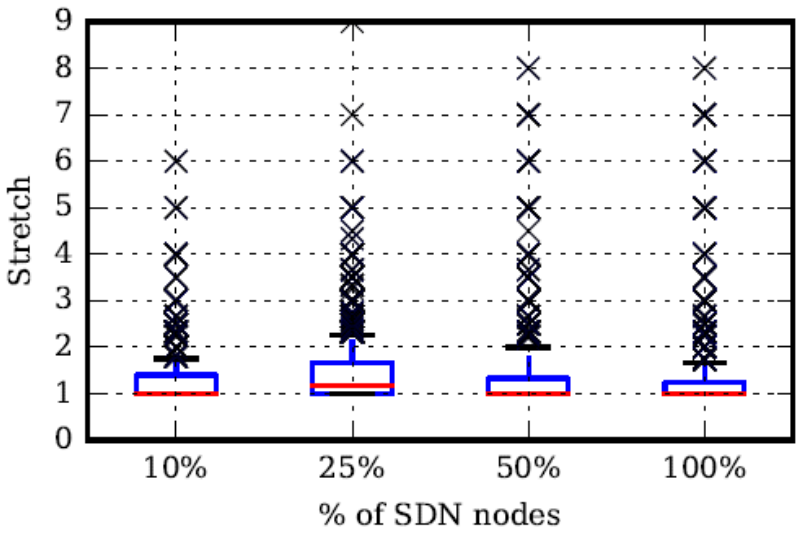
$$sleep = 0.6 * online$$



Numerical Evaluation: Stretch Ratio



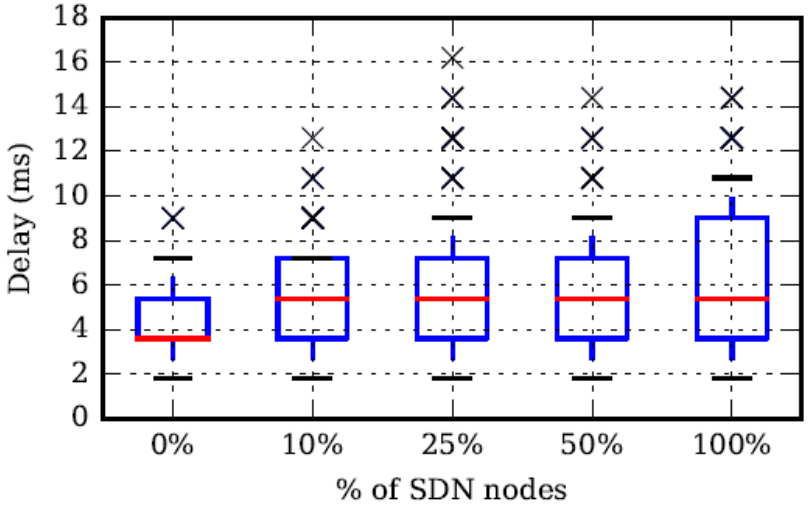
Atlanta



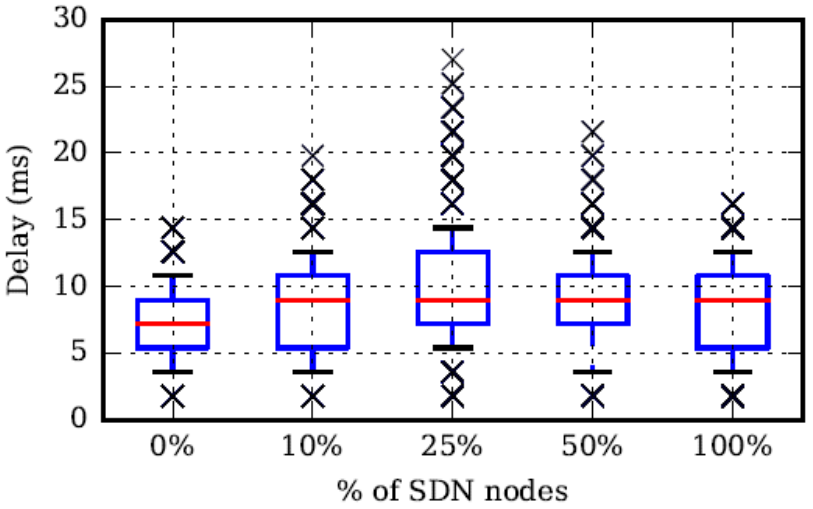
Ta2

Stretch ratio= Difference in number of nodes between the used path (when links are turned off) and the shortest path in the original topology

Numerical Evaluation: End-to-end delay



Atlanta



Ta2

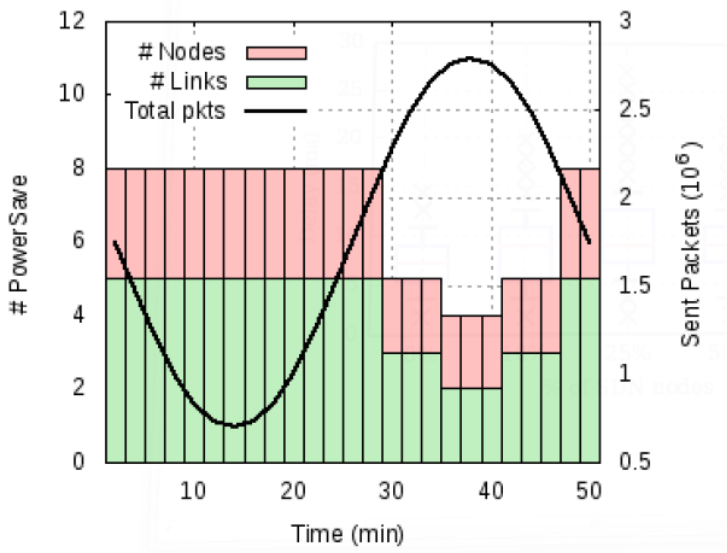
End to end delay of all paths in the network

Emulation Testing Scenarios

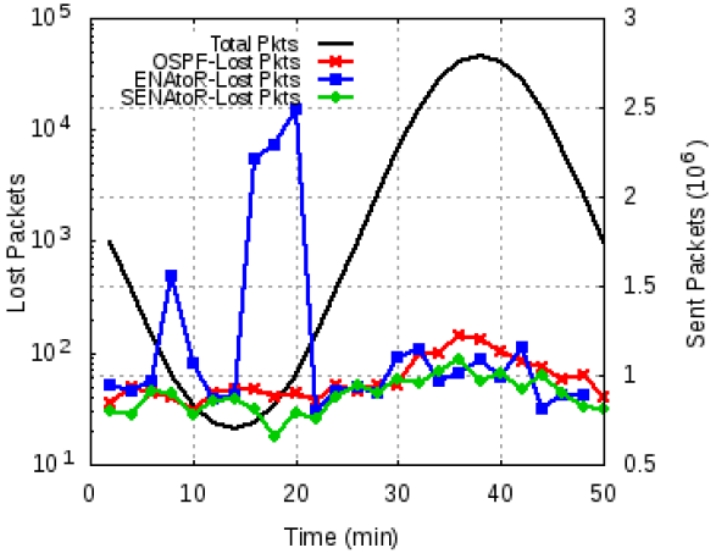
- Atlanta (15 PoP nodes, 22 links) topology from SNDlib
- Percentage of SDN nodes k= 50%
- GRE tunnels used to reroute traffic when the legacy routers have not yet converged to the new topology designed by SENAtoR
- Mininet
- UDP traffic

Aim: Test the performance mechanisms.

Emulation (Atlanta): Packet Loss



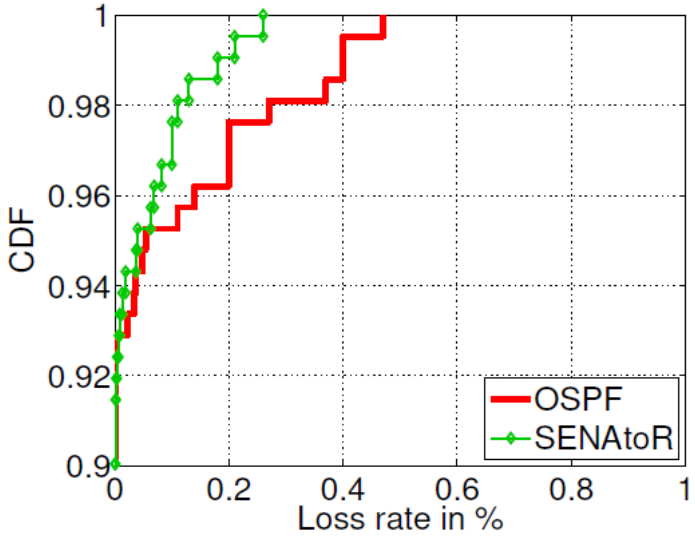
Number of turned off links



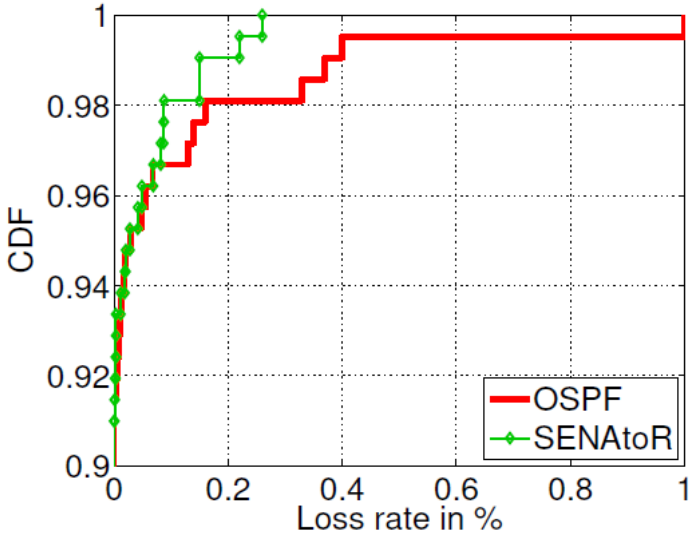
Packet Loss

SENAtor: with smooth link failure
ENAtor: without smooth link failure

Emulation (Atlanta): Traffic spike loss rate



(a) In an SDN-OSPF link

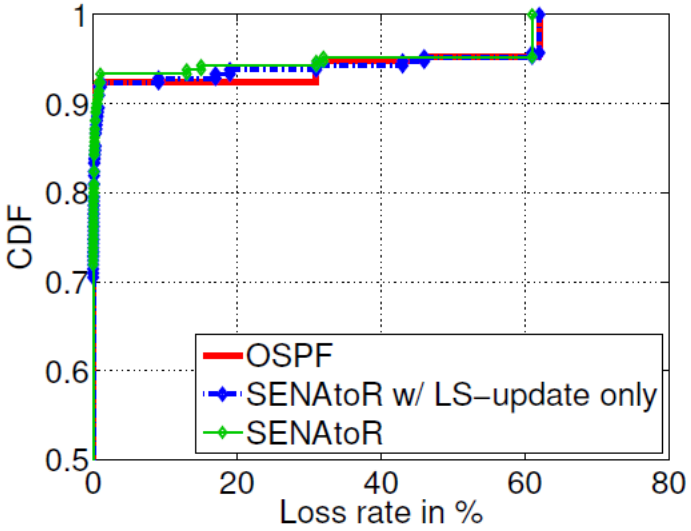


(b) In an OSPF-OSPF link

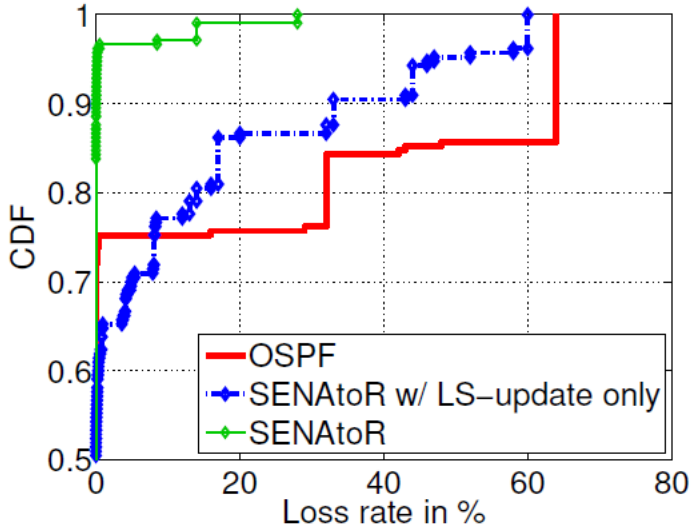
$$E_i(t) \geq X * E_i^{ES}(t)$$

With X= 1.5

Emulation (Atlanta): Link failure loss rate



(a) On an SDN-OSPF link



(b) On an OSPF-OSPF link

$$E_i(t) \leq Y * E_i^{ES}(t)$$

With Y= 0.5

SENAtoR w/LS-update only: nodes turned on upon reception of LS-Update packet

Conclusion

- SENAtoR saves energy consumption in hybrid SDN networks:
  - By turning off/putting in sleep mode SDN nodes
- while maintaining network performance:
  - By smoothly turning off network interfaces
  - Using tunnels to prevent packet loss
  - Link failure and traffic peak mitigation mechanisms

Future Work

- SENAtoR has to be tested in:
  - medium to large size ISP network
  - network traffic varies
  - multiple link failures might occur
- A dynamic threshold should be found to detect traffic peaks and link failures:
  - e.g. dynamic threshold based on the full network current and estimated utilization information, network topology and flows information.

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