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Motivation

- Multi-layer techniques improve the network resource utilization.

- The main motivation for multi-layer integration is cost reduction:
  - CAPEX: reduction in the equipment investment.
  - OPEX: improve the provisioning time for new services.

Architecture Overview

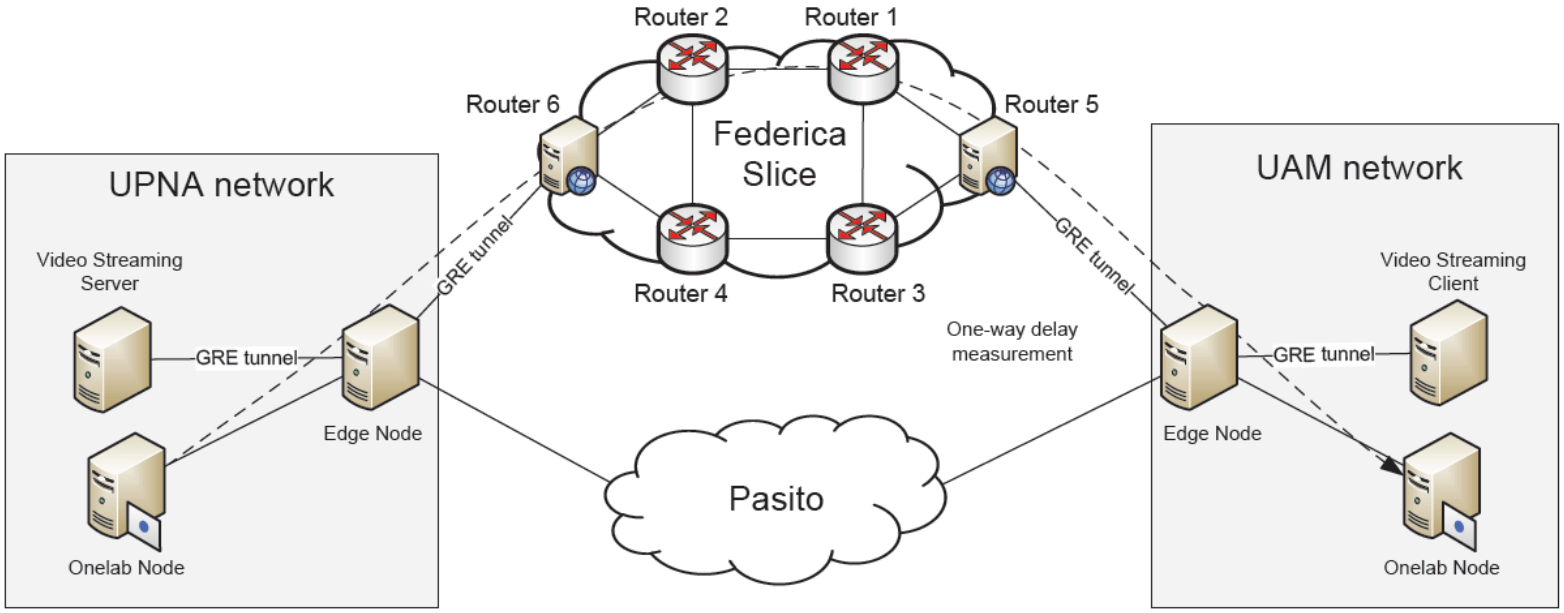
- The test-bed scenario is a distributed network communicating UAM and UPNA premises.
- The architecture uses resources from three facilities:
  - **PASITO**, a layer-2 network that connects main network research workgroups in Spain.
  - **FEDERICA**, a network infrastructure that lets the creation of virtual networks on top of it.
  - **OneLab**, an open federated laboratory, where researchers can have timeslots to do their experiments on real nodes connected to Internet.

FEDERICA

OneLab
FUTURE INTERNET TEST BEDS

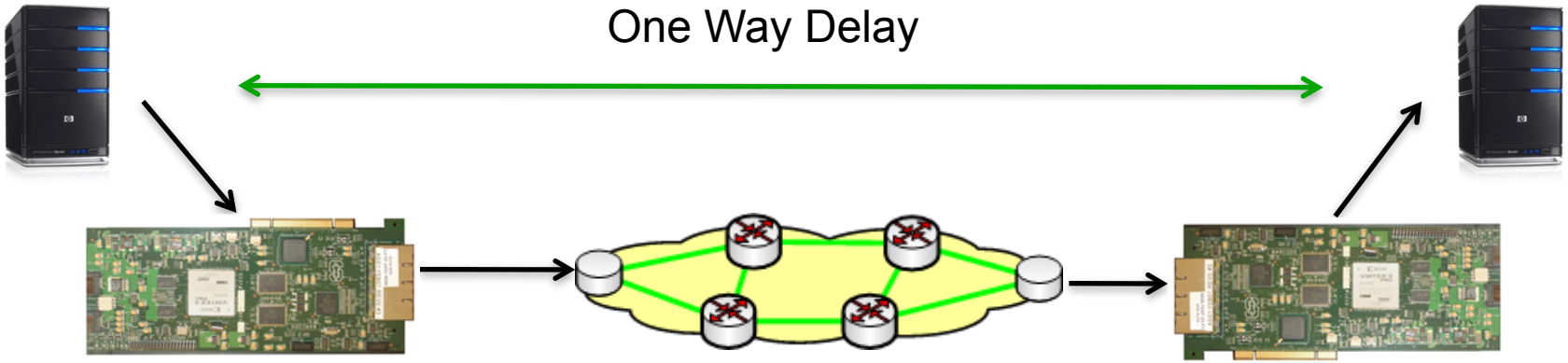
Multi-layer network architecture

- **Federica:** The requested virtual network for our experiment is composed by six nodes: four Juniper (routers 1 to 4) and two Linux (routers 5 and 6).
- **Pasito:** PASITO network is isolated from Internet providing a single VLAN between associated research centers.



End-to-end Quality of Service monitoring

- Argos cards were developed in OneLab project.
- The ARGOS source card marks the packets with the departure GPS time information:
  - Implementation using NetFPGA platform and a sister card.
  - Developed at UAM
- At the reception with the GPS information the One Way Delay (OWD) can be computed.

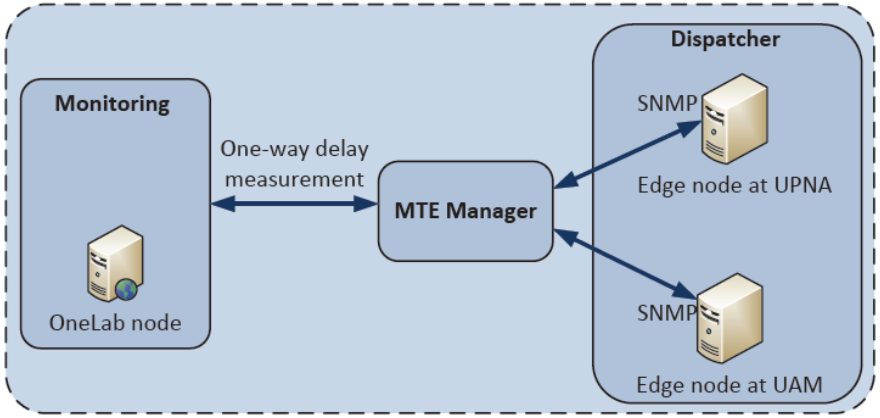


Experimental validation

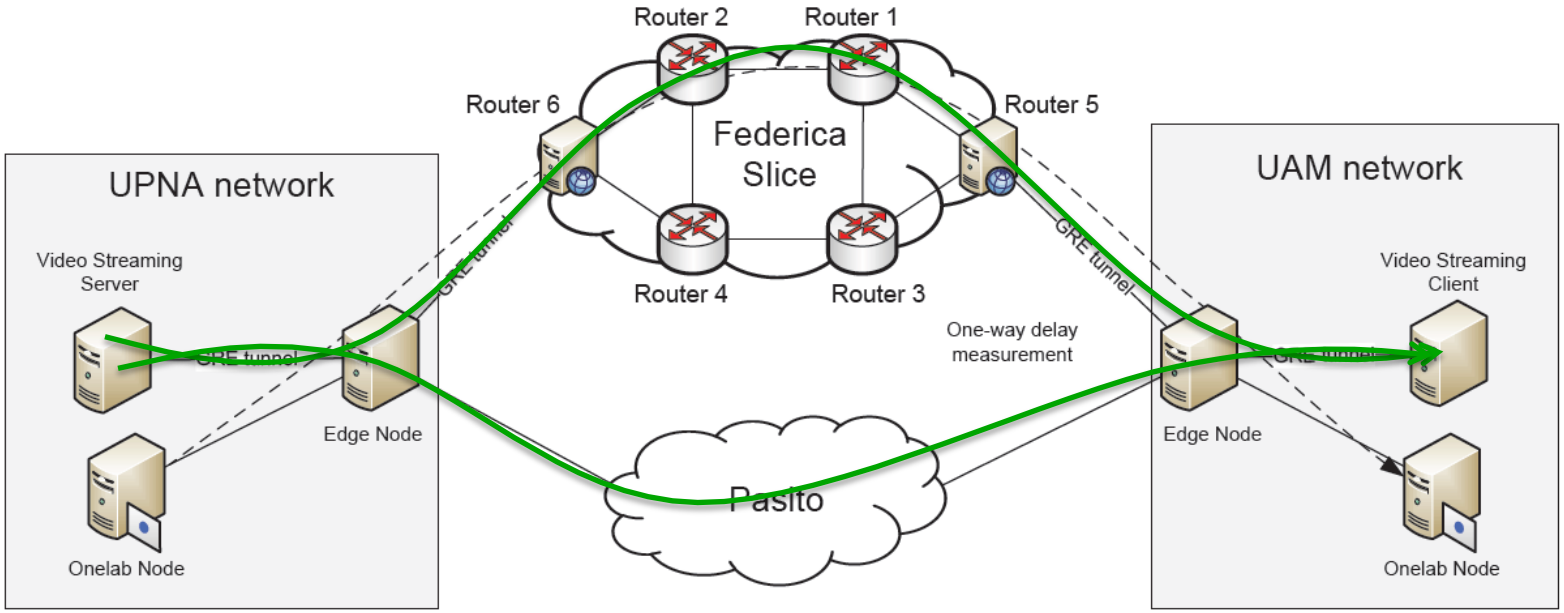
- Two experiments were done:
  - Assessment of Multi-layer Traffic Engineering.
    - Objective: Demonstrate the coordination of multiple layers using a MTE manager with information from Federica and Pasito.
  - Validation of Path Computation Element Protocol
    - Objective: Validate an implementation of the Path Computation Element Protocol developed at UAM for multi-layer networks.

Assessment of Multi-layer Traffic Engineering

- The coordination between both layers is done via a MTE Manager:
  - Monitoring module: get information from the OWD provided by the OneLab infrastructure.
  - Dispatcher modules: configure edge nodes using SNMP.

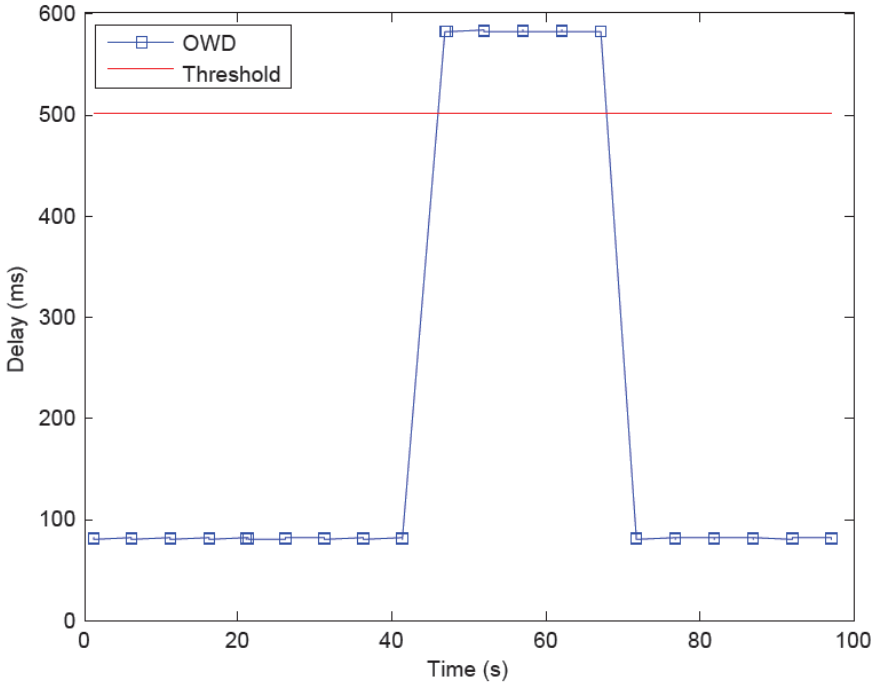


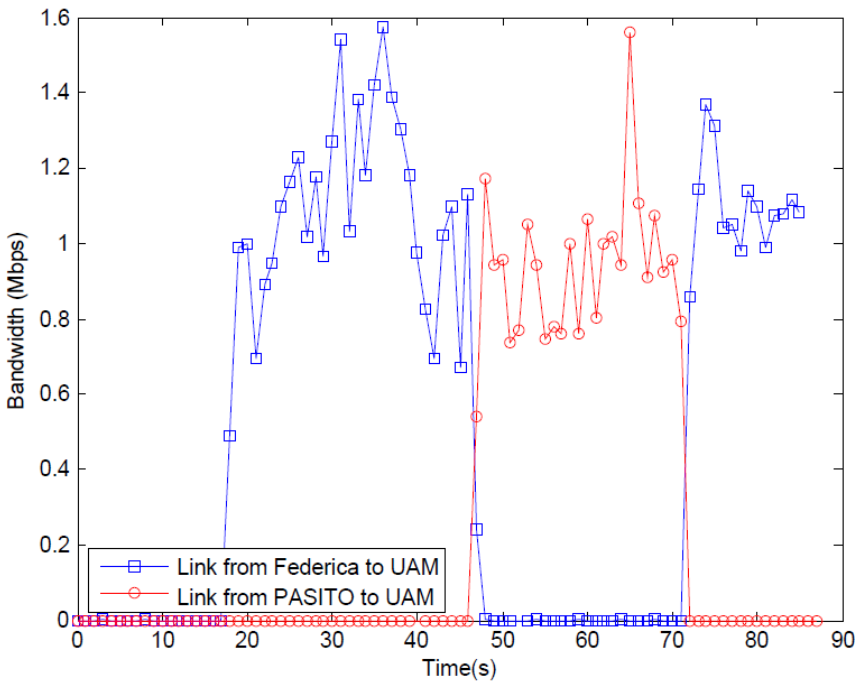
Experiment definition



- Algorithm
  1. The traffic is sent using layer 3 network.
  2. When the QoS is not good enough (OWD > 500ms), layer 2 network is used.

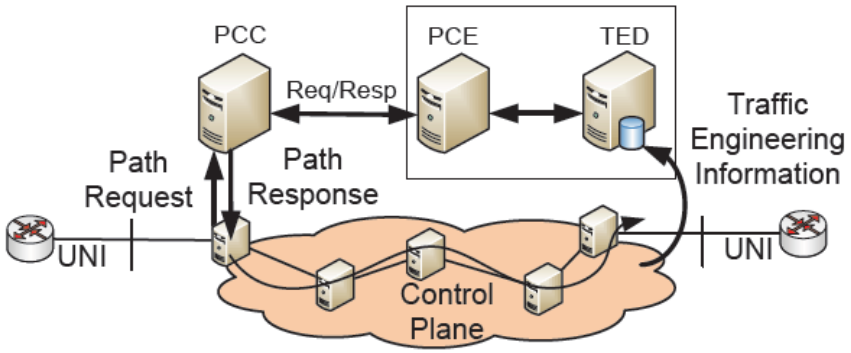
Experiments Results



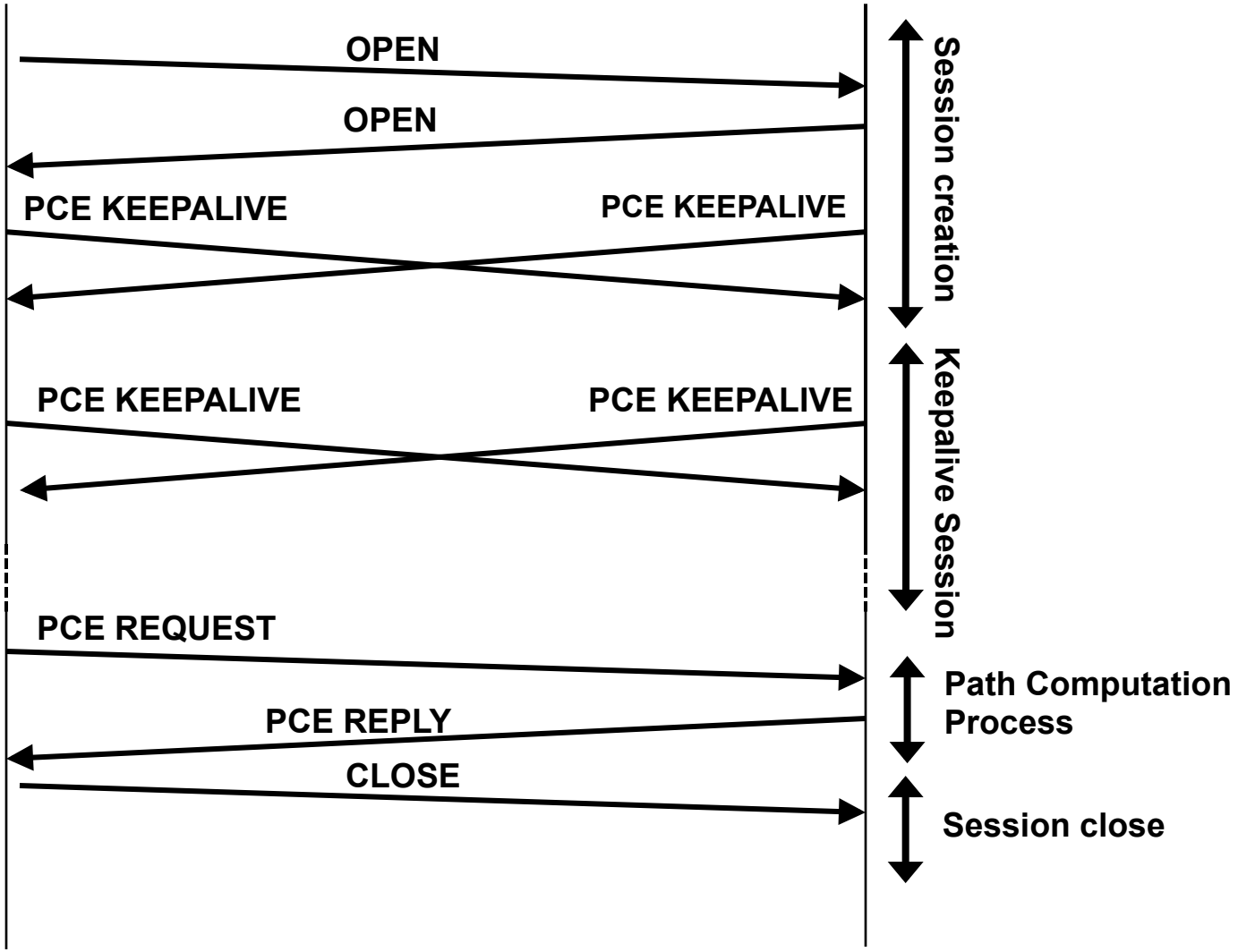


Path Computation Element Protocol

- The Path Computation Element (PCE) is “an entity (component, application, or network node) that is capable of computing a network path or route based on a network graph and applying computational constraints”
- Path Computation Element Protocol (PCEP) follows a request/response scheme where a Path Computation Client (PCC) is asking to the PCE for routes



PCEP phases


OPEN
OPEN
PCE KEEPALIVE
PCE KEEPALIVE
Session creation
PCE KEEPALIVE
PCE KEEPALIVE
Keepalive Session
PCE REQUEST
PCE REPLY
Path Computation Process
CLOSE
Session close

Validation of the PCEP

- PCE has the same algoritm implemented than MTE manager.
- The first request provides a path with Federica IPs, while the second request is composed by Pasito IPs.

	Time	Source	Destination	Protocol	Info
1	0.000000	130.206.162.25	150.244.56.33	PCEP	OPEN MESSAGE
2	0.021050	150.244.56.33	130.206.162.25	PCEP	OPEN MESSAGE
3	0.021141	130.206.162.25	150.244.56.33	PCEP	KEEPALIVE MESSAGE
4	0.041696	150.244.56.33	130.206.162.25	PCEP	KEEPALIVE MESSAGE
5	0.041766	130.206.162.25	150.244.56.33	PCEP	PATH COMPUTATION REQUEST MESSAGE
6	0.071580	150.244.56.33	130.206.162.25	PCEP	PATH COMPUTATION REPLY MESSAGE
7	0.071641	130.206.162.25	150.244.56.33	PCEP	CLOSE MESSAGE
8	4.770338	130.206.162.25	150.244.56.33	PCEP	OPEN MESSAGE
9	4.791264	150.244.56.33	130.206.162.25	PCEP	OPEN MESSAGE
10	4.791324	130.206.162.25	150.244.56.33	PCEP	KEEPALIVE MESSAGE
11	4.812387	150.244.56.33	130.206.162.25	PCEP	KEEPALIVE MESSAGE
12	4.812450	130.206.162.25	150.244.56.33	PCEP	PATH COMPUTATION REQUEST MESSAGE
13	4.834436	150.244.56.33	130.206.162.25	PCEP	PATH COMPUTATION REPLY MESSAGE
14	4.834484	130.206.162.25	150.244.56.33	PCEP	CLOSE MESSAGE

Conclusions

- Assessment of multi-layer techniques in a realistic scenario involving three infrastructures: FEDERICA, PASITO and OneLab.
  - ARGOS cards are used to perform highly accurate network QoS measurements.
- Validation of an implementation of the Path Computation Element Protocol in multi-layer networks.

Thanks
Questions?

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