OFC Review 2013
Software Defined Network (SDN)

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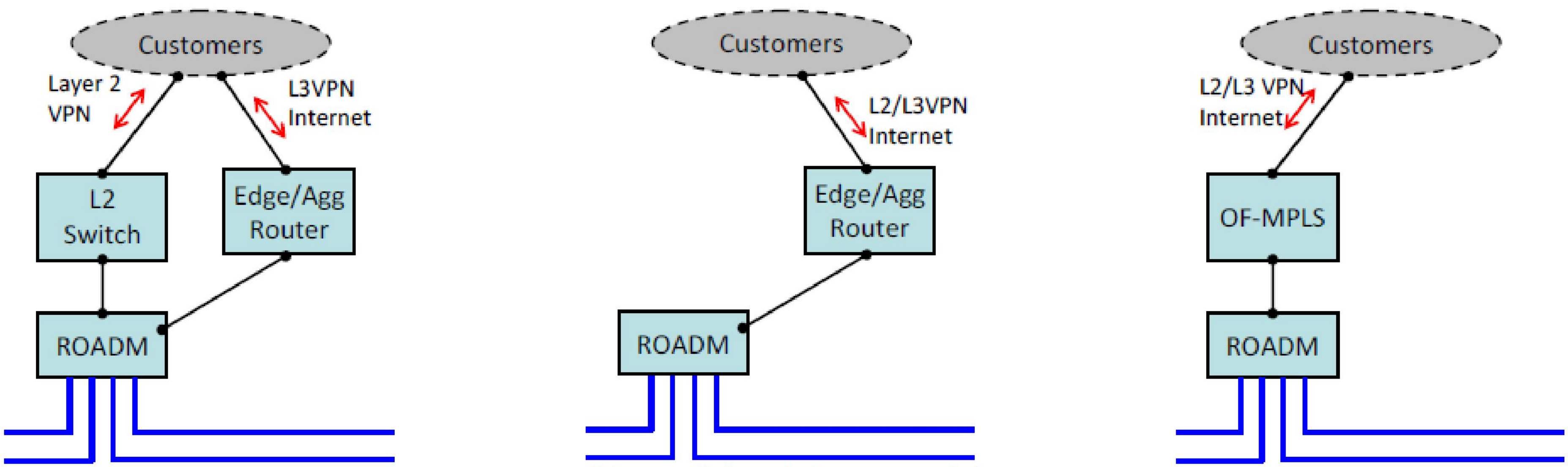
NTu3F: SDN in Today's Network

SDN: What and Why

- Traditional distributed control plane
  - Pros: Plug and play feature
  - Cons:
    - Lack of flexibility and extensibility (policy-based routing)
    - the more plenty and powerful functions the control plane offers, the more expensive the cost per bit becomes
    - Amount of packet flow is on the rise
- SDN: Separation of control and data plane
  - Pros:
    - The prices of switches get lower since they contain only the data plane
    - Network operators may program their own control plane as they want
  - Cons: Scalability?
- OpenFlow: a SDN protocol

NTu3F: SDN in Today's Network

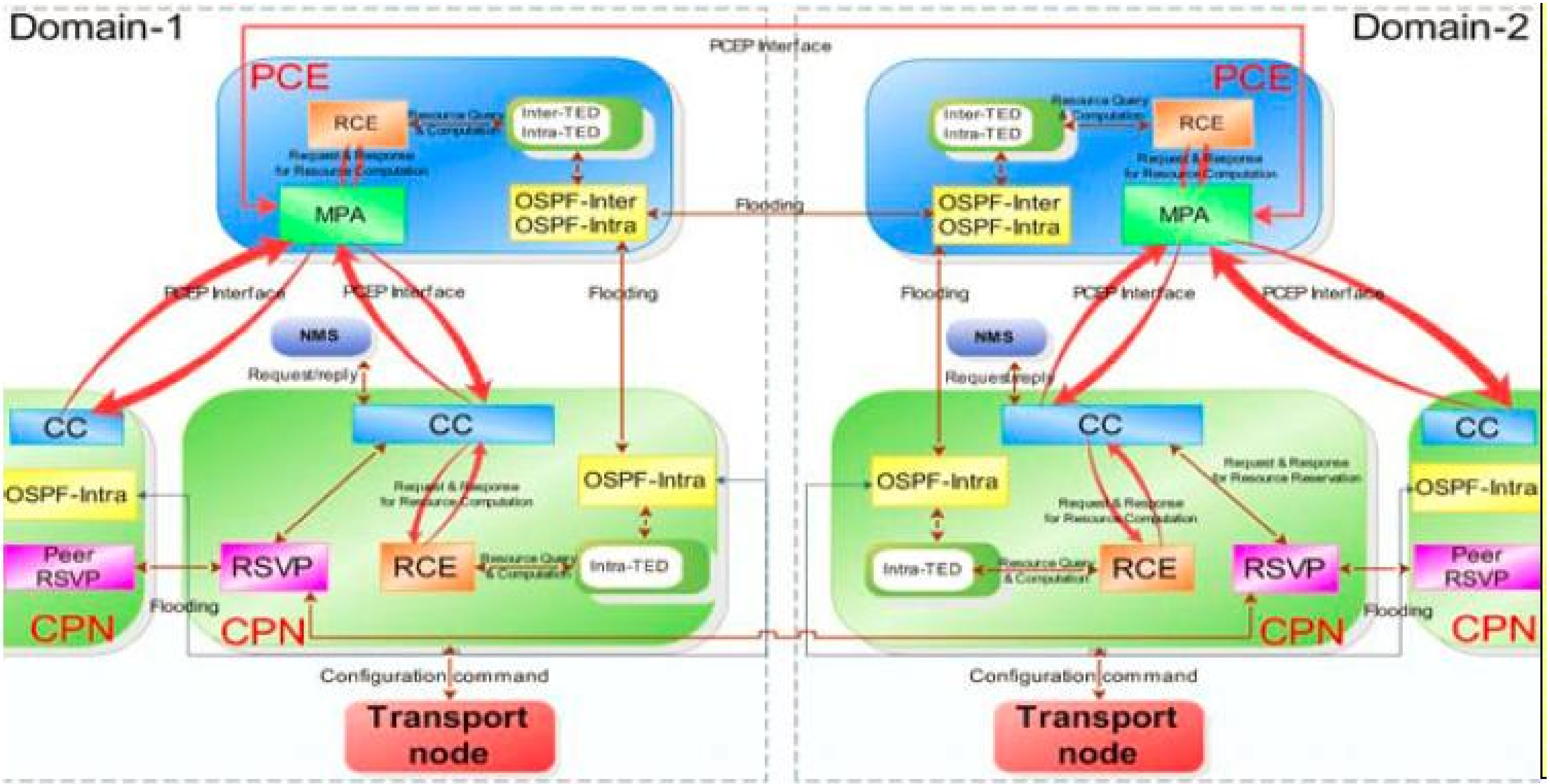
Title	Authors	Proposal/Contribution	Result
Software-Defined Packet Optical Transport Networks Offering Multiple Services	S. Ishida and I. Nishioka NEC, USA	OpenFlow-enabled MPLS switches for metro networks	Around 30% cost reduction



(a) Traditional (hybrid) (b) Traditional (router-only) (c) SDN

NTu3F: SDN in Today’s Network

Title	Authors	Proposal/Contribution	Result
Which Is More Suitable for the Control over Large Scale Optical Networks, GMPLS or OpenFlow?	Y. Zhao, J. Zhang, H. Yang, Y. Yu, X. Niu, X. Lin BUPT, ZTE	Testbed to compare GMPLS and OpenFlow	OpenFlow performs better



CPN: Control Plane Node
TED: Traffic Engineering Database
RCE: Resource Computation Element
MPA: Message Policy Analyzer
CC: Connection Controller

Lightpath Provisioning in GMPLS

Procedure of lightpath provisioning

Step1: CC transfers request to PCE

Step2: PCE1 computes domain sequence

Step3: PCE1 computes local domain path

Step4: PCE1 returns result to source CC

Step5: source CC triggering signaling

Step6: PCE2 finishes step3 to step5 in the second domain.

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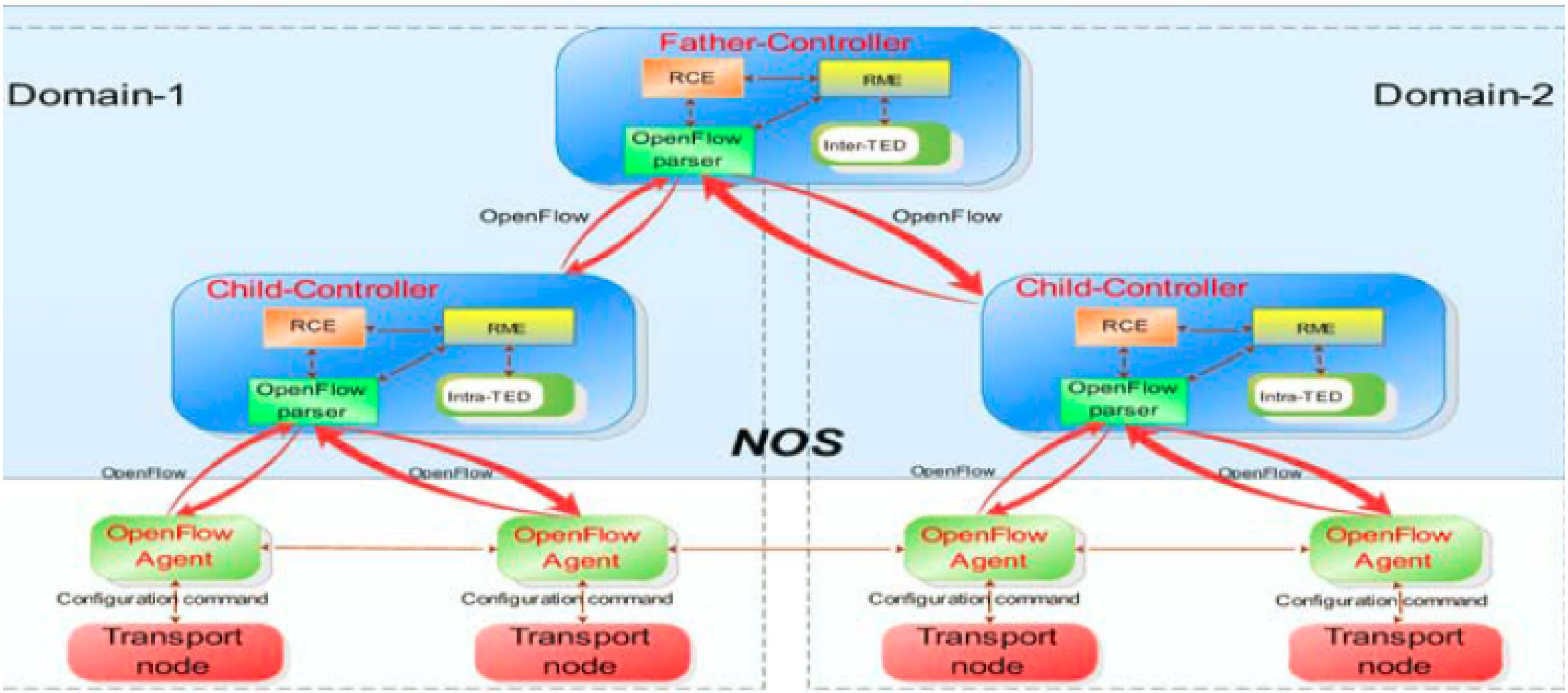
Step7: The last PCE conducts same action

OpenFlow



Father-Controller
RCE
RME
OpenFlow parser
Inter-TED
Domain-1
Domain-2
OpenFlow
OpenFlow
Child-Controller
RCE
RME
OpenFlow parser
Intra-TED
Child-Controller
RCE
RME
OpenFlow parser
Intra-TED
NOS
OpenFlow
OpenFlow
OpenFlow
OpenFlow
OpenFlow Agent
OpenFlow Agent
OpenFlow Agent
OpenFlow Agent
Configuration command
Configuration command
Configuration command
Configuration command
Transport node
Transport node
Transport node
Transport node

Lightpath Provisioning in OpenFlow

Procedure of lightpath provisioning

Step1: First Child-Controller receive request from edge node or client

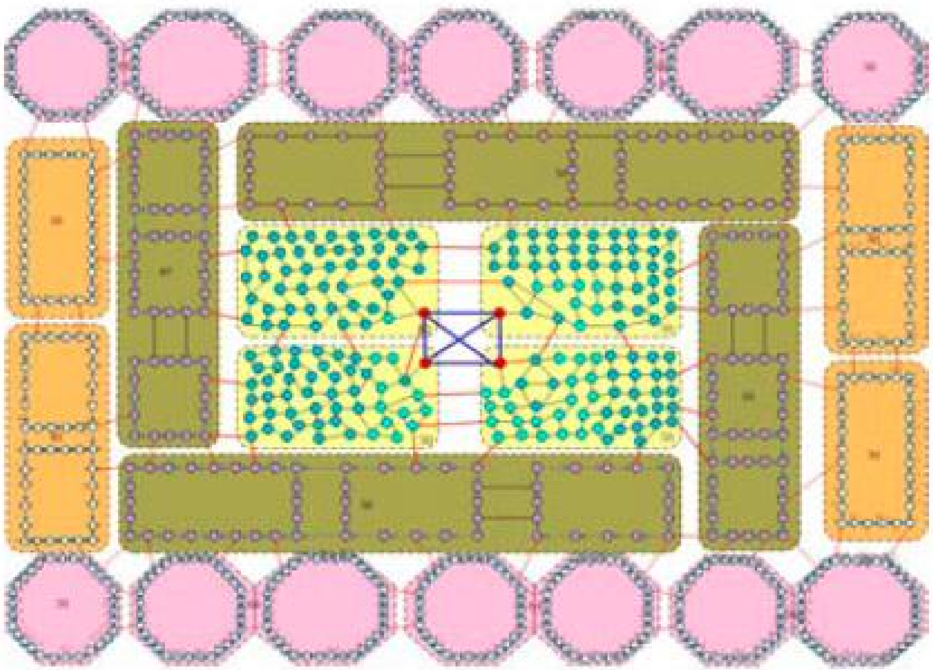
Step2: First Child-Controller PCEI determines if destination in local domain

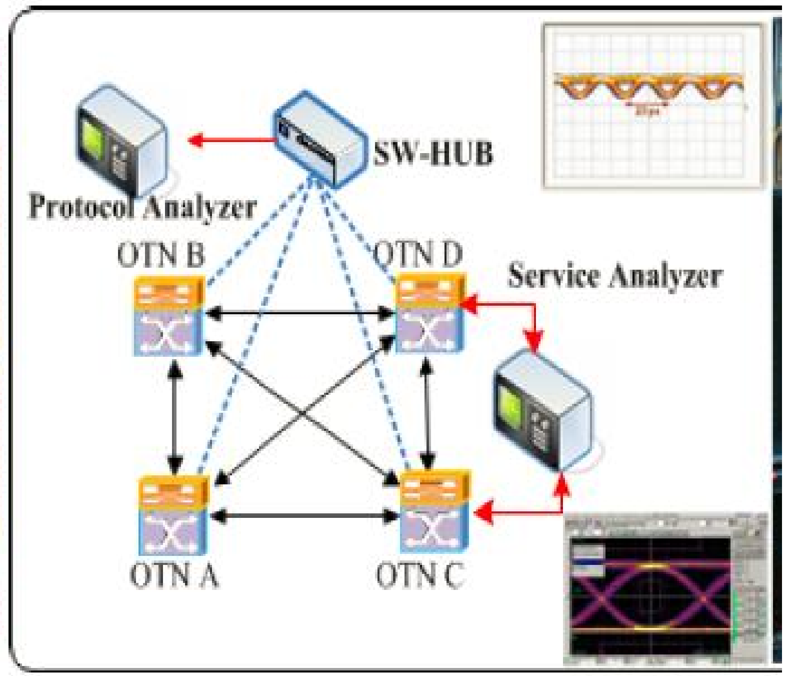
Step3: It transfers request to Father-Controller in destination in another domain

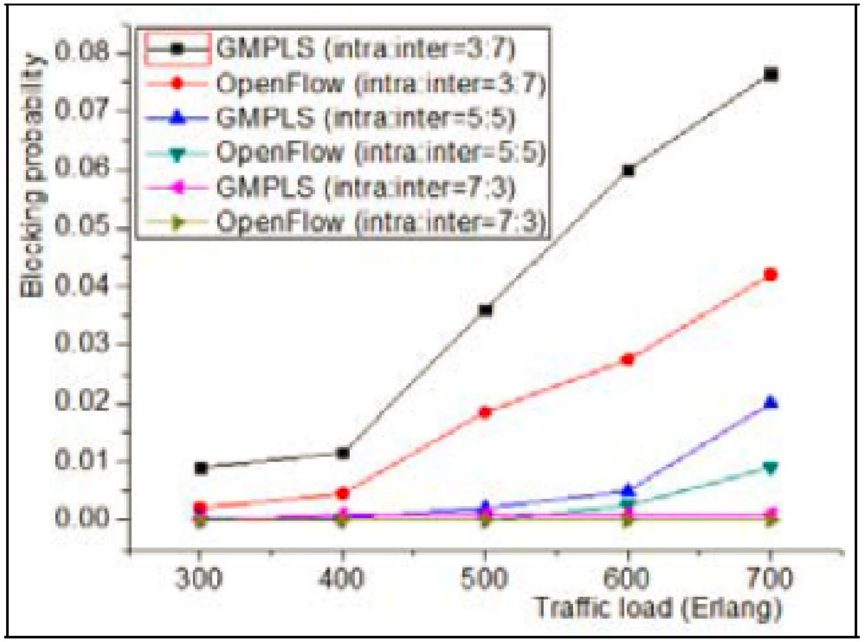
Step4: Father-Controller gains domain sequence and sends to Child-Controllers

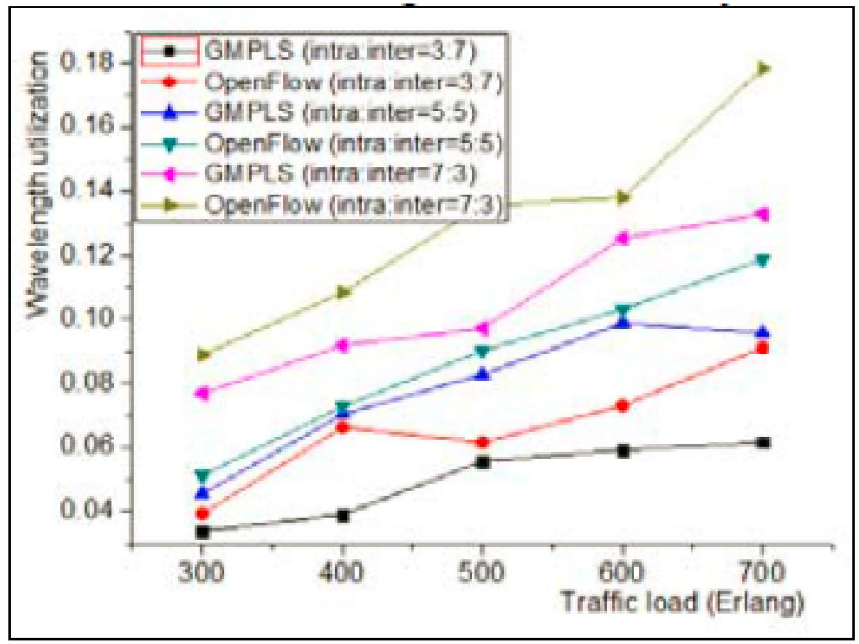
Step5: Child-Controller finishes path computation and resource reservation along the domain sequence parallel

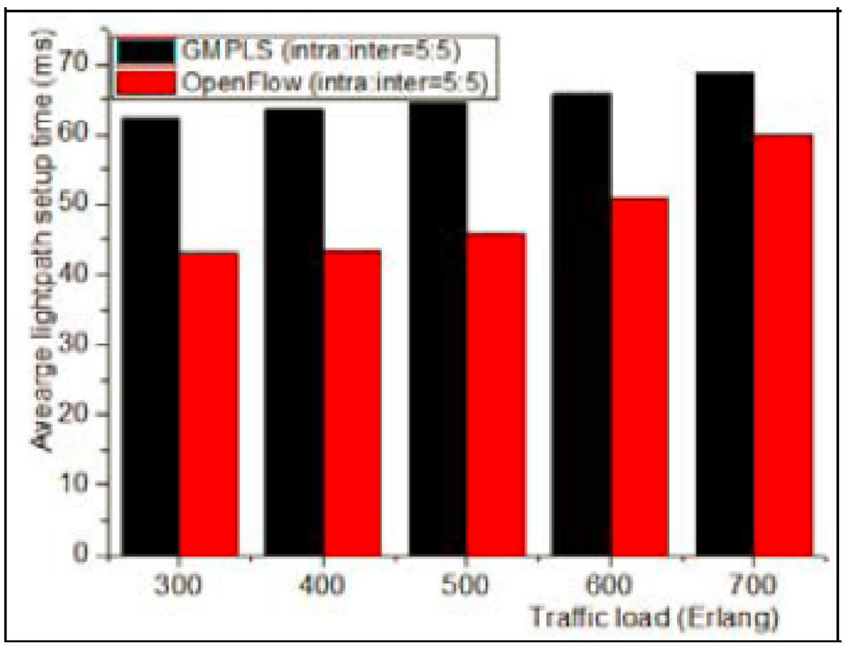
NTu3F: SDN in Today's Network











Child-controllers can complete path-computation, resource assignment, and reservation parallelly.

NTu3F: SDN in Today’s Network

Title	Authors	**Proposal/Contribution**	**Result**
Survivability Strategies for PCE-based WDM Networks Offering High Reliability Performance	J. Ahmed, C. Cavdar, P. Monti, L. Wosinska KTH, Sweden	Protection by path restoration	High availability in double failure scenarios

Protection by Path Restoration

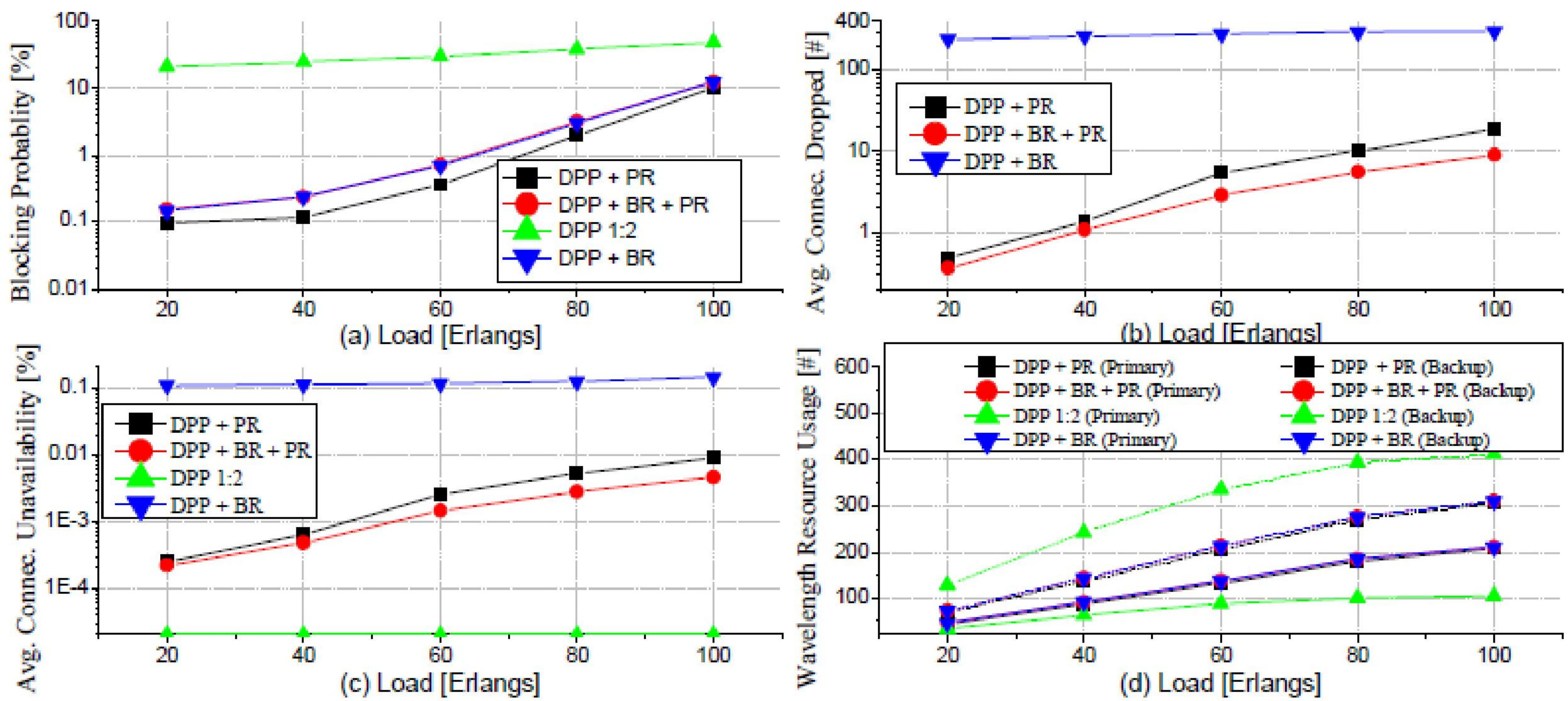


Fig.1. (a) Blocking Probability, (b) Avg. # of Dropped Connections, (c) Avg. Connection Unavailability, (d), Number of Used Wavelengths.

	DPP+PR			DPP+BR+PR			DPP+BR		
Load [Erlangs]	20	60	100	20	60	100	20	60	100
Downtime [time-units]	0.415	5.31	17.56	0.345	3.34	8.68	273	284	309

Table.1. Total connection downtime for different schemes.

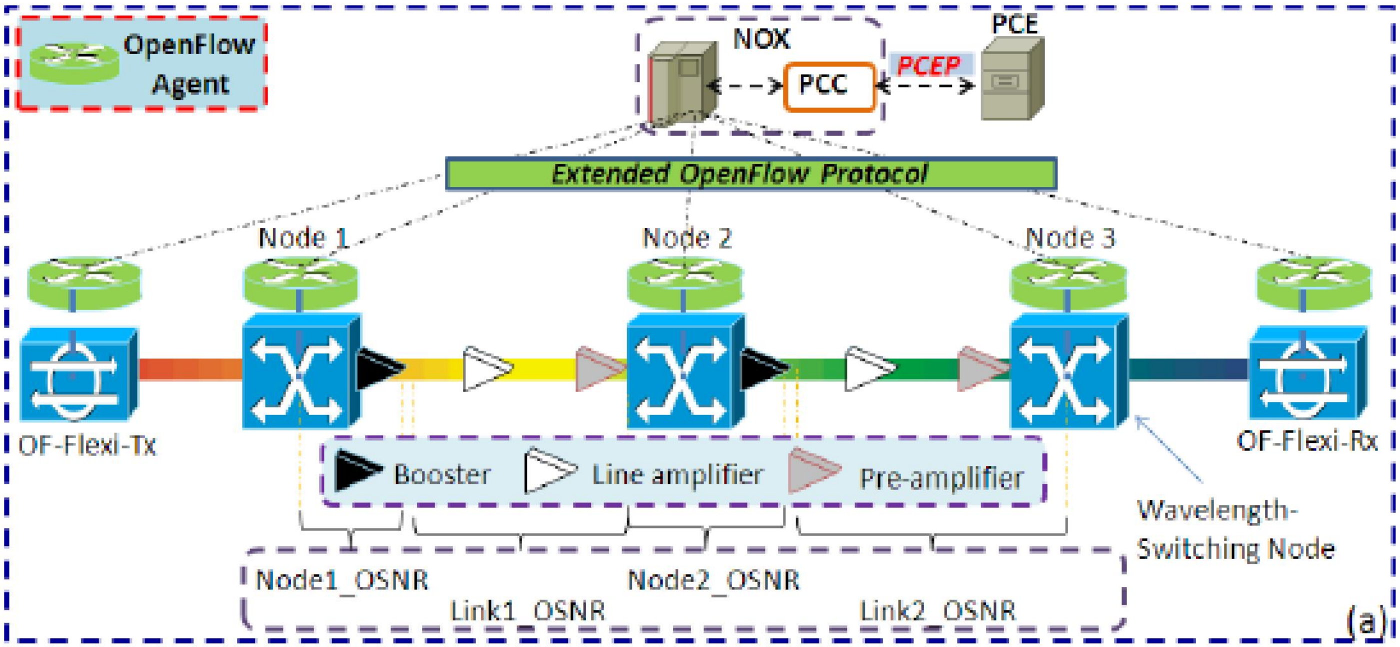
NTu3F: SDN in Today’s Network

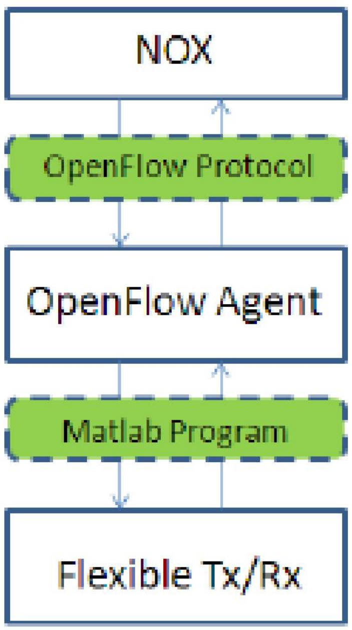
Title	Authors	Proposal/Contribution	Result
Demonstration of a Dynamic Transparent WSON Employing Flexible Transmitter/Receiver Controlled by an OpenFlow/Stateless PCE Integrated Control Plane	L. Liu, H. Choi, R. Casellas, T. Tsuritani, I Morita, R. Martínez, R. Muñoz KDDI, Japan CTTC, Spain	OpenFlow/Stateless PCE integrated control plane for WSON employing Flexi-Tx/Rx	Flexibility of the proposed solution is verified

Flexible Tx/Rx can change the modulation format and transmission rate w/o hardware change

Dedicated PCE to scale OpenFlow architectutre

Network Architecture





Path Provisioning and Restoration

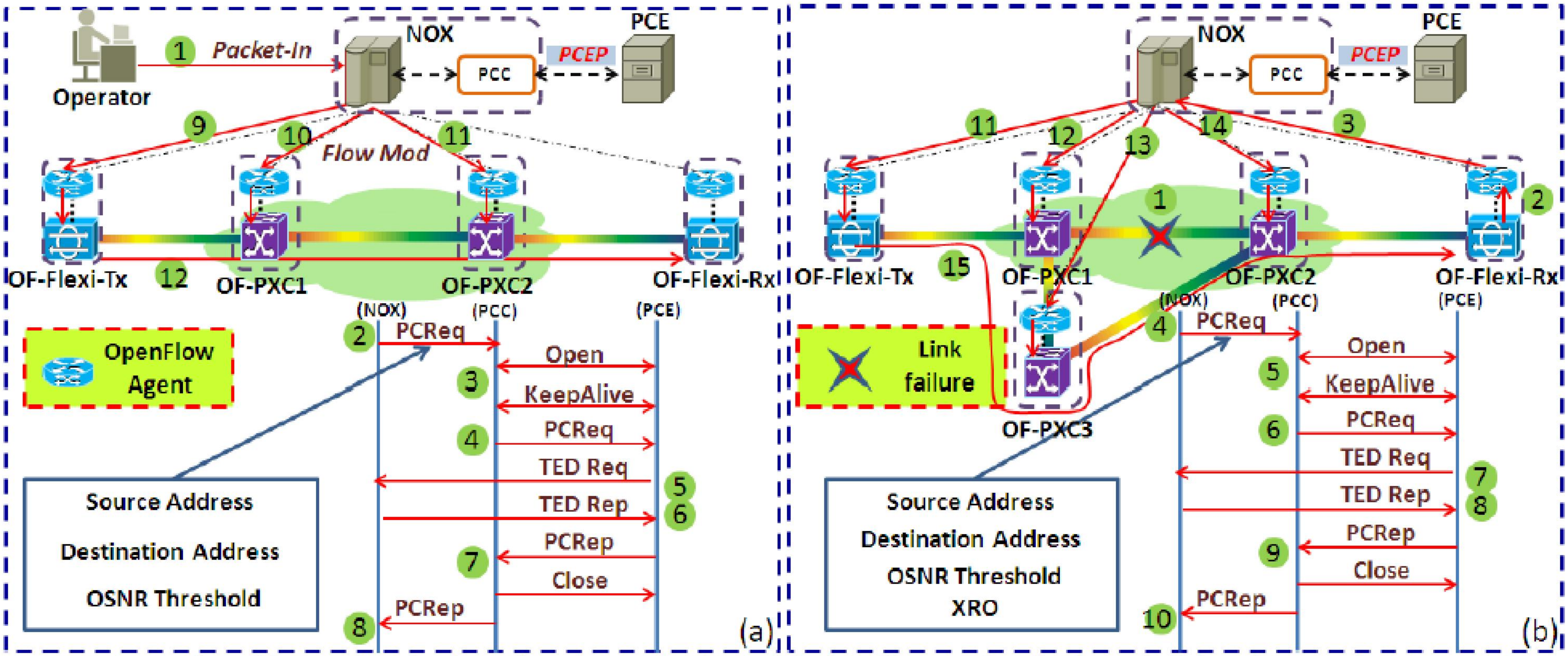


Fig.2: (a) Procedure for dynamic end-to-end path provisioning; (b) Procedure for dynamic lightpath restoration.

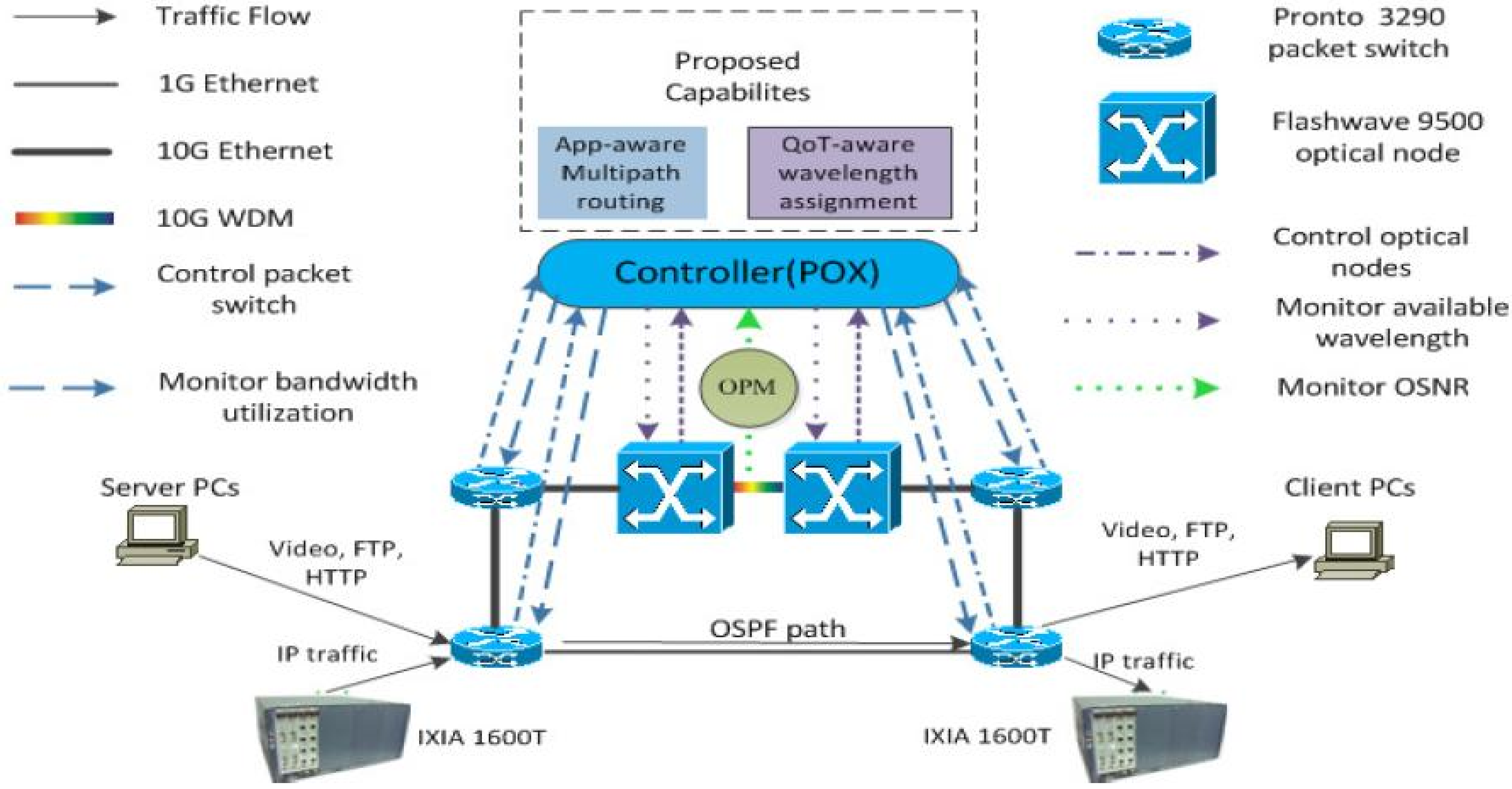
	PCE Path Computation Latency	Control plane Processing Latency	Overall Latency
Working Path Provisioning	14.6 ms	140.5 ms	392.1 ms
Restoration for the First Link Failure	15.1 ms	142.1 ms	392.7 ms
Restoration for the Second Link Failure	14.3 ms	143.8 ms	394.5 ms

(f)

NTu3F: SDN in Today's Network

Title	Authors	Proposal/Contribution	Result
Situation-Aware Multipath Routing and Wavelength Reassignment in a Unified Packet-Circuit OpenFlow Network	W. Mo, J. He, M. Karbassian, J. Wissinger, and N. Peyghambarian Uni. of Arizona	multipath routing and wavelength re-assignment in OpenFlow-enabled packet-circuit network, aware of links' bandwidth utilization, applications' protocol, and quality of transmission	effectiveness of the proposed solution is verified

Network Architecture



Situation-aware Routing

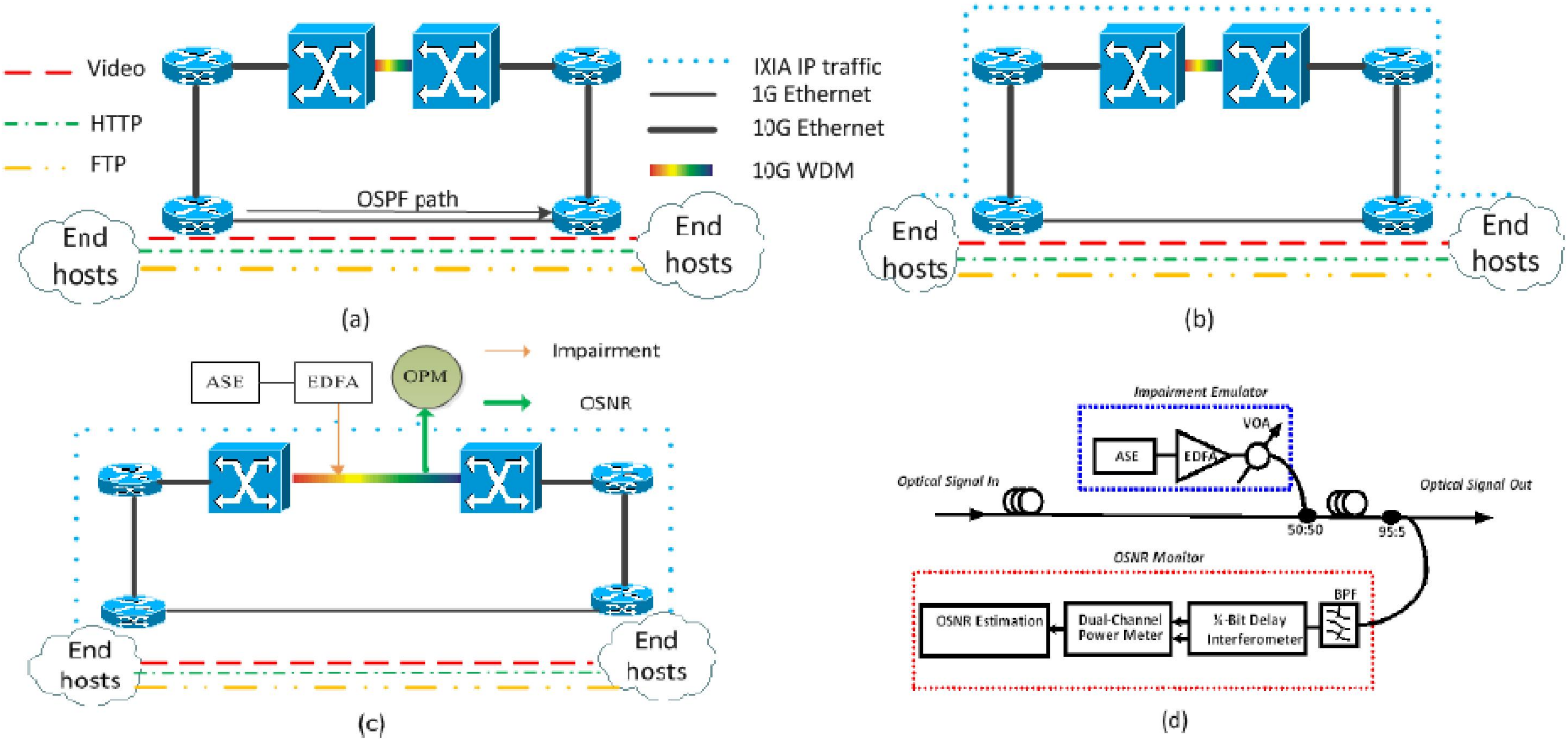


Fig.2. The topology and traffic flows of packet-circuit OpenFlow network, a) The network before traffic congestion, b) The network after multipath routing to eliminate traffic congestion, c) QoT-awareness in WDM link, d) OPM and ASE noise schematic

NTu3F: SDN in Today’s Network

Title	Authors	Proposal/Contribution	Result
Path Computation Elements (PCE): Applications and Status	R. Casellas, R. Muñoz, and R. Martínez CTTC, Spain	An overview of Path Computation Elements in optical networks, highlighting the motivations behind their adoption, common deployment models, and new trends such as its use as stateful entities in software defined networks.	-

NW1F : Control Plane and Packet Transport Networks

Control Plane and Packet Transport Networks

Title	Authors	**Proposal/Contribution**	**Result**
MPLS-TP: Overview and status	Y. Koike, NTT	MPLS-TP: Overview and status.	-

Control Plane and Packet Transport Networks

Title	Authors	Proposal/Contribution	Result
Integration of Planning and Control Plane in Packet Optical Multilayer Network	P. Iovanna , A. Germoni, and V. López Ericsson, Italy CoRiTel, Italy Telefonica, Italy	An integrated solution relying on a centralized management and a distributed control plane is presented for packet optical networks.	Simulations results show up to 42% CapEx saving.

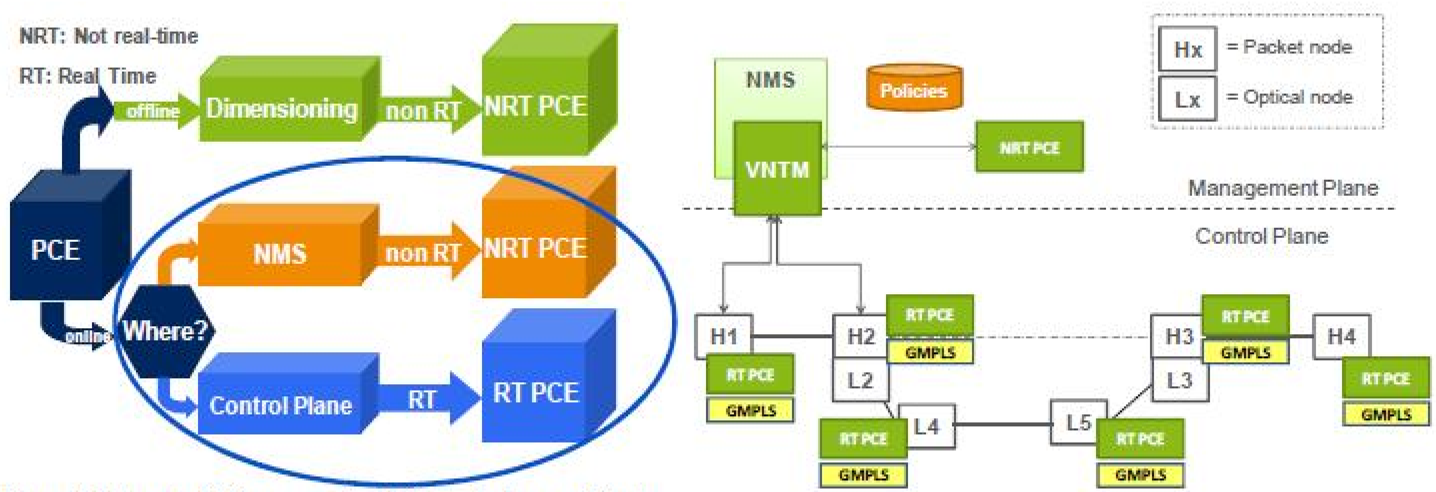


Figure 1.Integrated Management and Control plane architecture.

Control Plane and Packet Transport Networks

Title	Authors	**Proposal/Contribution**	**Result**
IP-Optical Interaction during Traffic Restoration	O. Gerstel, C. Filsfils, and W. Wakim Cisco, Israel	Analyzed the required interaction between the optical and IP layers to enable restoration of IP links in the optical layer.	Optical restoration alone is insufficient. Instead, the IP layer and optical layer must collaborate before, during, and after a failure. The multiple interactions – in particular the negotiation during the restoration process – might slow down this process.

IP-Optical Interaction during Traffic Restoration

- Issues:
  - The exponential growth of bandwidth over the internet is not sustainable unless the cost of the network drops significantly
  - One way to reduce cost is to restore links between IP routers in the optical layer, as this can be done using the same router interfaces and DWDM transponders that were used for the original working path
- if both layers are designed to protect all traffic then the savings achieved compared to today's solution (i.e., the IP layer protects against optical failures and IP failures) will be minimal

IP-Optical Interaction during Traffic Restoration

- Optical layer restoration cannot replace IP layer restoration because:
  - Only it can deal with IP layer failures,
  - Only it can decide which traffic can be dropped
  - Only it understands latency constraints for different traffic types
  - It provides sub-second recovery, while DWDM layer restoration is inherently slow, and
  - Only it has the flexibility to protect via other routers, instead of limiting the protection to the link that had failed

Negotiation between two layers: Example

1. The router initially asks for a path with latency<X, cost<Y, while avoiding SRLGs {A,B}
2. Upon failure, the router first asks for a path with the same constraints
3. The optical layer cannot satisfy the request and notifies the router that no such path exists
4. The router now relaxes the latency constraint to “latency<X+Z”
5. The optical layer can still not satisfy the request
6. The router now relaxes also the SRLG constraint to just {A}
7. The optical layer can now satisfy the request and the restoration path is set up.

Conclusion:

- Multi-layer restoration is cost-efficient
- Requires tight coordination between the layers
- Restoration might be slow

OTh1H : Future SDN Applications

Future SDN Applications

Title	Authors	Proposal/Contribution	Result
Defining Optical Software-Defined Networks (SDN): From a Compilation of Demos to Network Model Synthesis	N. Cvijetic, M. Angelou, A. Patel, P. Nan Ji, T. Wang NEC, Princeton AIT, Greece	SDN model (ILP) for network optimization.	Accuracy of the model is validated.
Software Defined Optical Networks Technology and Infrastructure: Enabling Software-Defined Optical Network Operations	D. Simeonidou, R. Nejabati, M. P. Channegowda *University of Bristol, UK*	SDON testbed.	OpenFlow performs better than GMPLS.
Software Defined Code-rate-adaptive Terabit/s based on Time-frequency Packing	N. Sambo et al. CNIT, Italy Ericsson, Italy Scuola Superiore Sant'Anna, Italy	Demonstrated a software-defined code-adaptive Tb/s based on time-frequency packing technique. Enhanced OpenFlow architecture is proposed to set transmission parameters (e.g., code rate) of 1Tb/s.	-

Future SDN Applications

Title	Authors	Proposal/Contribution	Result
Software-defined Transport Network for Cloud Computing	J. HE Huawei, China	Software defined optical transport network is introduced with intelligent and open control plane and flexible data plane to convey distinct DC-to-DC traffic for cloud computing.	-

- Observations:
  - Telco may convey DC-to-DC traffic as they have legacy point-of-presence near users
  - DC-to-DC traffic has following distinct characteristics:
    1. moving big data in quite short time
    2. predictable, or even schedulable

OW1H : Cognitive Networks

Cognitive Networks

Title	Authors	Proposal/Contribution	Result
Cognitive Dynamic Optical Networks	I. Miguel et al. University of Valladolid, Spain, Technical University of Denmark, Huawei, Germany Orange Labs Poland, AIT (Greece), CREATE-NET (Italy)	Presented cognitive network framework to control heterogeneous optical networks.	-

CHRON: Cognitive Heterogeneous Reconfigurable Optical Networks

Cognitive Network

- ***"A network with a process that can perceive current network conditions, and then plan, decide, and act on those conditions. The network can learn from these adaptations and use them to make future decisions, all while taking into account end-to-end goals"***
- Three main components:
  1. Monitoring element
  2. Software adaptable element
  3. Cognitive process: learn or make use of past history

     when facing two equivalent scenarios, the network may act in a different way if its previous history is different

Cognitive Optical Network Architecture

- Software-defined cognitive transceivers
- Cognitive network node
- Cognitive central node

Application of Cognition

- QoT estimator

  makes a prediction of signal quality of new lightpaths to be established in the network (as well as of the impact on existing connections) by using past history
- Virtual topology design (impairment-aware and survivable)
- Cognitive transceivers

Cognitive Networks

Title	Authors	Proposal/Contribution	Result
Demonstration of EDFA Cognitive Gain Control via GMPLS for Mixed Modulation Formats in Heterogeneous Optical Networks	J. Oliveira et al. CPqD Foundation, Brazil Tech. Univ. of Denmark PADTEC, Brazil	Demonstrated cognitive gain control for EDFA operation in real-time GMPLS controlled heterogeneous optical testbed with 10G/100G/200G/400G lightpaths. Cognitive control maintains the network BER below FEC-limit for up to 6 dB of induced attenuation penalty.	-
An introduction to routing and wavelength assignment algorithms for fixed and flexgrid	E. Varvarigos University of Patras , Greece	Presented general algorithms and techniques that can be used to solve network optimization problems.	

OW4G : PCE

PCE

Title	Authors	Proposal/Contribution	Result
Assessing the Performance of Multi-Layer Path Computation Algorithms for different PCE Architectures	S. Martínez, V. López, M. Chamania, O. González, A. Jukan, J.P. Fernández-Palacios Telefonica, Spain Technical Technische Universität Carolo-Wilhelmina zu Braunschweig	Implemented a multi-layer PCE and compared performance of various algorithms using either one integrated, or two separate PCEs in each layer.	Multi-layer integration reduces blocking by 13.91%, but increases computation time by 49.24%.
An Integrated Stateful PCE / OpenFlow controller for the Control and Management of Flexi-Grid Optical Networks	R. Casellas, R. Martínez, R. Muñoz, L. Liu, T. Tsuritani, I. Morita CTTC, Spain KDDI, Japan	Designed and validated an integrated PCE/OpenFlow controller for fixed- and flexi- grid networks. Extended OpenFlow for elastic optical networks.	

PCE

Title	Authors	**Proposal/Contribution**	**Result**
Experimental Validation of Dynamic Restoration in GMPLS-controlled Multi-layer Networks using PCE-based Global Concurrent Optimization	R. Martínez, A. Castro, R. Casellas, R. Muñoz, L. Velasco, R. Vilalta, J. Comellas CTTC, Spain Universitat Politècnica de Catalunya (UPC), Spain	Experimental validation of a PCE-based GCO architecture for dynamic restoration in GMPLS multi-layer networks.	Blocking probability and response time are compared between bulk and sequential provisioning.
PCE: What is It, How Does It Work and What are Its Limitations?	R. Muñoz, R. Casellas, R. Martínez Centre Tecnològic de Telecomunicacions de Catalunya (CTTC)	Tutorial.	

NTh4J: Carrier Strategies and Network Evolution

Carrier Strategies and Network Evolution

Title	Authors	Proposal/Contribution	Result
Investigation of Energy Savings in Optical Networks using Bundle Link Rightsizing Methods	L. Liu and B. Ramamurthy University of Nebraska-Lincoln	Threshhold-based algorithms to rightsize the capacity of bundle links to achieve energy savings by shutting down corresponding layer-3 router ports and in layer-1 optical components (transponders and regenarators).	10-30% energy savings.
Virtual Network Reconfiguration in Optical Substrate Networks	F. Gu, M. Peng, S. Khan, A. Rayes, N. Ghani University of New Mexico Wuhan University North Dakota State University Cisco Systems Inc.	Studied VN reconfiguration in optical networks and presents a novel reactive algorithm to migrate multiple VN nodes to minimize substrate link congestion	lower blocking and increased revenues as compared to existing strategies

NTu3J: NG Applications and Home Networking

NG Applications and Home Networking

Title	Authors	Proposal/Contribution	Result
WDM-FDM approach for a Multiservice Home Network	J. Guillory, K. Chikha, A. Pizzinat, P. Guignard, B. Charbonnier, J. Etrillard, C. Algani Orange Labs, France ESYCOM laboratory, France.	Proposed a passive star based on a NxN optical splitter to deliver simultaneously Ethernet, terrestrial television and 60GHz wireless connectivity (RoF). WDM multiplexing with FDM demultiplexing is adopted and validated by real-time signals transmissions.	

Motivation

- Home Area Network (HAN) is evolving towards multi-Gbps
  - HD/3D TV, VoD, cloud computing
  - Exploding number of devices inside the home
  - High broadband optical access netwoks (e.g., FTTH)
- Current technology: Ethernet + WiFi (2.5 and 5 GHz)
- WiFi provides a few hundreds of Mbps
- New wireless standard: 57-66 GHz millimeter wave band
  - Pros: upto 7 Gbps
  - Cons: coverage limited to a single room
- Solution: RoF

NG Applications and Home Networking

Title	Authors	Proposal/Contribution	Result
Next Generation Applications and Services for Ultra-fast Broadband	G. Ricart US Ignite, Utah	US Ignite is catalyzing the development of 60 next-generation applications that take advantage of advanced network services such as ultra-fast broadband. This paper discusses relevant advanced network services and gives examples of new applications they make feasible.	

OTh4B: Node Architecture

Node Architecture

Title	Authors	Proposal/Contribution	Result
Dynamic Wavelength Assignment and Burst Contention Mitigation for the LOBS-over-WSON Multilayer Networks with an OpenFlow based Control Plane	D. Zhang, H. Guo, L. Liu, T. Tsuritani, J. Wu, I. Morita BUPT, China KDDI, Japan	By utilizing the OpenFlow-based unified control plane, the dynamic wavelength assignment and a novel burst contention mitigation approach which features an Enforced Waiting Control (EWC) scheme have been proposed.	