Why Data Center Requires Both, OPS and OCS !

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The future of optical networking
and communications is here.

Technical Conference: 22-26 March 2015

Exposition: 24-26 March 2015

Los Angeles Convention Center,
Los Angeles, California, USA

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Plenary Session (/en-us/home/program-

Monday, March 23, 2015
9:00 AM - 12:00 PM

Event type: Workshop

Room number: 408B

Organizer:
Rich Baca; *CommScope, Inc., USA*; Nicola Calabretta; *Technische Universiteit Eindhoven, Netherlands*; Mark Feuer; *CUNY College of Staten Island, USA*; Adel Saleh; *University of California Santa Barbara, USA*

Acknowledgements

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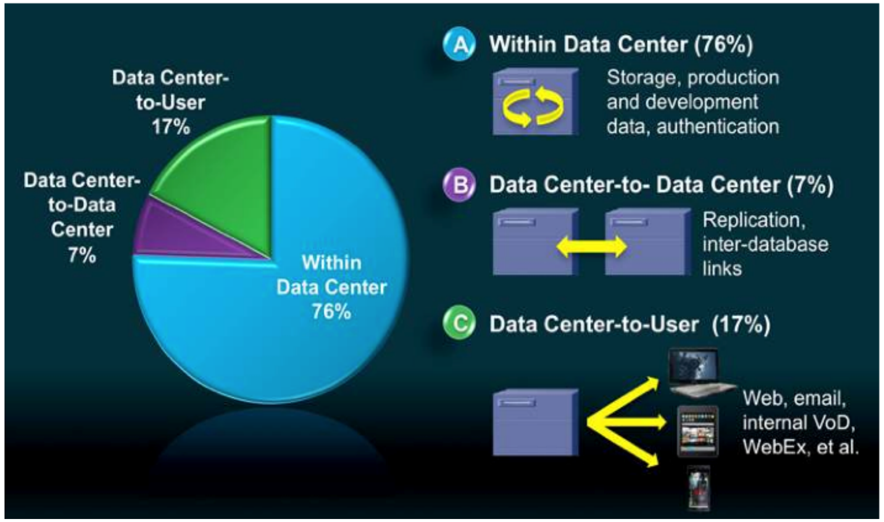
NICT

- I'd like to thank my collaborators of ;
  - NTT Laboratories
  - NEC Corporation
  - Kyushu University
  - Osaka University

ECOC2014, Tu.1.6.1

Data center traffic

- Data center (DC) traffic has surpassed ZettaByte (10^{21})
- 31% Compound annual growth rate during 2012~2017, quadruple to 7.7ZB in 2017
- Traffic within DC accounts for **76%** of data center traffic



Source: Cisco Global Cloud Index: Forecast and Methodology, 2011–2017

Outline

- OPS hardware has become in reality
- Energy-efficient NW topology: Fat-tree vs. torus
- Virtual-OCS(VOCS) in OPS network

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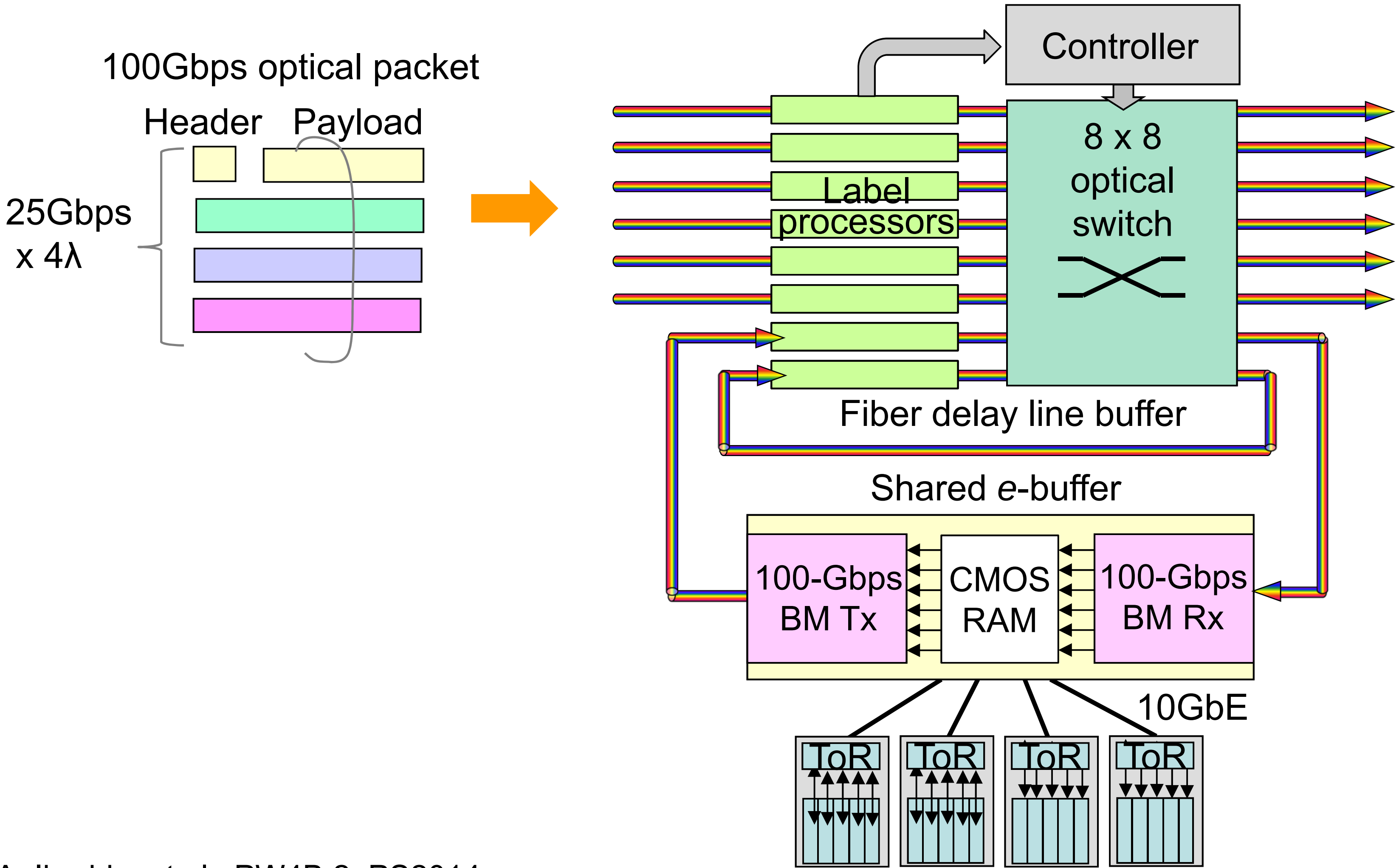
Target specification of HOPR

HOPR prototype developed in 2009

	Prototype in 2009	Under development
Data rate	10 Gbps	100 Gbps
Switching	4 x 4 (x 2λ)	8 x 8(x 4λ)
Throughput	160 Gbps	1,280 Gbps
Latency	380 ns	100 ns
Power consumption	360 W (2.25 W/Gbps)	120 W (90 mW/Gbps)
Size	0.6 m^3	0.06 m^3

Note: [W/Gbps]=[nJ/bit]

Hybrid optoelectronic packet router (HOPR)



S. A. Ibrahim et al., PW4B.2, PS2014.

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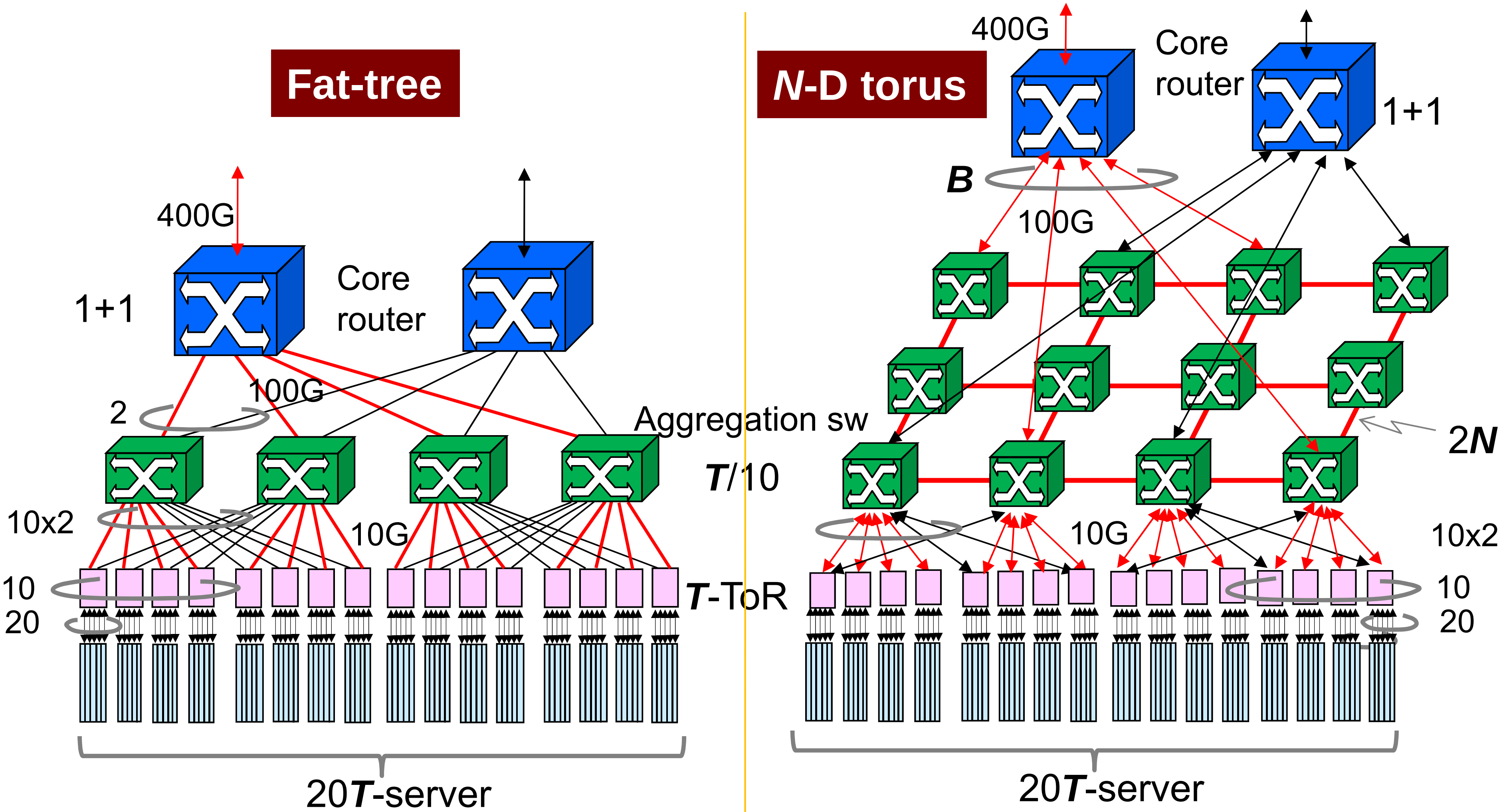
Network topology: *N*-D torus vs. fat-tree



Throughput
(100Gbpsx*T*/10+400G)x2
∨
(10Gbpsx10x2+100Gbpsx2)x2=800Gbps

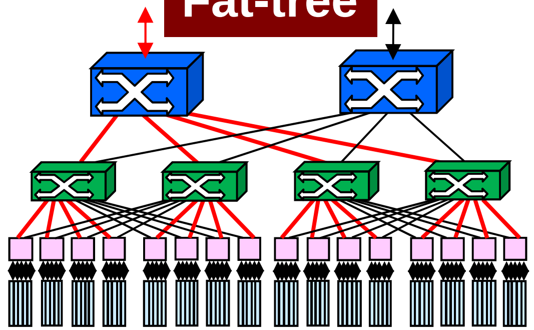
Throughput
(100GbpsxB+400G)x2
∨
(10Gbpsx10x2+100Gbpsx2*N*)x2

Network topology: *N*-D torus vs. fat-tree

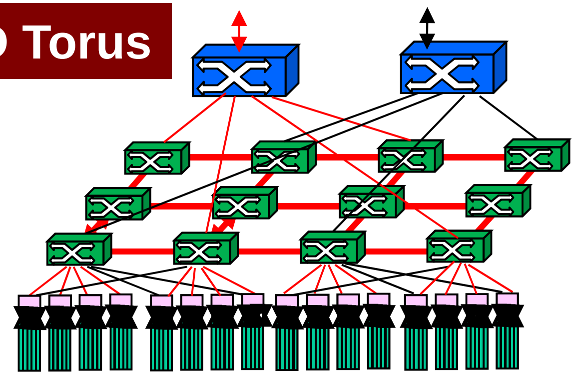
Assumptions

T=20,000
(400k-servers)
N=6
B=20
CFP=20W@100Gbps
SFP=1.5W@10Gbps

Fat-tree



6-D Torus



		Fat-tree	6-D Torus
EPS	2.4 W/Gbps	**400.8 Tbps** **1,002 kW**	**4.8 Tbps** **12 kW**
	0.5 W/Gbps	**0.8 Tbps** **470 W**	**2.8 Tbps** **1,670 W**
	Total	**1,942 kW**	**3,352 kW**
OPS	0.3 W/Gbps	~~400.8 Tbps~~ 120 kW	**4.8 Tbps** **1.5 kW**
	0.1 W/Gbps	0.8 Tbps 90 W	**2.8 Tbps** **310 W**
	Total	**300 kW**	**621.5 kW**

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Unified famework of OPS and OCS

Across the data centers, 80% of the flows are small (<10KB) in size. However, most of the bytes are in the top 10% of large flows.

T. Benson et al.,. "Network traffic characteristics of data centers in the wild." in Proc. IMC, 2010.

- Best effort service
- Relatively small data

Optical packet switching

+

- QoS required
- Large/stream data

Optical circuit switching

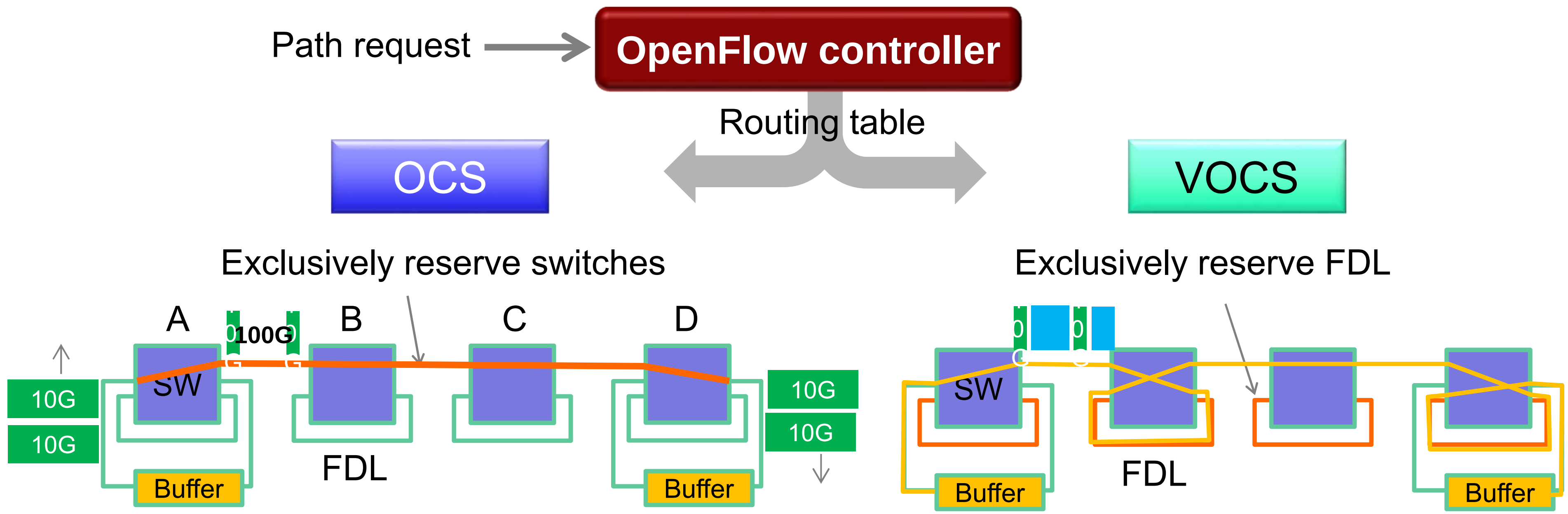
Forwarding on packet-by-packet basis
- High resource utilization due to statistical multiplexing
- Packet dropping due to contention

A flow (group of packets within a time duration) is transferred on a **dedicated optical path**
- No packet loss, arrival in a correct order
- Setting an optical path causes some delay

A unified framework of OPS-based network with flow management* w/o additional hardware

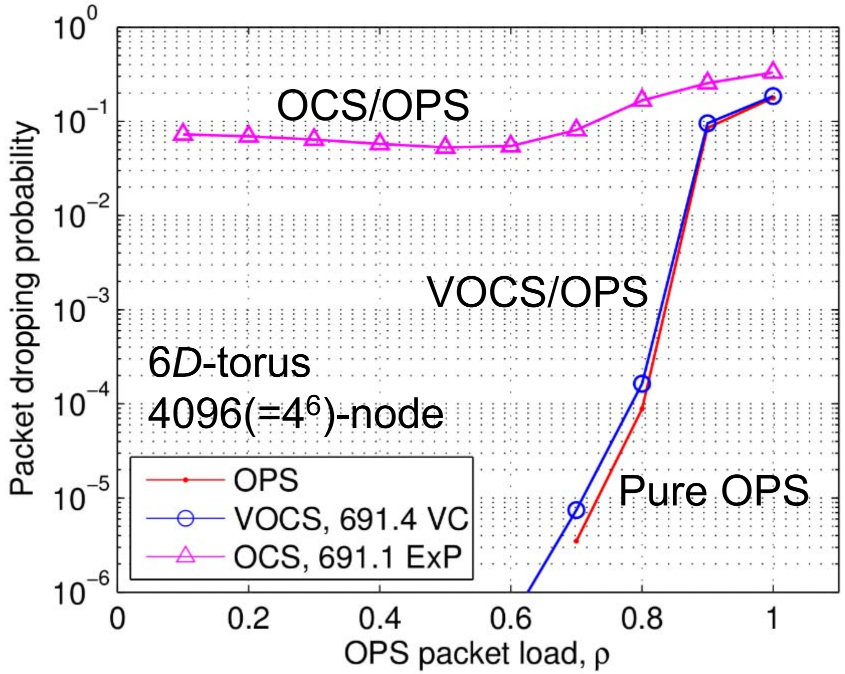
* L.Roberts, *IEEE Spectrum*, pp.34-39, July 2009.

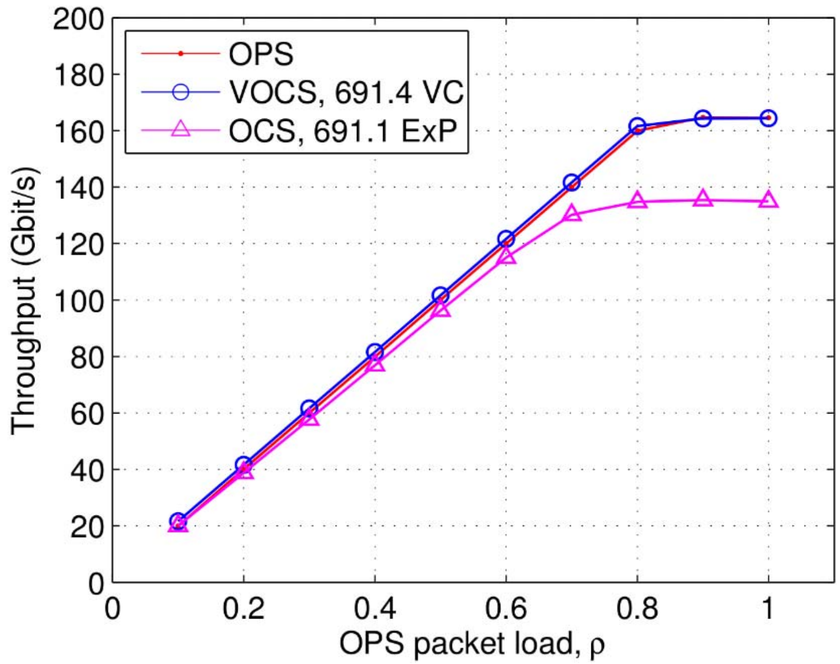
OCS vs. virtual OCS (VOCS)



Arrival timing	VOCS	OPS
VOCS	Forward	——
OPS	——	Forward
VOCS / OPS	Forward	Contetion resol.
VOCS / OPS	FDL	Forward

OPS with VOCS and OCS





- **Observations:**
  - PDP of OCS/OPS is much worse than pure OPS even in a light OPS load, because OCS partly breaks the topology by reserving links.
  - VOCS/OPS performs as good as pure OPS, showing little adverse effect on OPS performance.

OFC2015, W3D.4
ONDM2015 (Pisa, Italy, May 11-14, 2015)

Key messages

- 100Gbps hybrid optoelectric router (HOPR) prototype targeting at **90[mW/Gbps]=90[pJ/bit]** will be realized in 2016.
- **Torus topology** is favored for energy-efficient OPS DC network.
- **Virtual OCS (VOCS) + OPS** is the best mixture, serving as a unified framework for DC network.

Thank you !

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For more details;
- ECOC2014, Tu.1.6.1
- OFC2015, W3D.4
- ONDM2015 (Pisa, Italy, May 11-14, 2015)