Routed Optical Networks

Technology Economics

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SP Architecture Cisco
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Routed Optical Networking

IP and Optical Convergence

Sustainable Architecture

Routed Optical Networking Pillars

Increasing optics speed at a cost-efficient price point and a small footprint: silicon photonics + CMOS wafer

5x power reduction

70% space reduction

Silicon chipsets that are industry-leading in performance with no compromise on features enabling 12-18m Innovation cycles

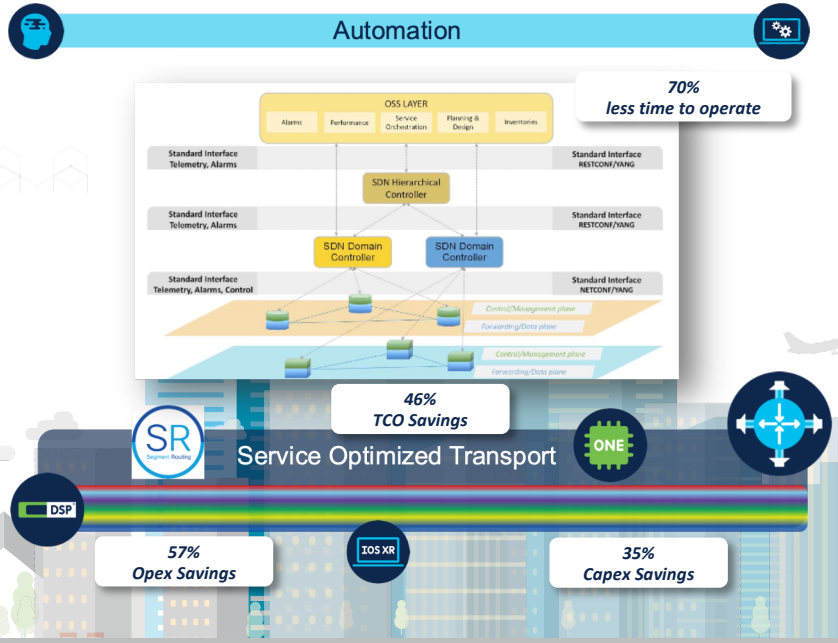
2x power reduction

3x space reduction

Evolution of NOS and cloud enhanced applications to enable new architectures

2x memory reduction

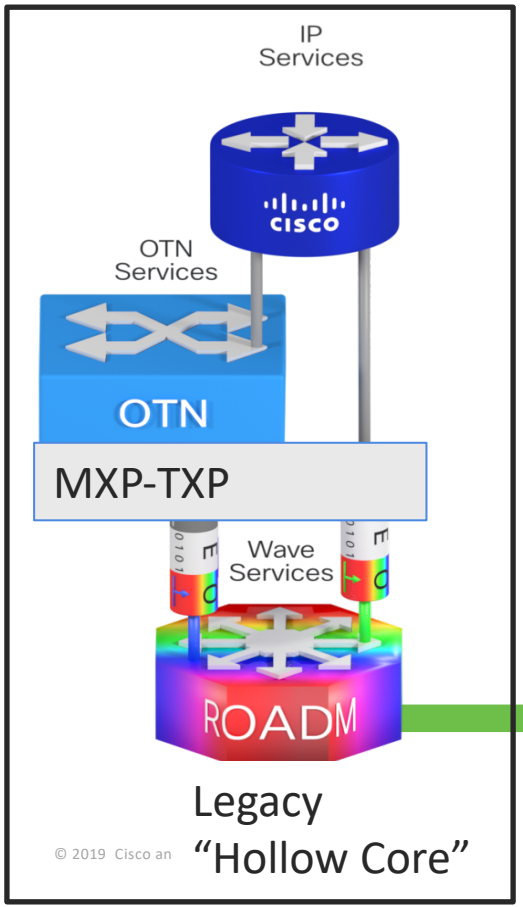
2x boot time reduction



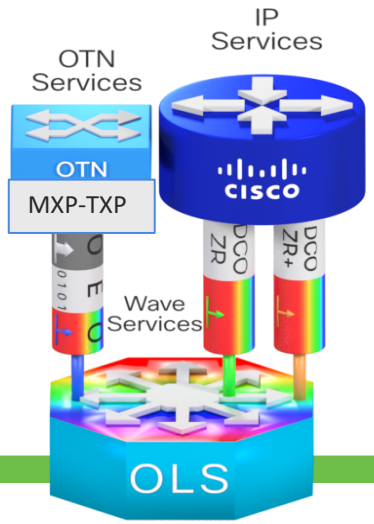
Routed Optical Networking Architecture

Customer Access Point	Access	Pre Aggregation	Aggregation	Core	Peering
	NCS 540	**NCS 560-57C3**	**NCS & ASR 9000**	**CISCO 8000**	**NCS**

Evolution Steps



Legacy
"Hollow Core"



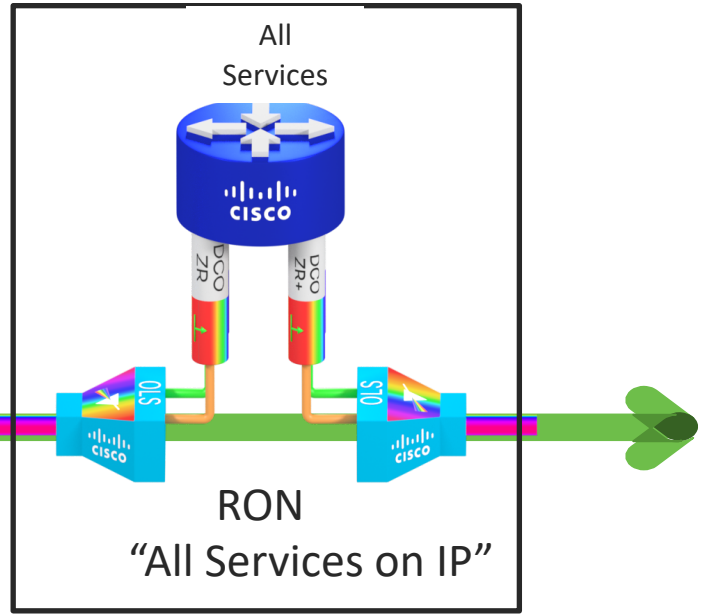
RON-OTN
"Side by Side"

Routed Optical Network = RON

Traffic follows fiber topology

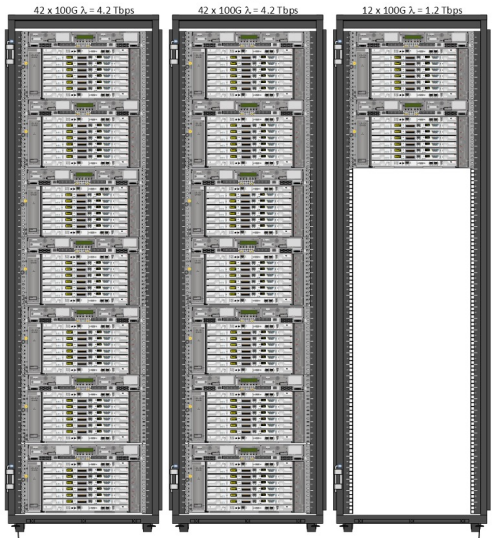
Challenges legacy layered approach on few concepts:

1) Source of colored traffic, @L3
2) Traffic switching, @L3
3) Single control plane, L3
4) Model driven automation and telemetry
5) OTN services are emulated (PLE)



RON
"All Services on IP"

Example –
BAU 96x100G TXP-MXP vs RON 64 x400G termination



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Watts	Amps at -48Vdc	Amps at -42Vdc	BTU/hr
22,179.00	462.06	528.07	75,674.75

+Router Power & Space

6 x 8201 Power Draw			
Typical Watts	Max Watts	BTU/Hr Typical	BTU/Hr Max
2,490.00	3,112.50	8,495.88	10,619.85

Routed Optical Networking Benefits

Up to ~57% OpEx savings, 46% total TCO savings

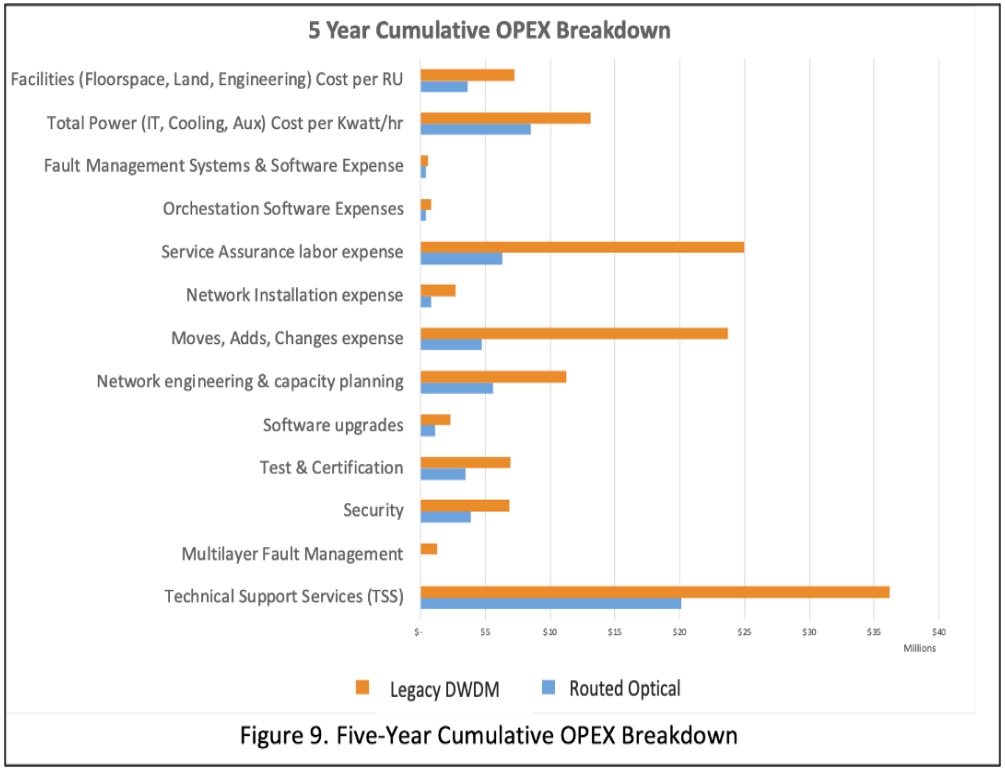


Figure 9. Five-Year Cumulative OPEX Breakdown

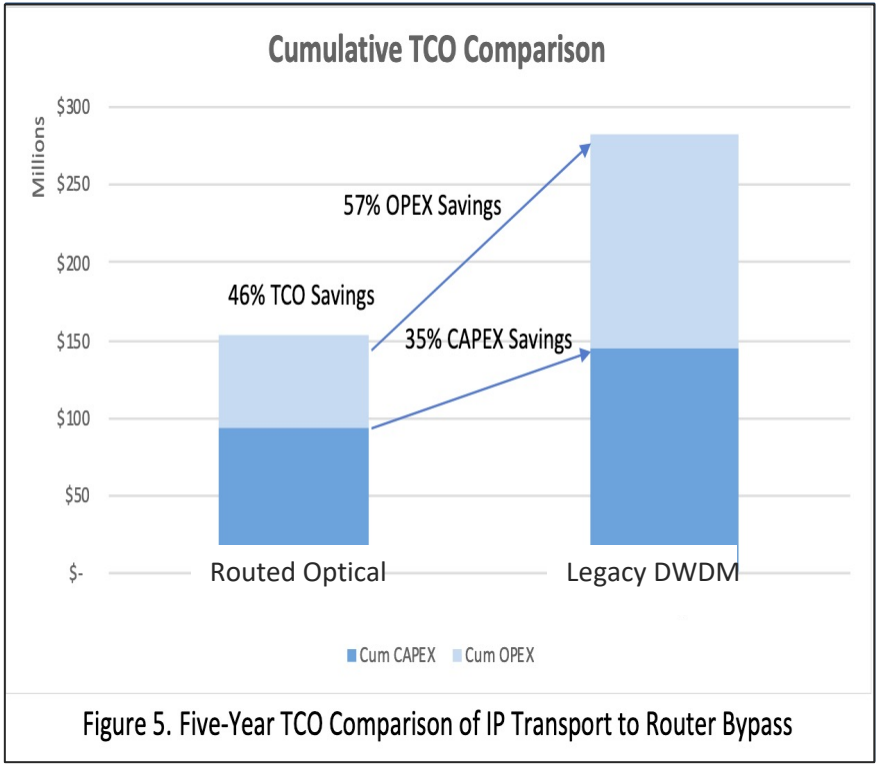
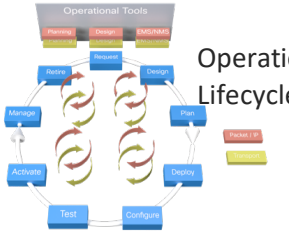


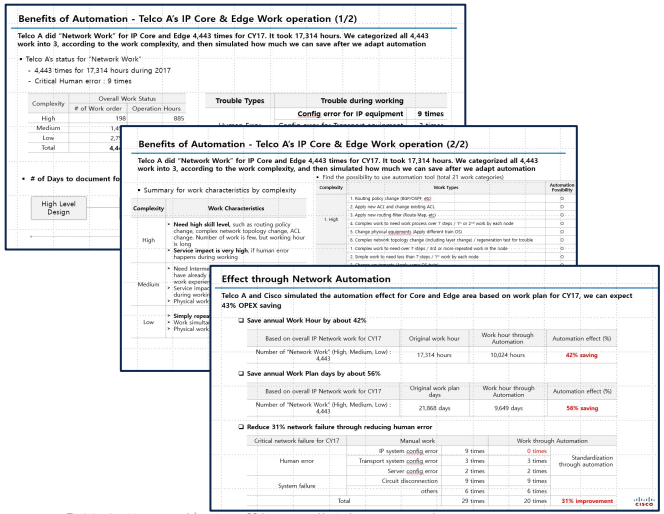
Figure 5. Five-Year TCO Comparison of IP Transport to Router Bypass

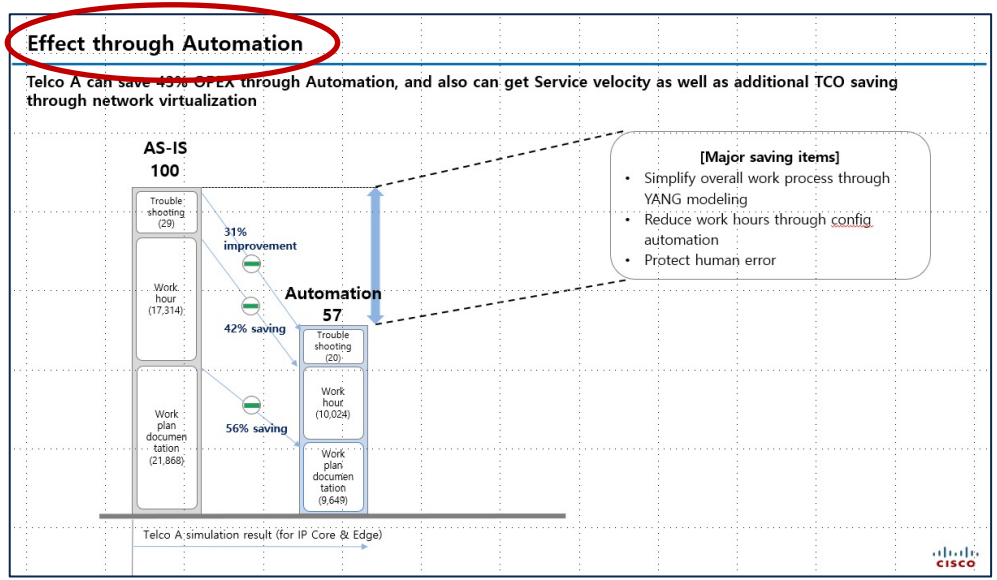
ACG Reference: https://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/routed-optical-networking/white-paper-sp-acg-400g-ip-transport.pdf

Operational Savings, Calculation



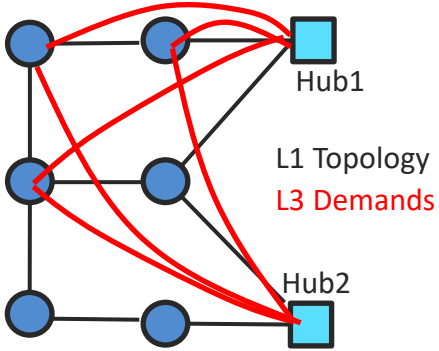
Operational Lifecycle





RON TCO Baseline

Analyzing a Simple Network …



Geographical Names, distance

Site	N1	Edge	5	10	-110	50
Site	N2	Edge	10	10	-70	52
Site	N3	Edge	10	5	-75	45
Site	N4	Edge	5	5	-100	40

L1/Fiber

Span	Link-1	N1	N2	450	
Span	Link-2	N2	N3	225	TW105/EL60/60
Span	Link-3	N3	N4	600	
Span	Link-4	N4	N1	300	

L3 demand & Traffic matrix BW

Demand	Dem-1-W	N1	N2	1200	Link-1	Working
Demand	Dem-1-P	N1	N2	1200	Link-4, Link-3, Link-2	Protect
Demand	Dem-2	N1	N4	817	Link-4	Working
Demand	Dem-3	N3	N4	1420	Link-3	Working
DefaultLoad	4637					

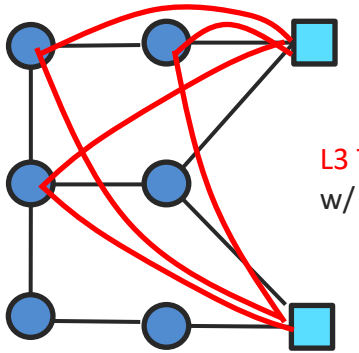
The ASK:

- Compare Legacy DWDM vs RON
- Cost, Power, Rack space
- Sensitivity analysis

The Input:

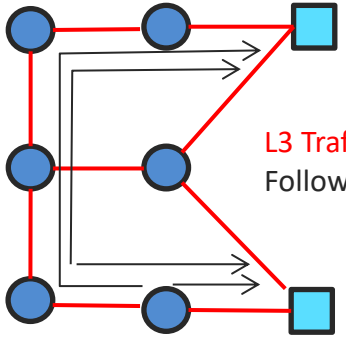
- 6 spokes dual-homed to 2 Hubs
- L1 Topology, spans ~100-200 Km
- 400Gbps DWDM design
- Most 20-60 Gbps per spoke, random

Legacy DWDM
"Hollow Core"



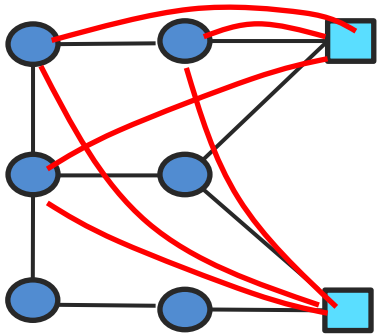
L3 Traffic
w/ optical bypass

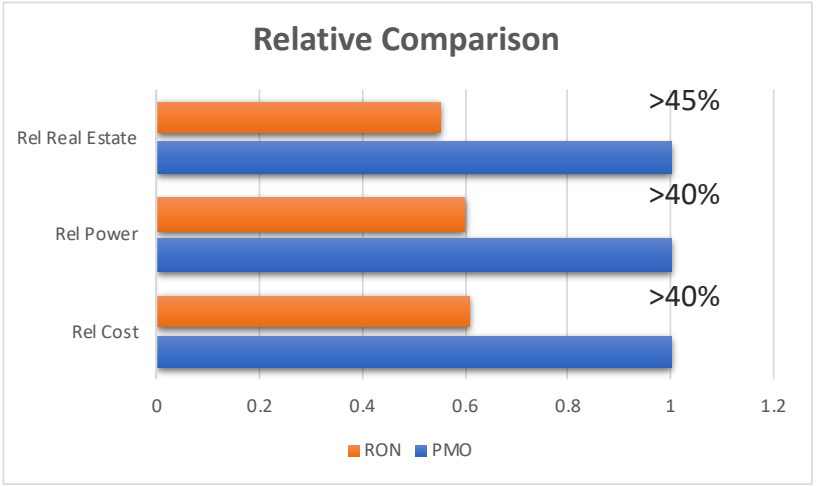
Routed Optical "RON"



L3 Traffic
Follows L1 topology

Simple Network Simulations
6 spokes + 2 Hubs



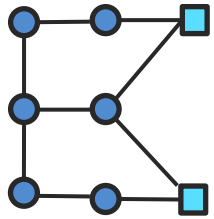


Goal - **Identify CapEx Savings Inflexion Points**:

- Changing number of nodes per ring
- Changing amount of traffic per node
- Changing traffic pattern H&S -> Mesh
- Changing the platform choice (82xx, NCS 5500, ASR9K)

When will the above results change ?

Simple Network Simulation
CAPEX Savings Analysis



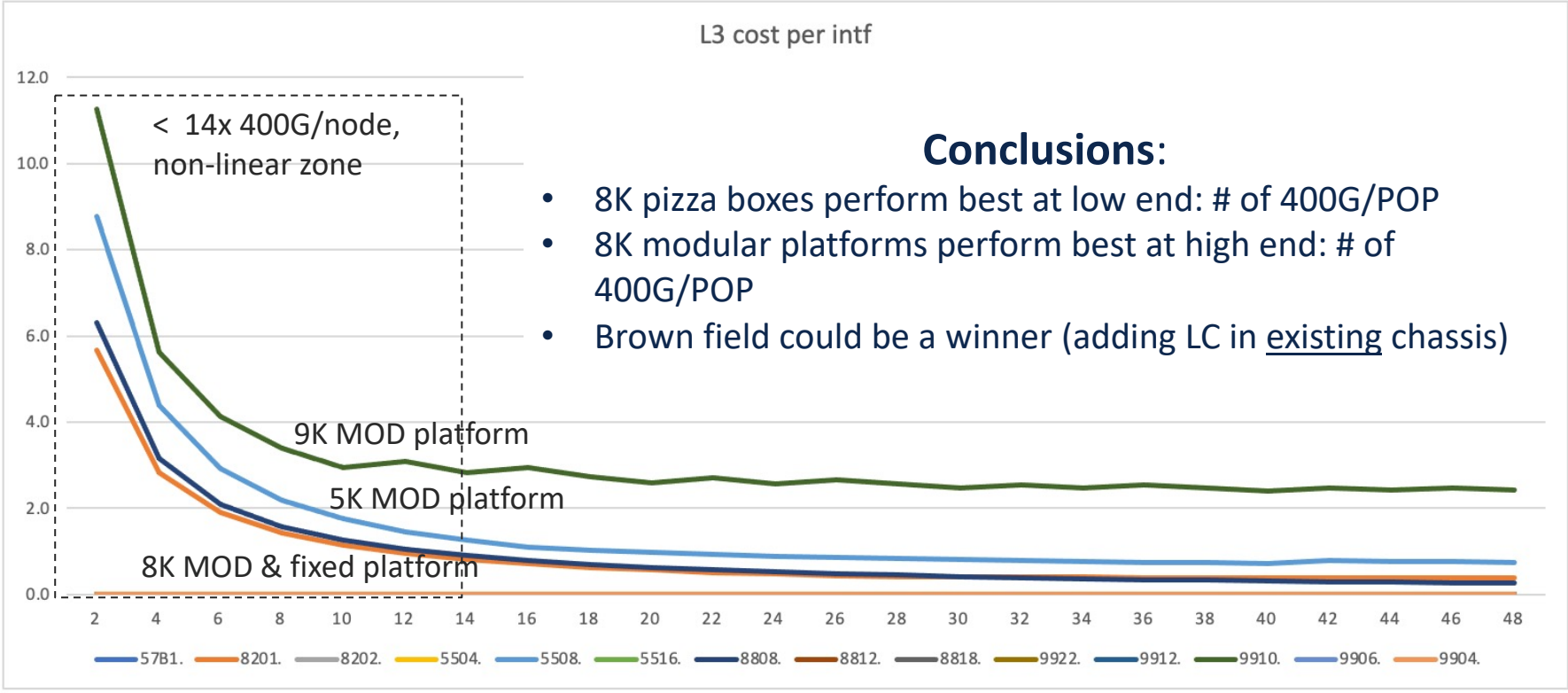
SENSITIVITY Analysis, RON Savings, in a ring of nodes with dual-homed traffic

Gbps/node	Nodes per RING												
22%	1	2	3	4	5	6	7	8	9	10	11	12	13
10	22%	22%	22%	22%	22%	22%	22%	22%	22%	22%	22%	22%	22%
20	22%	22%	22%	22%	22%	22%	22%	22%	22%	22%	22%	22%	18%
30	22%	22%	22%	22%	22%	22%	22%	22%	18%	18%	18%	18%	18%
40	22%	22%	22%	22%	22%	22%	18%	18%	18%	18%	18%	18%	-16%
50	22%	22%	22%	22%	22%	18%	18%	18%	18%	18%	-16%	-16%	-16%
60	51%	51%	51%	51%	48%	48%	48%	48%	27%	27%	27%	27%	7%
70	51%	51%	51%	48%	48%	48%	48%	27%	27%	27%	7%	7%	7%
80	51%	51%	51%	48%	48%	48%	27%	27%	27%	7%	7%	7%	-14%
90	51%	51%	48%	48%	48%	27%	27%	27%	7%	7%	7%	-14%	-14%
100	51%	51%	48%	48%	48%	27%	27%	7%	7%	7%	-14%	-14%	-35%
110	64%	64%	62%	62%	47%	47%	32%	32%	32%	17%	17%	2%	2%
120	64%	64%	62%	62%	47%	47%	32%	32%	17%	17%	2%	2%	-13%
130	64%	62%	62%	47%	47%	32%	32%	17%	17%	2%	2%	-13%	-13%
140	64%	62%	62%	47%	47%	32%	32%	17%	17%	2%	-13%	-13%	-32%
150	64%	62%	62%	47%	47%	32%	17%	17%	2%	2%	-13%	-32%	-32%
160	72%	70%	70%	58%	46%	46%	35%	35%	23%	11%	11%	-4%	-25%
170	72%	70%	70%	58%	46%	46%	35%	23%	23%	11%	-4%	-4%	-25%
180	72%	70%	58%	58%	46%	35%	35%	23%	11%	-4%	-4%	-25%	-49%
190	72%	70%	58%	58%	46%	35%	23%	23%	11%	-4%	-25%	-25%	-49%
200	72%	70%	58%	46%	46%	35%	23%	11%	-4%	-4%	-25%	-49%	-74%
210	78%	77%	67%	58%	48%	48%	39%	30%	18%	1%	-17%	-17%	-37%
220	78%	77%	67%	58%	48%	39%	30%	30%	18%	1%	-17%	-37%	-59%
230	78%	77%	67%	58%	48%	39%	30%	18%	1%	1%	-17%	-37%	-59%
240	78%	77%	67%	58%	48%	39%	30%	18%	1%	-17%	-37%	-59%	-82%
250	78%	77%	67%	58%	48%	39%	30%	18%	1%	-17%	-37%	-59%	-82%
260	80%	72%	64%	56%	48%	40%	30%	15%	0%	-17%	-36%	-55%	-77%
270	80%	72%	64%	56%	48%	40%	30%	15%	0%	-17%	-36%	-55%	-77%
280	80%	72%	64%	56%	48%	40%	30%	15%	0%	-17%	-55%	-77%	-99%
290	80%	72%	64%	56%	48%	40%	30%	0%	-17%	-36%	-55%	-77%	-99%
300	80%	72%	64%	56%	48%	30%	15%	0%	-17%	-36%	-55%	-99%	-123%
310	82%	75%	68%	61%	47%	39%	26%	12%	-3%	-36%	-54%	-74%	-95%
320	82%	75%	68%	61%	47%	39%	26%	12%	-19%	-36%	-54%	-74%	-117%
330	82%	75%	68%	54%	47%	39%	12%	-3%	-19%	-36%	-74%	-95%	-117%
340	82%	75%	68%	54%	47%	39%	12%	-3%	-19%	-54%	-74%	-95%	-140%
350	82%	75%	61%	54%	47%	26%	12%	-3%	-36%	-54%	-95%	-117%	-140%
360	84%	78%	66%	59%	46%	34%	22%	-5%	-21%	-55%	-73%	-93%	-135%
370	84%	78%	66%	59%	46%	34%	9%	-5%	-21%	-55%	-73%	-113%	-135%
380	84%	78%	66%	59%	46%	34%	9%	-5%	-37%	-55%	-93%	-113%	-157%
390	84%	72%	66%	53%	46%	22%	9%	-21%	-37%	-73%	-93%	-135%	-157%

Capex savings influenced by:

- Traffic - bandwidth & patterns
- Network topology
- Network modelling constraints
- Choice of equipment

Capex Savings
Impact of L3 Platform Choice for 400G Transport …



Conclusions:

- 8K pizza boxes perform best at low end: # of 400G/POP
- 8K modular platforms perform best at high end: # of 400G/POP
- Brown field could be a winner (adding LC in existing chassis)

RON Economics

Real Simulations

RON Economics - Evaluation Methodology

Customer Input
. Traffic matrix
. Topology info
. Growth projection

1

2

Network Modeling
Input = "1"
Processing:
. Routing
. Optical Feasibility
Results:
. # of interfaces per node
. Json or csv output format

3

Post Processing=
BOM + Comparisons
. Traffic growth, projection
. Equipment selection

Network Operator Input

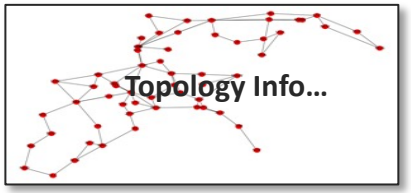
Geographical Names, distance

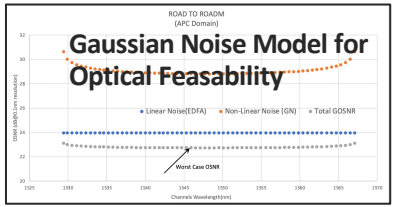
L1/Fiber

L3 demand & Traffic matrix BW

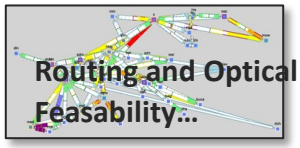
Site	N1	Edge	5	10	-110	50
Site	N2	Edge	10	10	-70	52
Site	N3	Edge	10	5	-75	45
Site	N4	Edge	5	5	-100	40
Span	Link-1	N1	N2	1200		
Span	Link-2	N2	N3	1200		
Span	Link-3	N3	N4	600		
Span	Link-4	N4	N1	300		
Demand	Dem-1-W	N1	N2	1200	Link-1	Working
Demand	Dem-1-P	N1	N2	1200	Link-4, Link-3, Link-2	Protect
Demand	Dem-2	N1	N4	817	Link-4	Working
Demand	Dem-3	N3	N4	1420	Link-3	Working
DefaultLoad	4637					

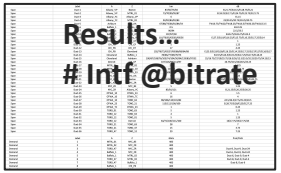
Traffic matrix…

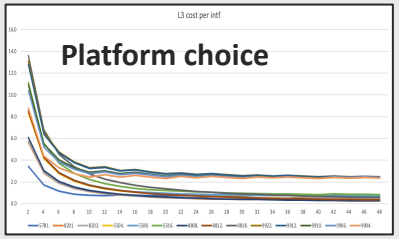


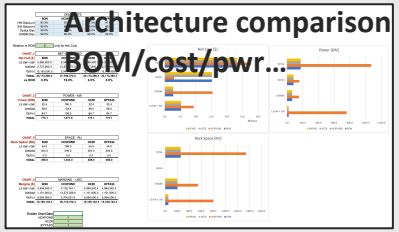


Processing Engine Results









Capex Results and Analysis

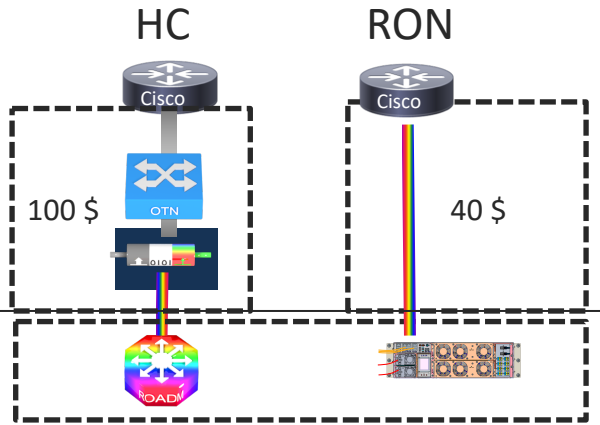
RON Economics vs. Legacy Networks

Legacy DWDM (Hollow core)

- L3 HW (8202, fixed cfg 2RU)
  100G grey pluggables
- TXP HW (NCS1004 + TXP board)
- ROADM (NCS 2K)
  +Optical amplifiers, if needed
- SW + services (3Y)

RON (Hop by Hop)

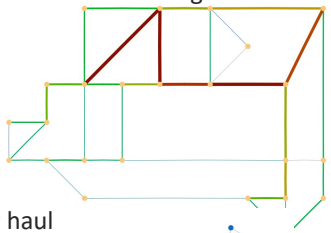
- L3 HW (8201, fixed cfg 1RU)
  400G optics DCO ZR/ZR+
- ~~(no TXP)~~
- OLS or ROADM (legacy or NCS1010)
  +Optical amplifiers, if needed
- SW + services (3Y)



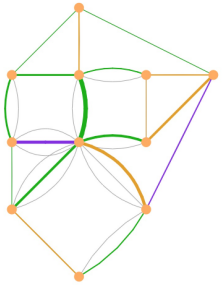
Modelling the Networks

Low Capacity Metro / Access

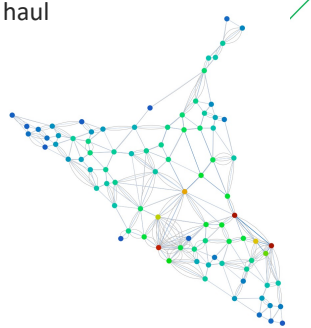
North American Regional



European Long haul



Asian Long haul



Network Models - Low & High Capacity

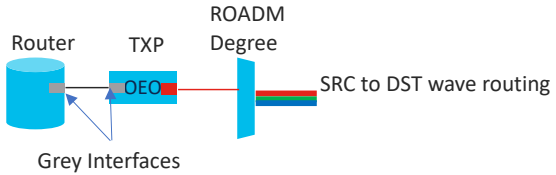
- Access
- Metro
- Long haul

Across Geographies

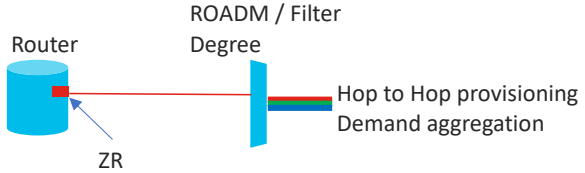
Modelling encompasses

- Hollow Core (HC), Optimal Bypass (OB) and Routed Optical Network (RON)
- Relative comparison of above networks around Cost, Power and Real estate

HC / OB



Routed Optical Network



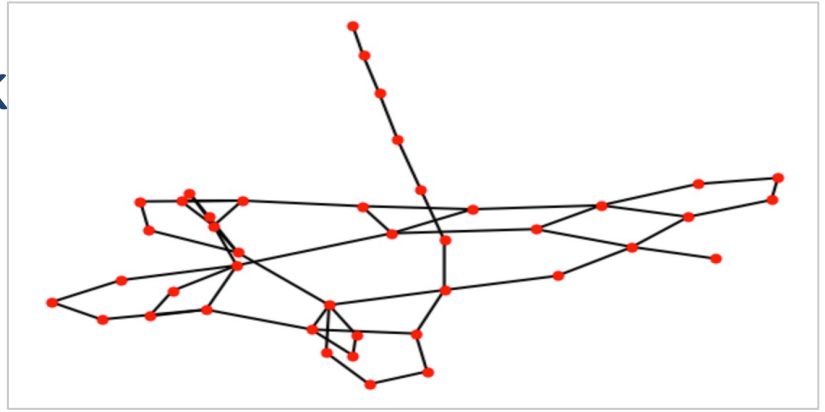
A National EU Regional Network

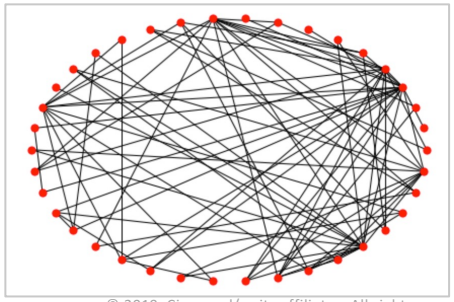
National DWDM Network

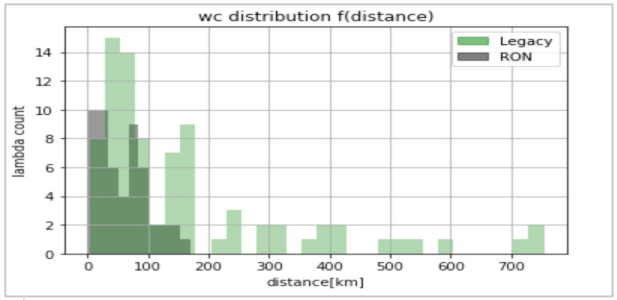
- 40+ Sites
- ~4,000 km of fiber

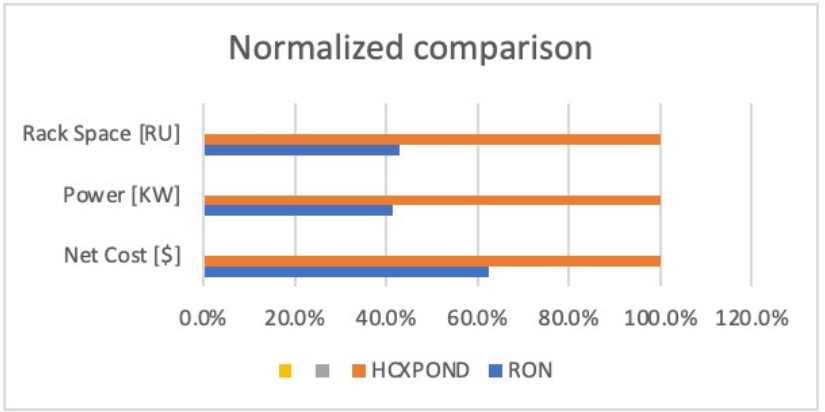
Approximately 40% Cost savings

- Compared Hollow Core to Routed Optical Network
- Assumed Greenfield network



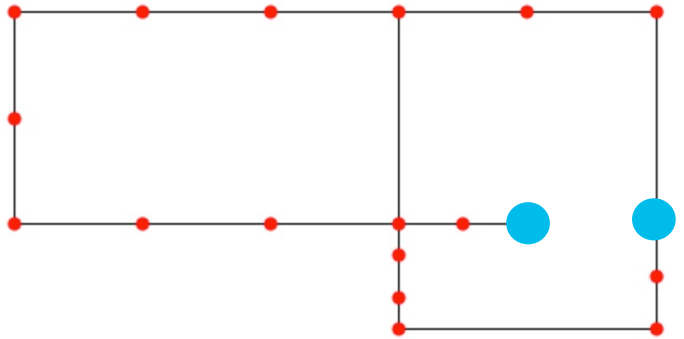






Routed Optical Network: ~ 40% Cost, 60% Power and 60% Real estate, savings over HC

National EU Metro Network

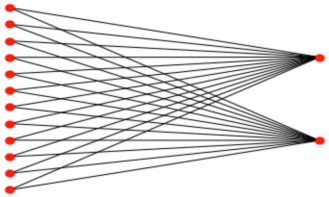


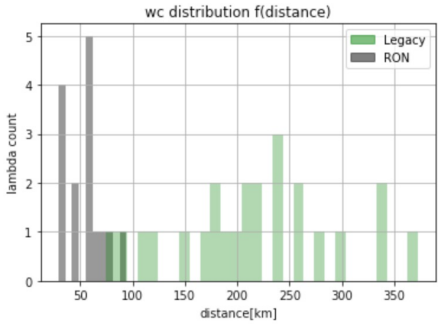
National DWDM Network

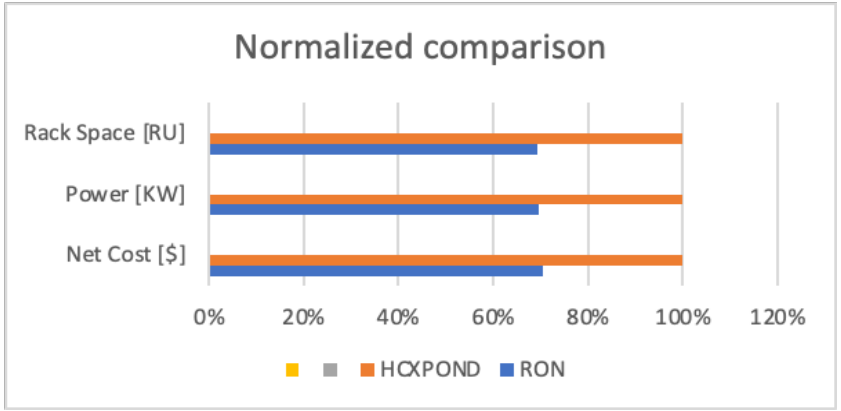
- 15 Sites
- ~1,200 km of fiber
- 2-Homed traffic, 30-120 Gbps/spoke

Approximately 35% Cost savings

- Compared Hollow Core to Routed Optical Network







Routed Optical Network: ~ 30% Cost, 35% Power and 35% Real estate savings over HC

National Metro Network – EU

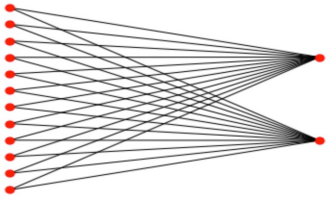
Finding the breaking point …

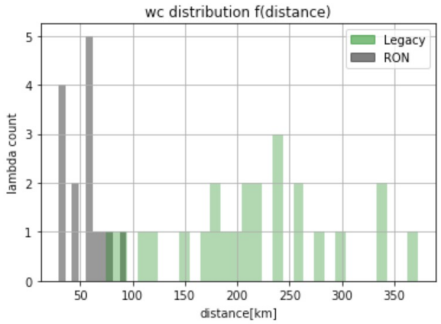
National DWDM Network

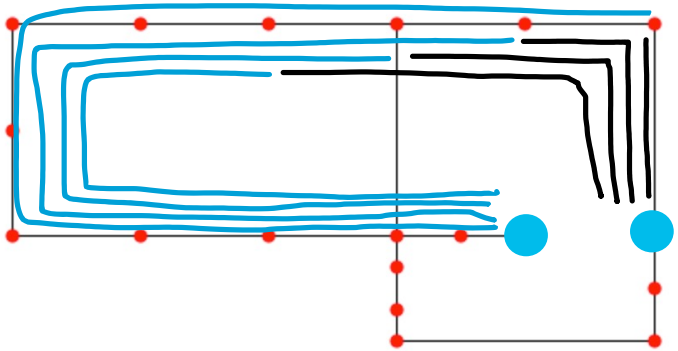
- 15 Sites, Scenario = **Traffic x 3** !!!!
- 2-Homed traffic, **no oversubscription**

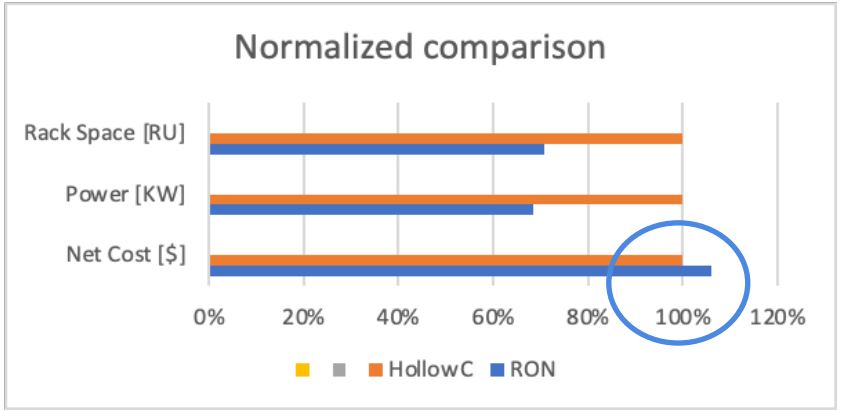
RON approximately 5% more expensive

High bandwidth/site => no advantage of grooming into 400G lambdas. **800G to the rescue …**









Routed Optical Network: ~ Capex, 40% Power and 45% Real estate savings over HC

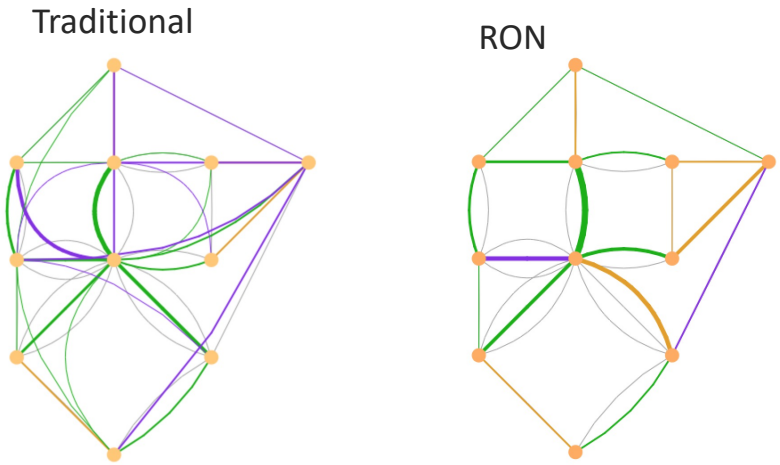
Long Haul Network, EU

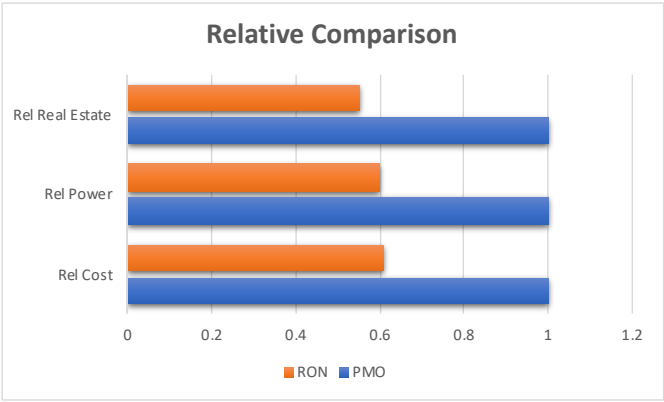
Sample European Long-Haul Network

- 11 Sites
- > 6,000 km of fiber

Approximately 40% Cost savings

- Compared Hollow Core to Routed Optical Network
- Assumed Greenfield network
- **Optical Bypass provided no significant advantage to RON**
- Routed Optical Network showed reduced TCO vs Traditional (HC) network





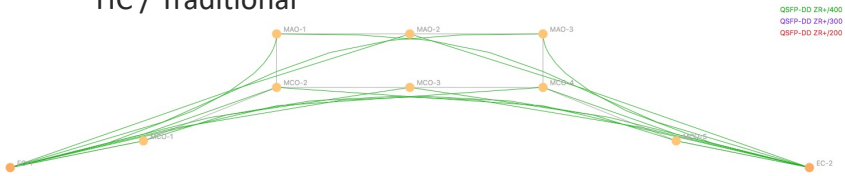
Routed Optical Network: ~ 40% Cost, 40% Power and 45% Real Estate Savings over HC

Low Bandwidth, Metro EU

Access / Metro Network

- Hollow Core(HC) – Typical Metro Mode of Operation leveraging OLS and Transponders
- Routed Optical Network – Moving to 400Gig QSFP-DD ZR+ Optics in a Hop2Hop architecture

HC / Traditional

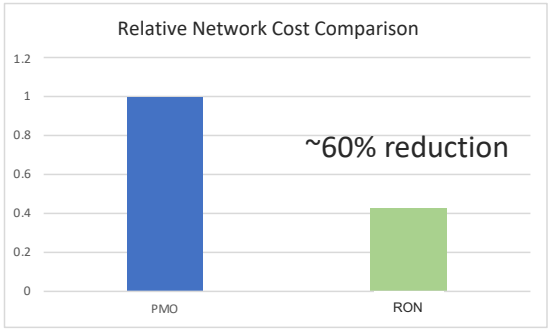


Routed Optical Network

Approximately ~60% cost savings

Where 40 X 10G DWDM was previously leveraged (PMO)

Routed Optical Network - single 400Gig integrated wavelength provides grooming advantage



Routed Optical Network = 60% Cost Savings

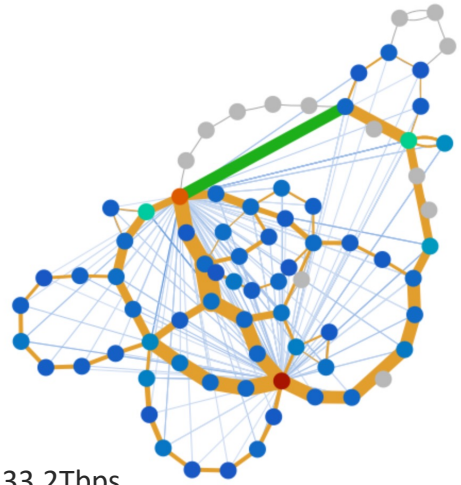
High Bandwidth Application - NA

North American Regional Network

- 70+ Sites
- > 4,000 km of fiber

Approximately 40% Cost savings

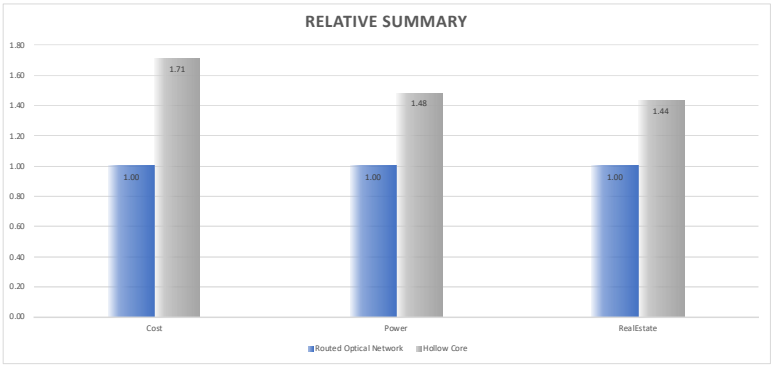
- Compared Hollow Core to Routed Optical Network
- Assumed Brownfield Network
- Routed Optical Network showed reduced TCO vs Traditional (HC) network
- Increases DWDM infrastructure longevity



Traffic Load = 33.2Tbps

Routed Optical Network requires >2X interfaces

Improves Infrastructure longevity – **max 15 λ / span vs 34**



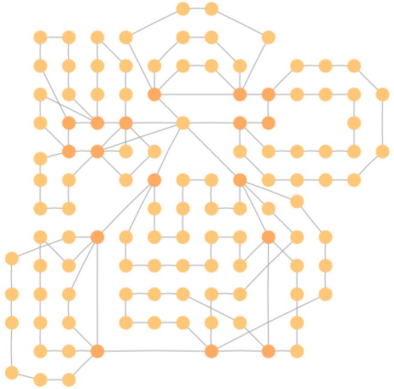
Routed Optical Network: > 40% Cost, >30% Power and >30% Real Estate Savings over HC

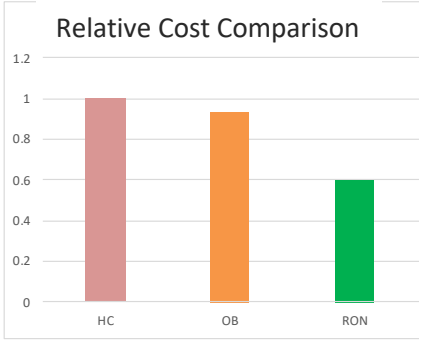
Metro – Regional – Long Haul, NA

Comparison of:

- Hollow Core (HC) – Reference Architecture
- Routed Optical Network

Routed Optical Network demonstrated ~40% savings





Routed Optical Network Enables ~40% CapEx Saving while providing Simplification

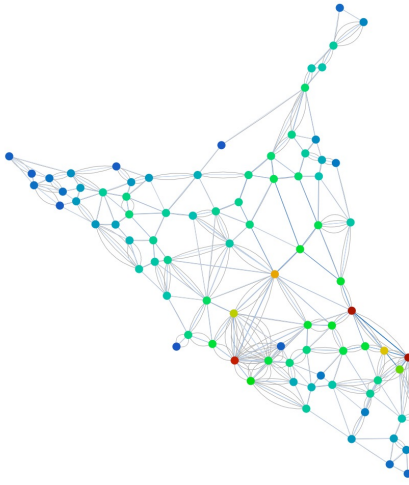
Long Haul Network - APAC

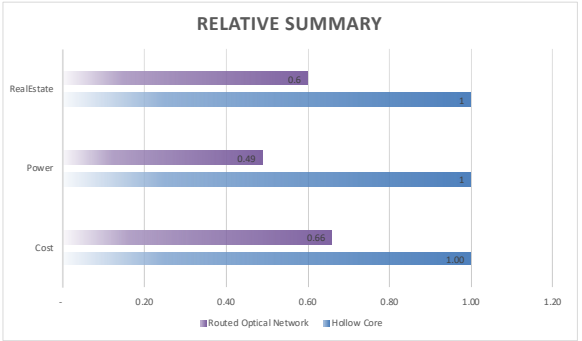
Sample Asian Long Haul Network

- 230 Sites
- ~80,000 km of fiber

Approximately 40% Cost savings

- Hollow Core vs Routed Optical Network
- **Optical vs L3 redundancy (1+1+R)**
- Assumed Greenfield network





Routed Optical Network: ~ 40% Cost, 40% Power and 45% Real Estate Savings over HC

Summary

Network transformation beyond just IP and Optical integration is coming. To be competitive it's important to educate and understand all aspects of the Routed Optical Network

- New generation of routers and NPUs optimized for **400G and beyond**
- New generation of compact pluggable modules with integrated DCO **allowing zero port density tradeoff**
- **De-layering** of networks through services convergence, including **private line emulation**
- Adoption of **simple topologies**, like hop-to-hop and point-to-point DWDM (simpler ROADMs)

Economics of networking must change with bigger focus on new architectures for operational simplicity and network optimization

Advantages

Fewer devices

Efficient network utilization

Traffic protection at single layer

Removes network complexity

SUSTAINABILITY less power & space

OPEX savings through automation

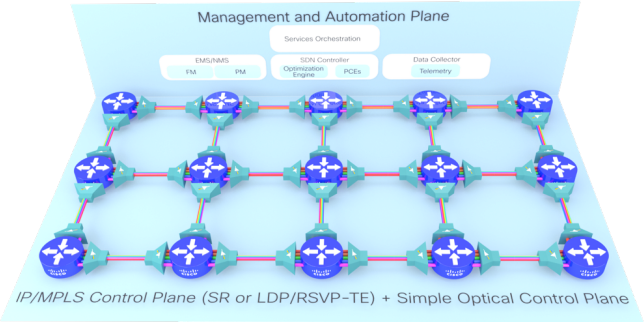
Reduced TCO


CISCO

Routed Optical Networks … in Simple Terms

Converged Architecture of P2P Routed Segments

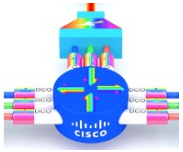
- *Integrates coherent optics in Routers*
- *Maximize transmission bit-rate per fiber segment –> 400Gbps*
- *Fiber Topology = Router Topology*
- *Simpler Network and Management Architecture*



A Set of Products to enable the Architecture

400G QSFP-DD-ZR/ZR+ Pluggables

400GE-capable Routers
New Silicon



Simpler /Open DWDM Line System

Advanced Automation and Control Plane

Cisco has industry-leading Products to support this open Architecture