Combining the benefits of multilayer optimization and packet-optical integration

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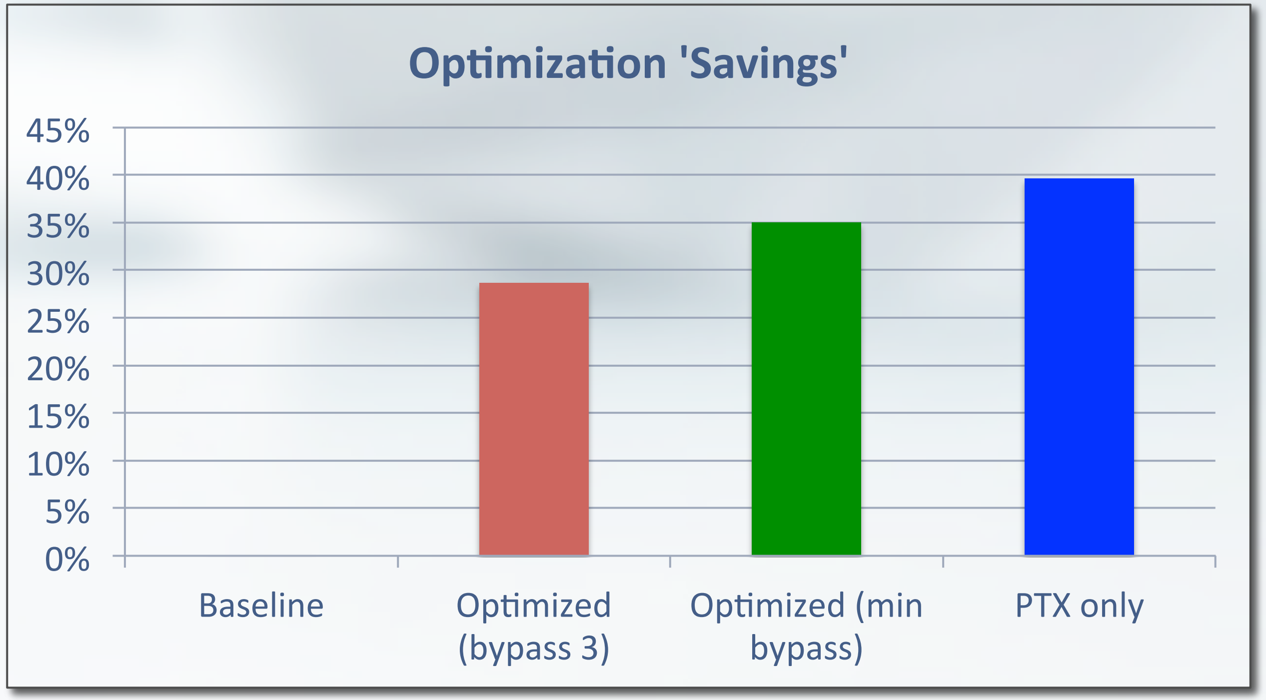
Introduction

- Multi-Layer Optimization combined with packet-Optical Integration can lead to significant network CAPEX & OPEX savings
- The following slides will discuss several network architectural options to help determine the best long term packet-optical strategy
- We will begin with a Baseline network & analyze several incremental optimizations



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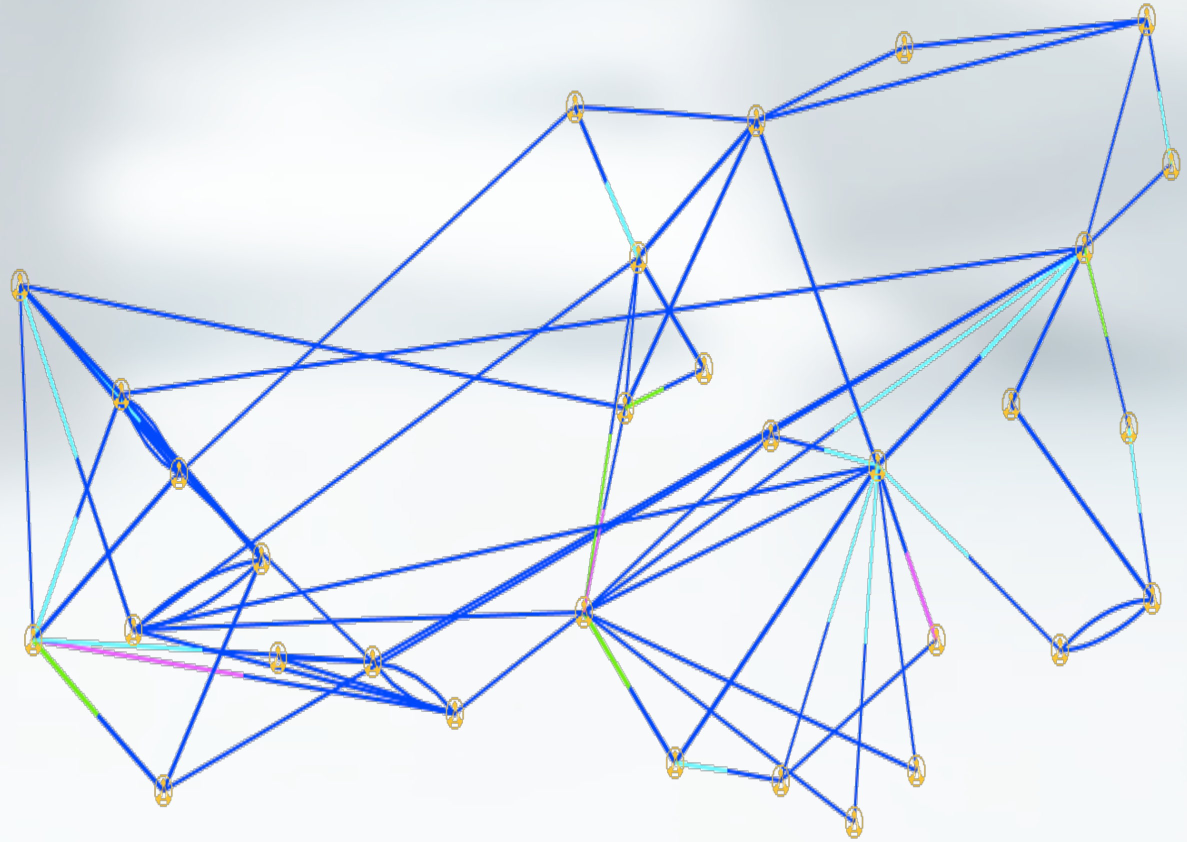
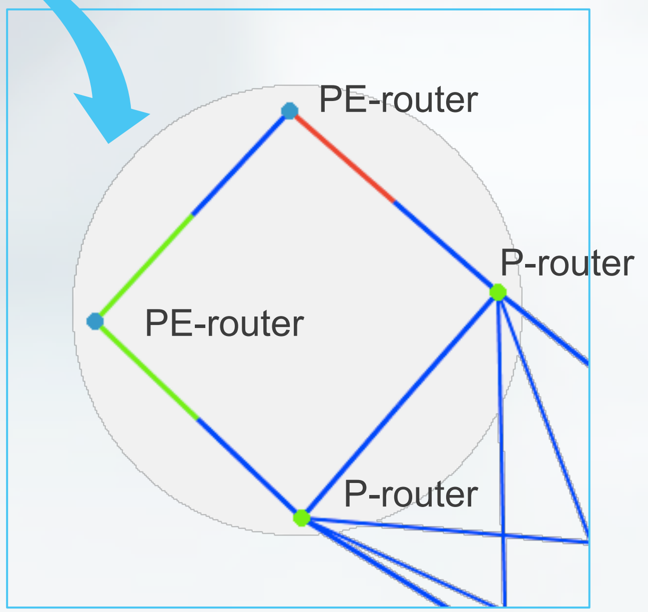
Methodology

- Create baseline using current network
  - Based on ‘fixing’ the links present in the current network (with a bit of cleaning up: aggregating parallel links, getting rid of remote ASs, etc. …)
  - In the IP layer, model intra-PoP connectivity as well as inter-PoP connectivity (total of 92 nodes, 32 PoPs)
  - Count the number of ports in each layer & apply generic costs





Internal PoP structure

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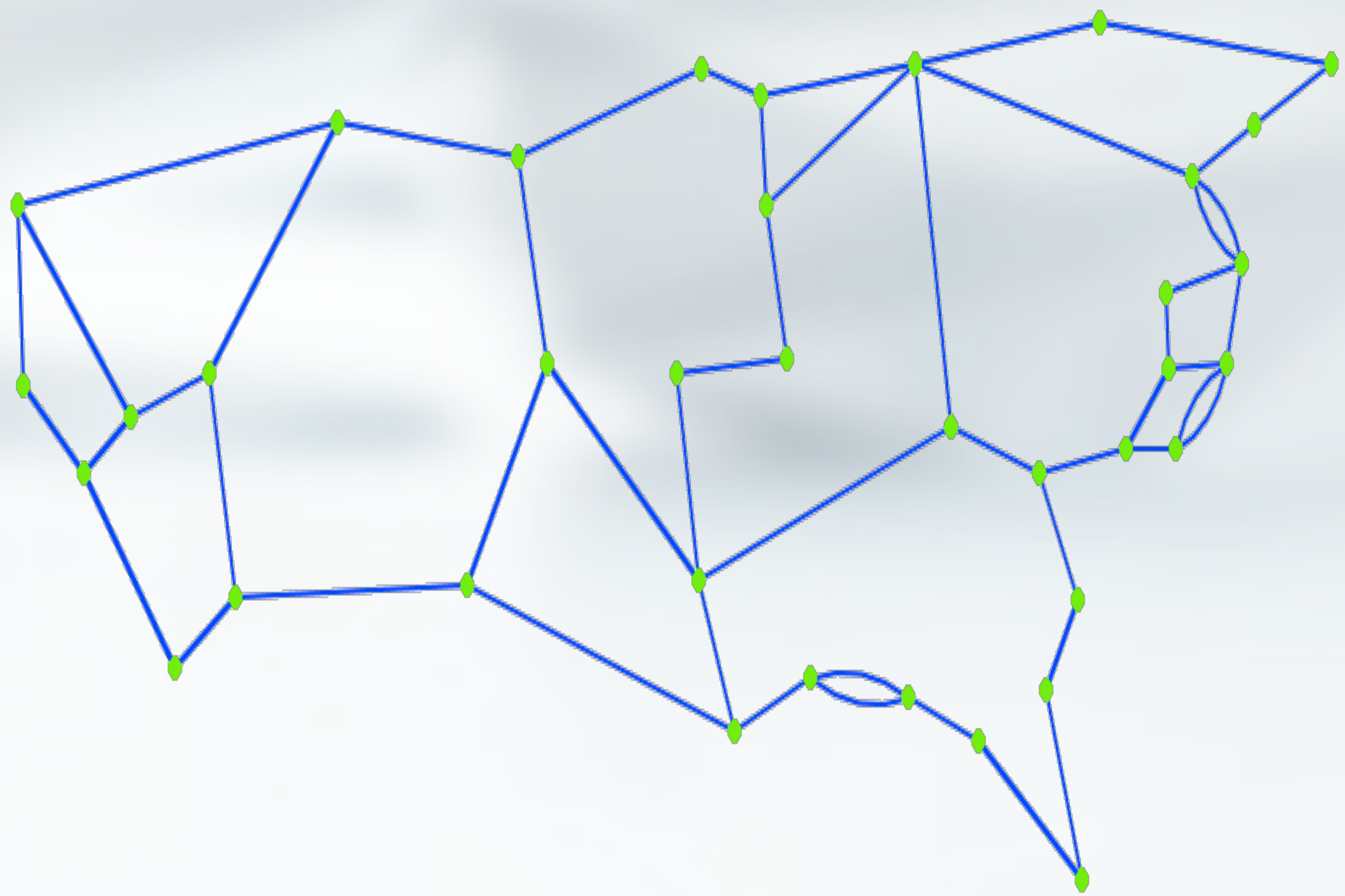
Transport network

- ROADM network, 100G wavelengths
  - Point-to-point DWDM map (41 nodes, 60 links)



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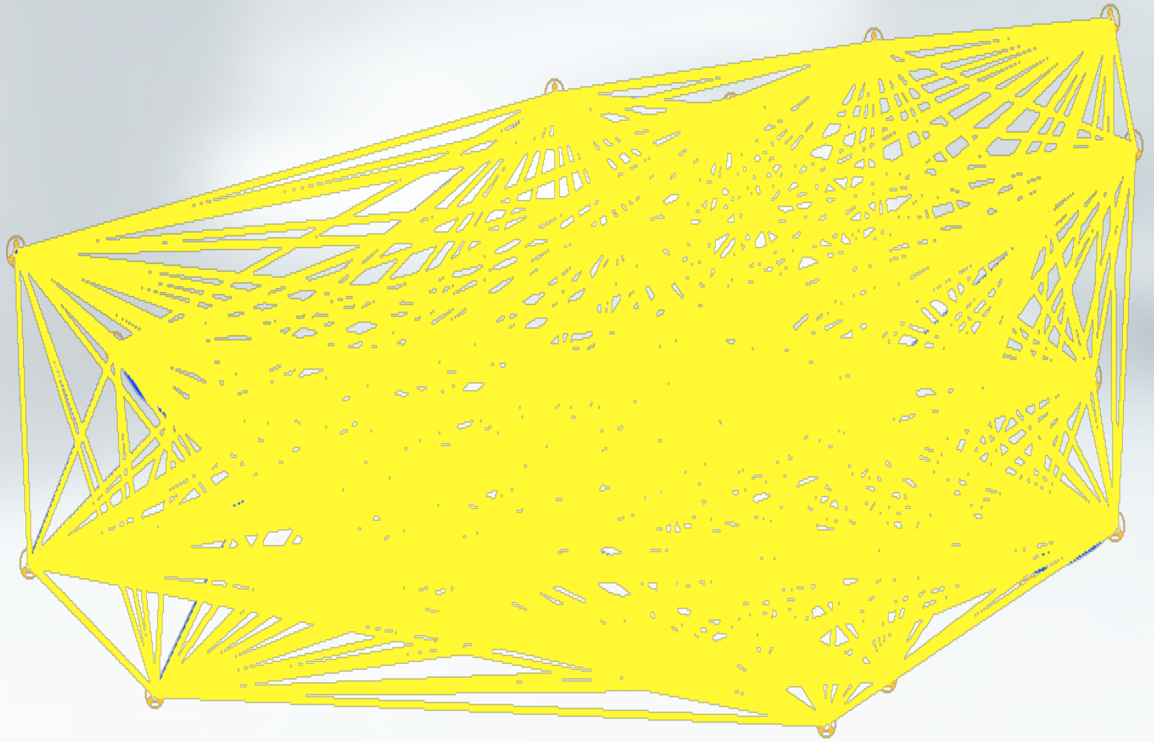
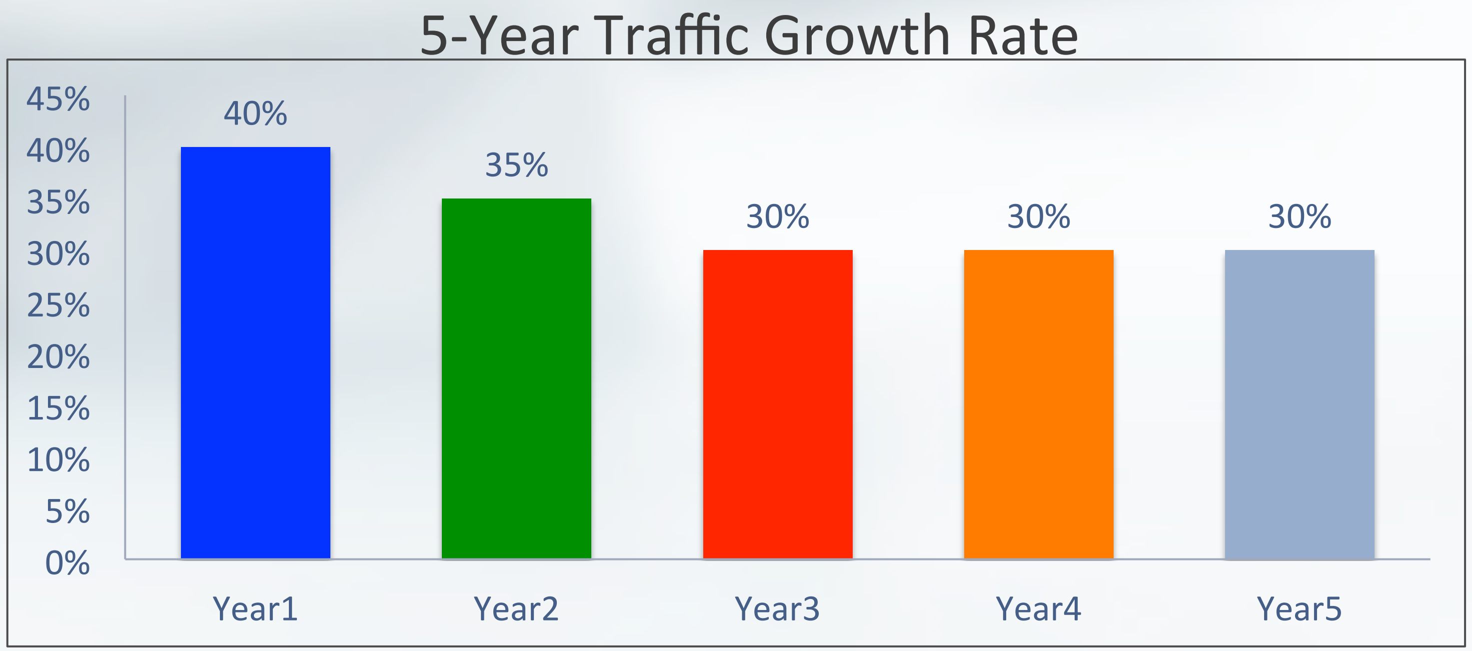
Traffic matrix

- The network provides reliable traffic data
  - Full mesh of auto-bandwidth RSVP-TE LSPs
  - Year1 traffic: 2.703T





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Cost model

- Generic costs

  We want to look at what aspects of cost can be used to influence the model without having specific vendor discounting interfering

  Counting ports, when considering multiple dimensions, does not always reflect the best/lowest cost design

- Other computation constraints

  250k iterations per design set

  100% B/W protection via IP/MPLS

  Never exceed 24T per PoP from Year-0 to 2

  Never exceed 48T from Year-3 to 5

Example generic ‘costs’
used in this exercise

Platform port types	Normalized cost
10G	1
100G SR	2
100G LR	3
100G ITU Tunable	22

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Calculating a baseline model

- Design rules
  - All core links are aggregated into Nx100G links
  - Connectivity (inter-PoP and intra-PoP) is ‘fixed’ and follows existing network
  - IP links routed on shortest transport path (or shortest diverse, for protecting traffic)
  - IP links dimensioned to carry all traffic, with 100% protection
- Costing the result
  - Count the number of interfaces
  - Apply generic costs

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Cost benefits of packet-optical integration

- The baseline network makes use of significant amounts of router bypass
  - Up to 6 bypassed routers for some IP links
- We want to show that
  - Reducing router bypass to an optimum amount provides a more cost efficient network
    - Improved latency without increasing hop count significantly
    - Improved link utilization while still guaranteeing 100% traffic protection
  - Leveraging packet-optical integration provides significant additional cost savings
    - Colored router ports
    - Scales well over a 5-year period with 30% to 40% traffic growth

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What is Packet Optical Integration?

Data Plane Integration

Colored optics in the router enable CAPEX savings by eliminating grey interfaces, transponder boards & shelves, and OPEX savings on power consumption and footprint.

Control Plane Integration

TE-controller and SDN for multi-layer, and application driven traffic engineering. Optimizes QoS (latency, throughput), network availability and utilization.

Management Plane Integration

End-to-end wavelength provisioning. Virtual transponders allow management of router interface through the transport NMS.

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Multilayer optimization scenarios

- Evaluate multiple optimization scenarios based on ‘cost’ & ‘design-rules’
  - Maintain Intra-PoP structure
  - Fixed traffic matrix: 96k demands, 2.7Tb of total traffic & fixed transport layer
  - 100% protection for single link & SRLG failures

- Optimized designs, comparing various levels of bypass
  - Bypass3: maximum allowed bypass between 2 remote sites = 3
  - BypassMin: maximum allowed bypass between 2 remote sites = 0
    - Some sites do not have a P-router and can still be bypassed (max bypass is 2)
  - PacketOptical: same design rule as bypassMin, but considering additional cost benefits of packet optical integration.

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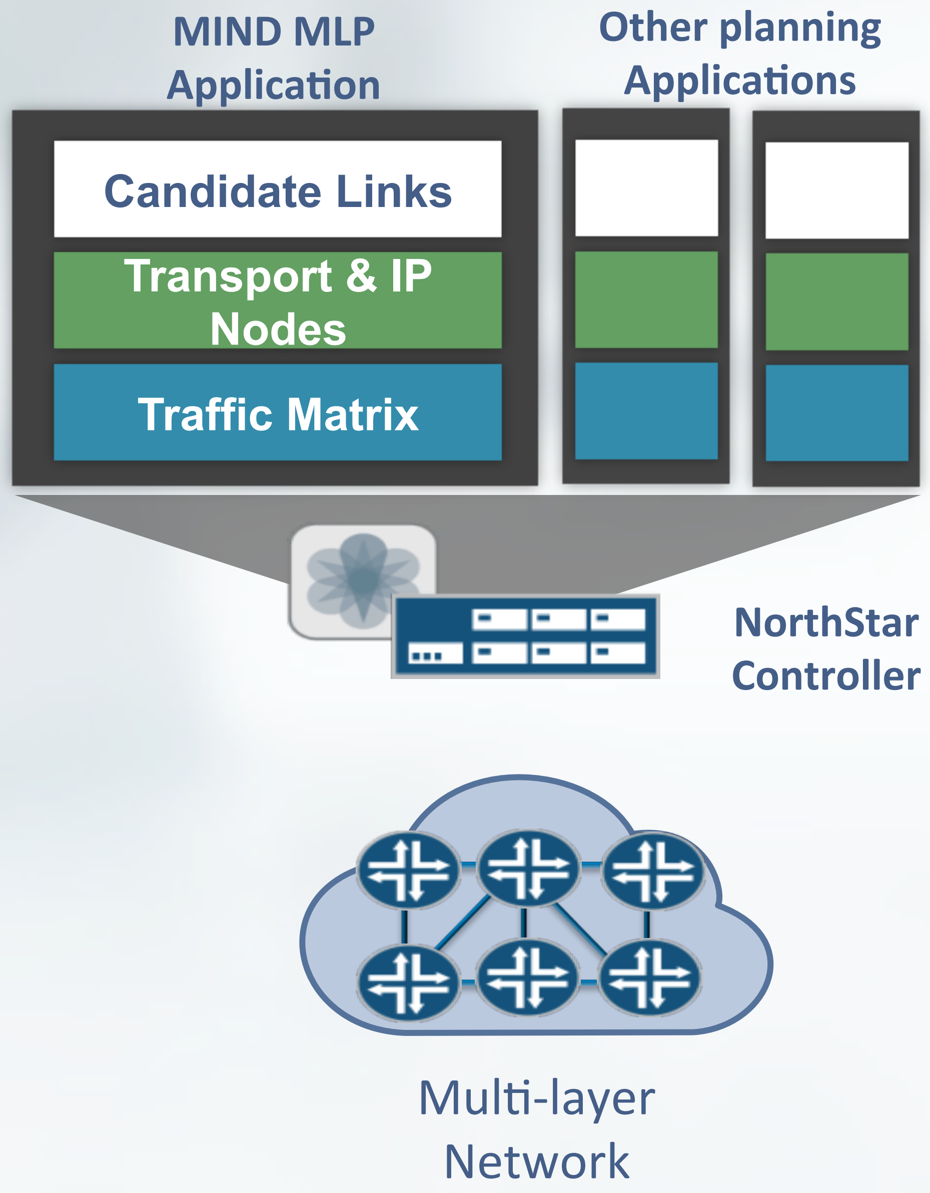
Multilayer planning engine

- MIND Optimization engine
  - Minimizes overall transmission and equipment costs while satisfying traffic, resiliency, and performance requirements for multilayer networks
- MIND Design Challenge
  - Create the optimal IP/MPLS (client-layer) design Given the PE-to-PE traffic matrix
  - Based on a known Transport (server layer) network Create Transport ‘routes’ to satisfy client layer design
  - Or based on abstract server-layer plus associated constraints to define the server topology and the SRLG information for the IP layer
  - The optimum solution is obtained by selectively pruning the IP topology from the set of possible links obtained from the transport layer or abstract links plus constraints



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Design parameters

- Design inputs
  - Node groups
  - Candidate link definitions
    - To restrict intra- and inter-PoP connectivity
    - (e.g. no PE to remote P-router connectivity)
  - Node multilayer mappings
    - Between nodes in same site
  - Project global design constraints
    - Maximum bypass
- Cost inputs
  - Hardware types and costs
  - Link types and costs

linkType	LayerName	carriedDemandType	linkBandwidth
ET10G	IP	Packets	10G
ET100G	IP	Packets	100G
ET100G	Transport	Packets	100G

hardwareType	LayerName	baseCost	portUnit
PE_router	IP	1000	10G
P_router	IP	1000	100G
ROADM	Transport	1000	100G

linkType	LayerName	Section	LinkCostFixed	LinkCostperKM
ET10G	IP	1	110	0.01
ET100G	IP	1	500	0.01
ET100G	Transport	1	500	0.01

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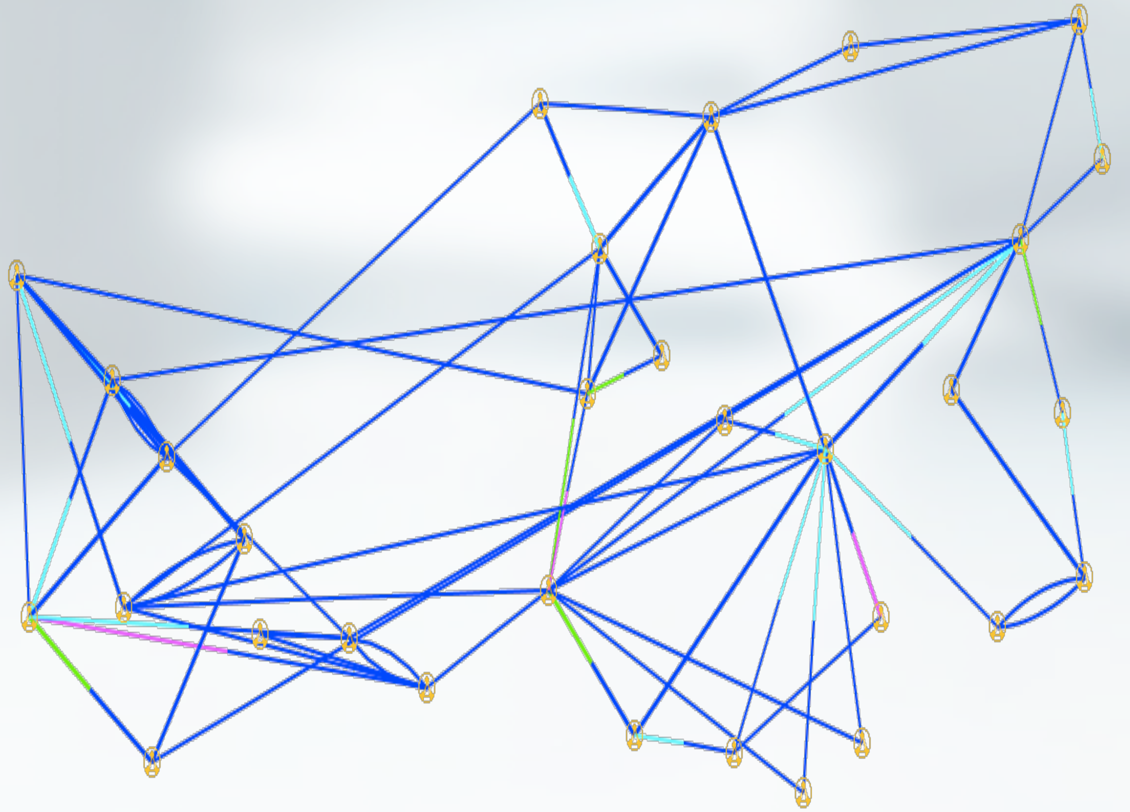
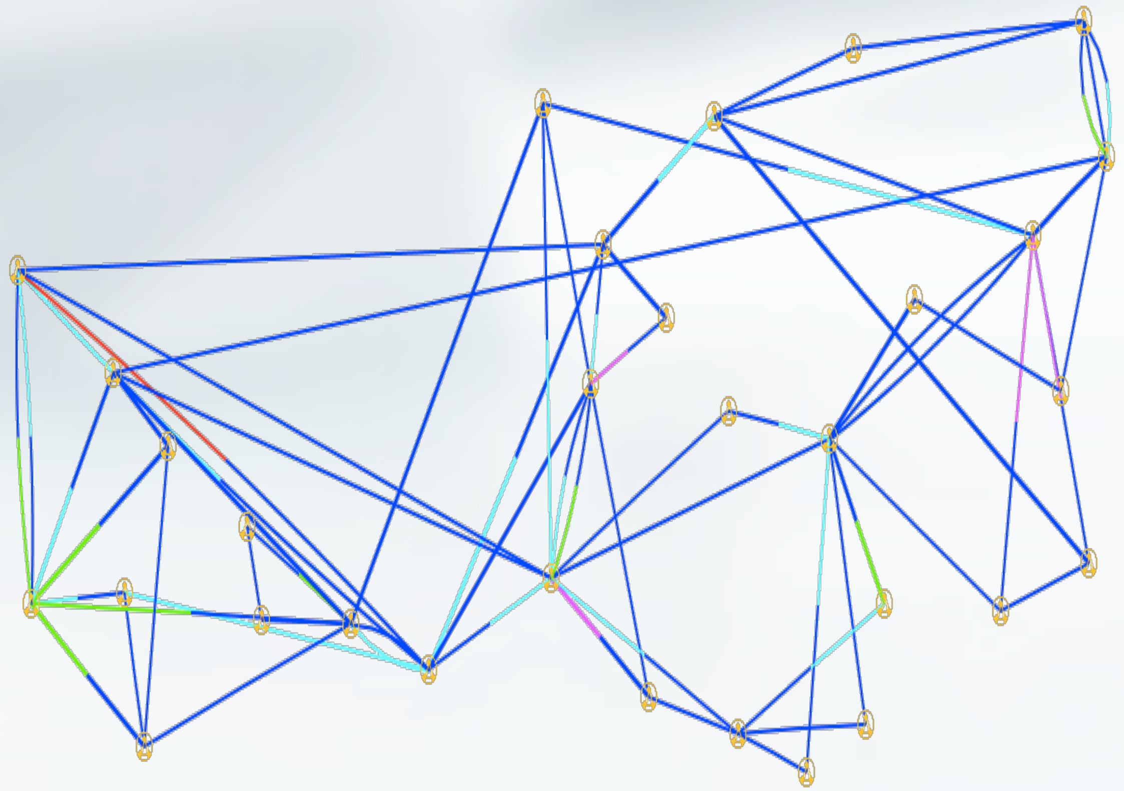
Optimized bypass3 model

- All core links are aggregated into (Nx)100G links
- Intra-PoP links are aggregated to 100G if the # of 10G > 5
- Intra-PoP connectivity structure is maintained
- Set a maximum bypass rule of 3 (going down from 6 in Baseline)



Baseline



Bypass3

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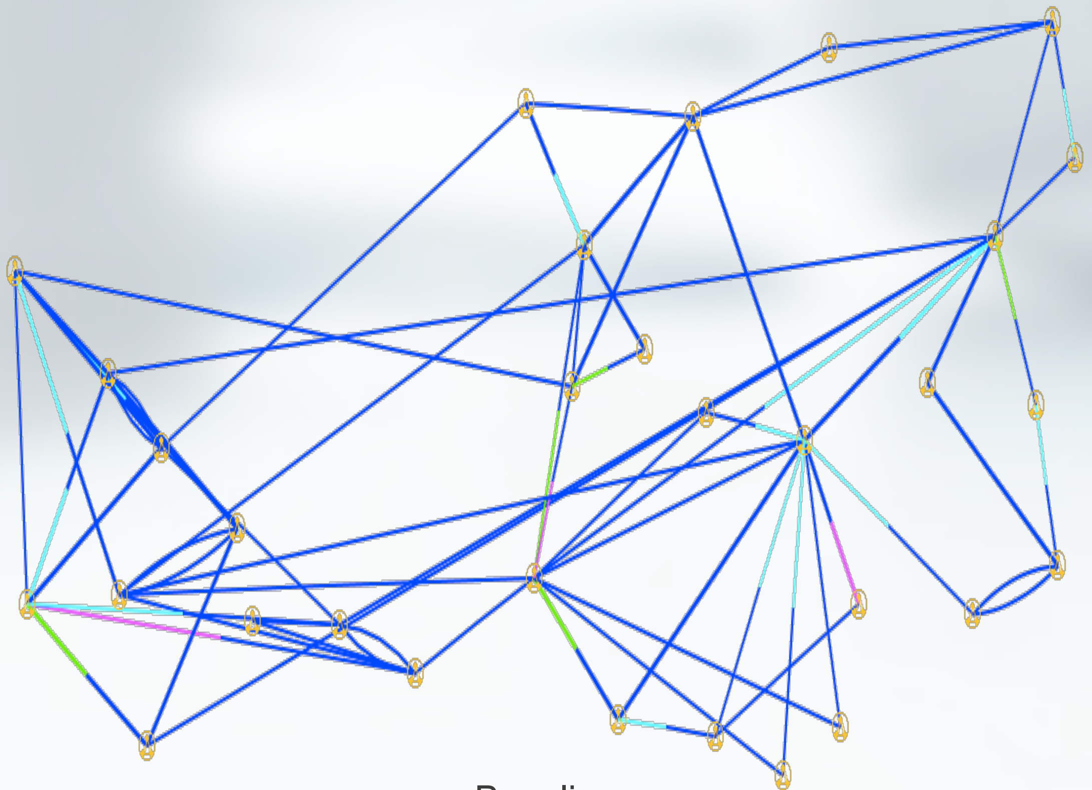
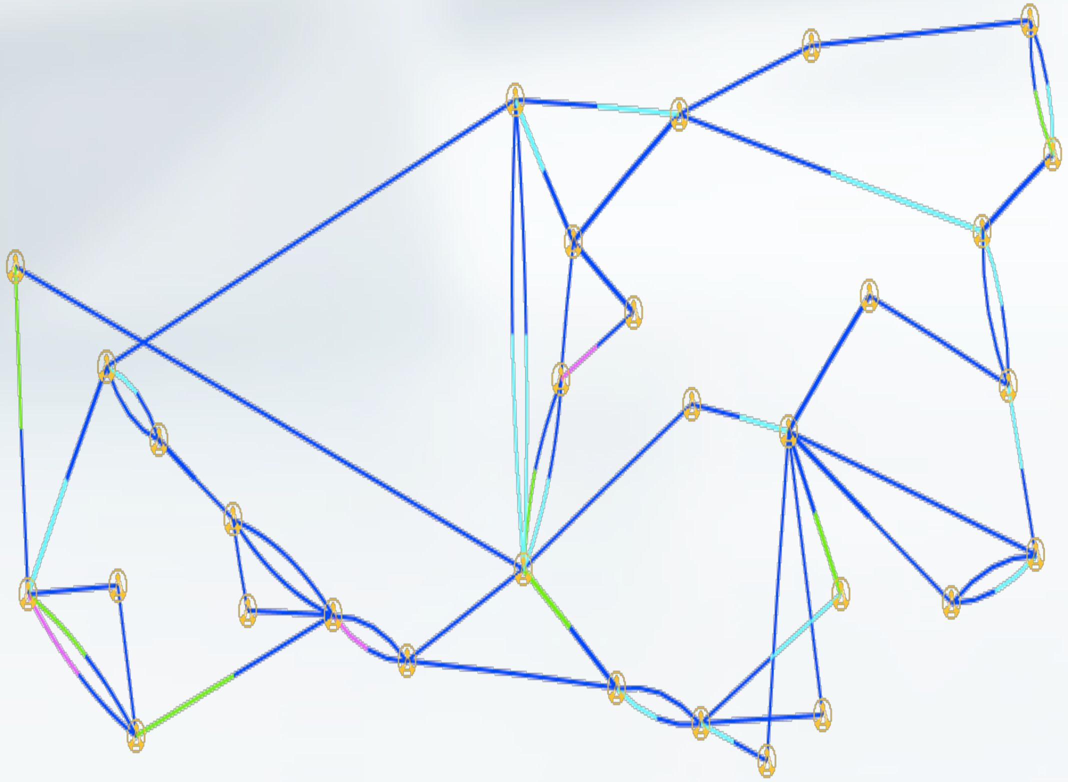
Optimized bypassMin model

- Same baseline rules as previous design
- Notes
  - Bypass = 0 except in a few areas where bypass = 2 (going down from a max of 3 in bypass3 scenario)
  - Some sites do not have a local P-router to connect directly too thus we need to traverse multiple ROADMs to connect to the nearest P-router



Baseline



BypassMin

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Optimized PacketOptical integration

- Same design rules as BypassMin
- Applying integrated packet-optical integrated architecture to count ports
- Notes
  - Cost reduction is dominated by the removal of the back-to-back client interfaces between P-routers and ROADMs

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Results

	ROADM			P-router		
	client side port reduct	line side port reduct		10G port reduct	100G Local port reduct	100G WAN port reduct
Baseline	-	-		-	-	-
Bypass3	12%	26%		100%	1%	15%
BypassMin	-12%	36%		99%	9%	-11%
PacketOptical	**89%**	**75%**		**99%**	**9%**	**-65%**

Normalized total network cost	PE-router	P-router	ROADM	Total	Savings
Baseline	888.00	1400.00	13908.00	16196.00	-
Optimized (bypass 3)	378.00	808.00	10368.00	11554.00	29%
Optimized (min bypass)	352.00	1008.00	9168.00	10528.00	35%
PacketOptical	352.00	6029.00	3398.00	9779.00	**40%**

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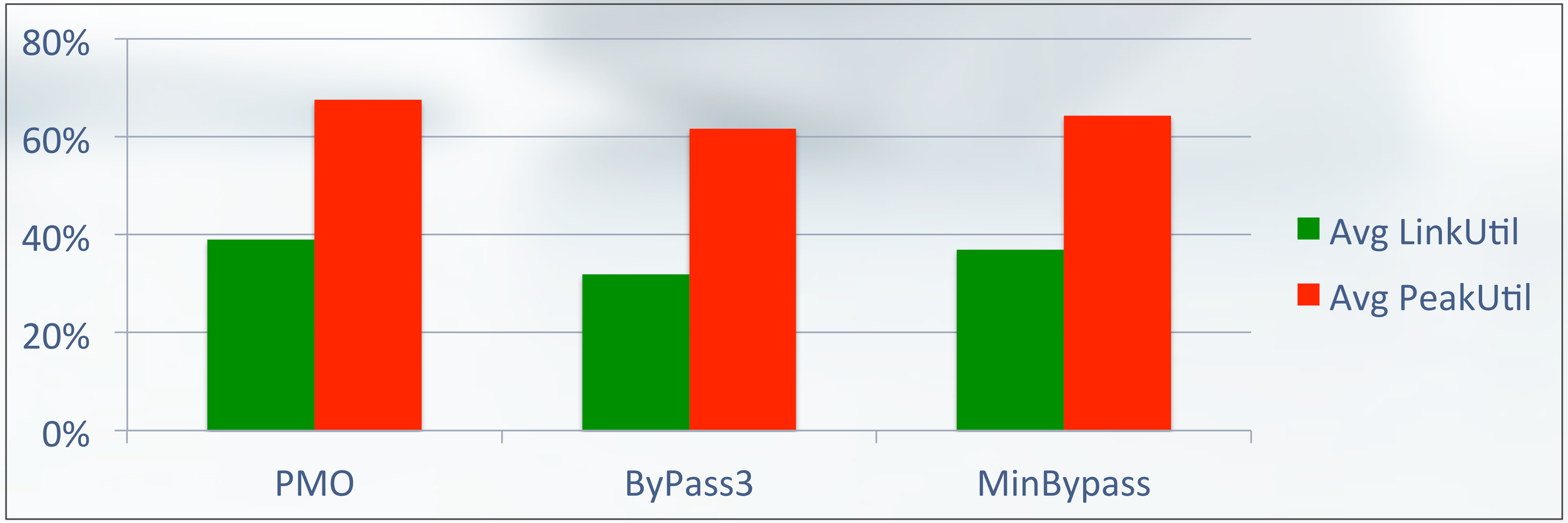
RSVP reserved vs. unreserved B/W

- Using the auto-bandwidth LSPs & IP/MPLSview CSPF
- More room to grow despite lower cost for Bypass3 & BypassMin

	Average link utilization	Average peak link utilization
Baseline	39.00%	67.59%
Bypass3	31.99%	61.68%
BypassMin	36.98%	64.33%



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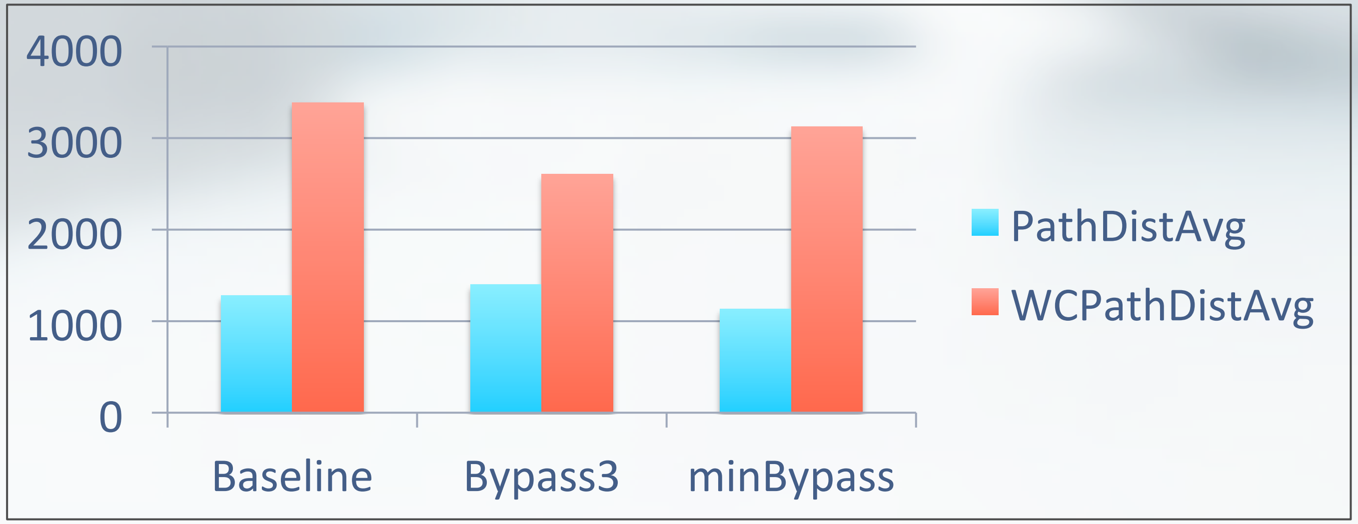
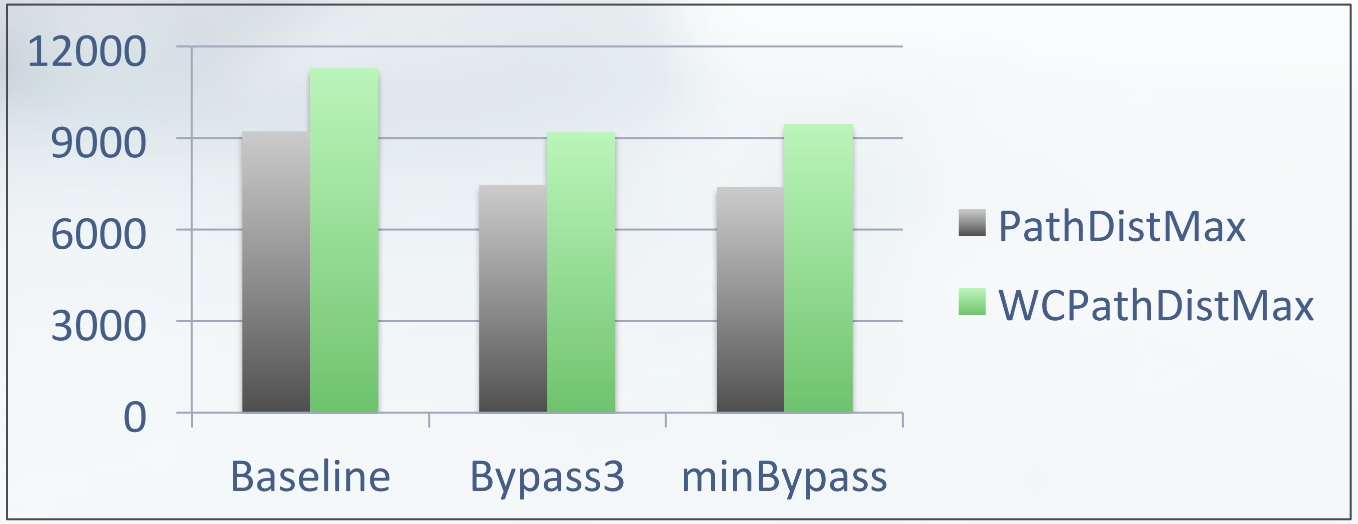
Min/Max latency comparison

- Hop count (steady-state & worst-case) increases while path distance (steady-state & worst-case) is reduced
- Better performance characteristics!

IP layer	Path distance (km)		Worst case path distance (km)		Hop count		Worst case hop count	
	Avg	Max	Avg	Max	Avg	Max	Avg	Max
Baseline	1279	9213	3392	11279	3.9	9	5.67	12
Optimized (bypass 3)	1399	7456	2608	9184	4.01	13	6.04	18
Optimized (min bypass)	1134	7399	3127	9459	4.57	14	7.42	19





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MLO trending

Long-term trending results in an increasing year-over-year savings

- Savings: ~40% in year-1 to ~90% in year-5

Analysis used a fixed A->Z traffic matrix with incremental growth over a 5-year cycle

- MLO enables YoY adaptation in the event the traffic changes

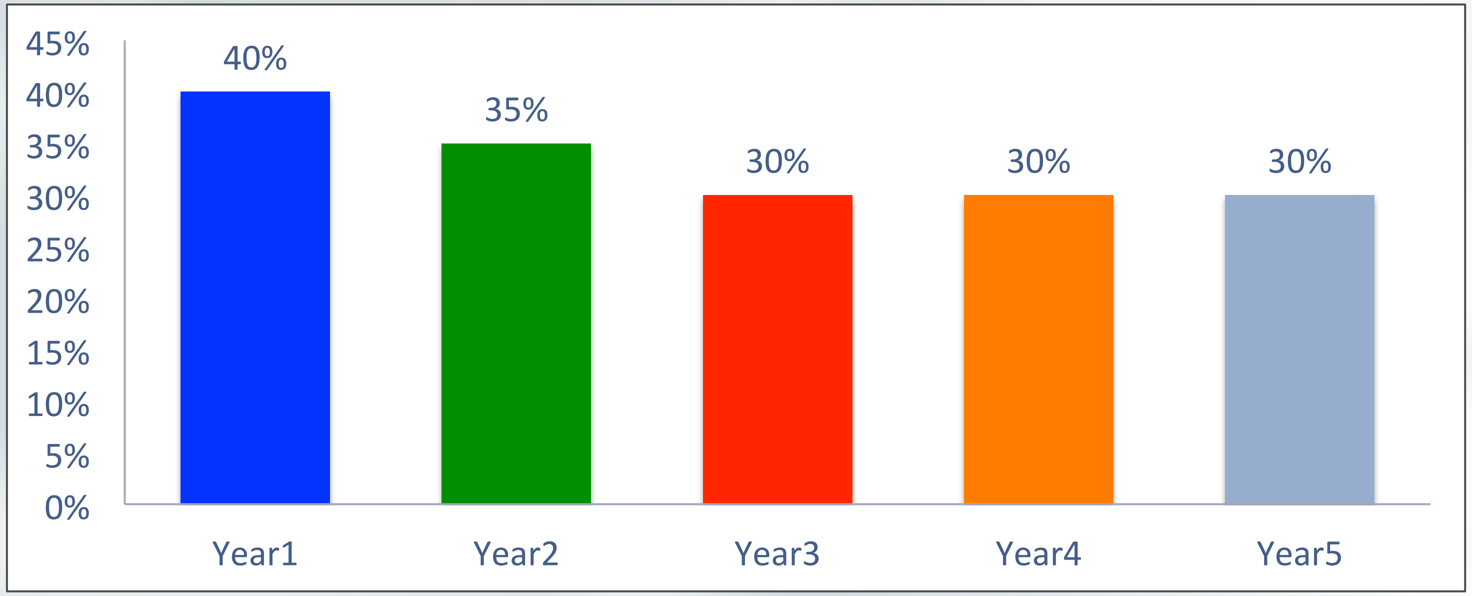
100% B/W protection via IP/MPLS for PTX-only model

System Capacities

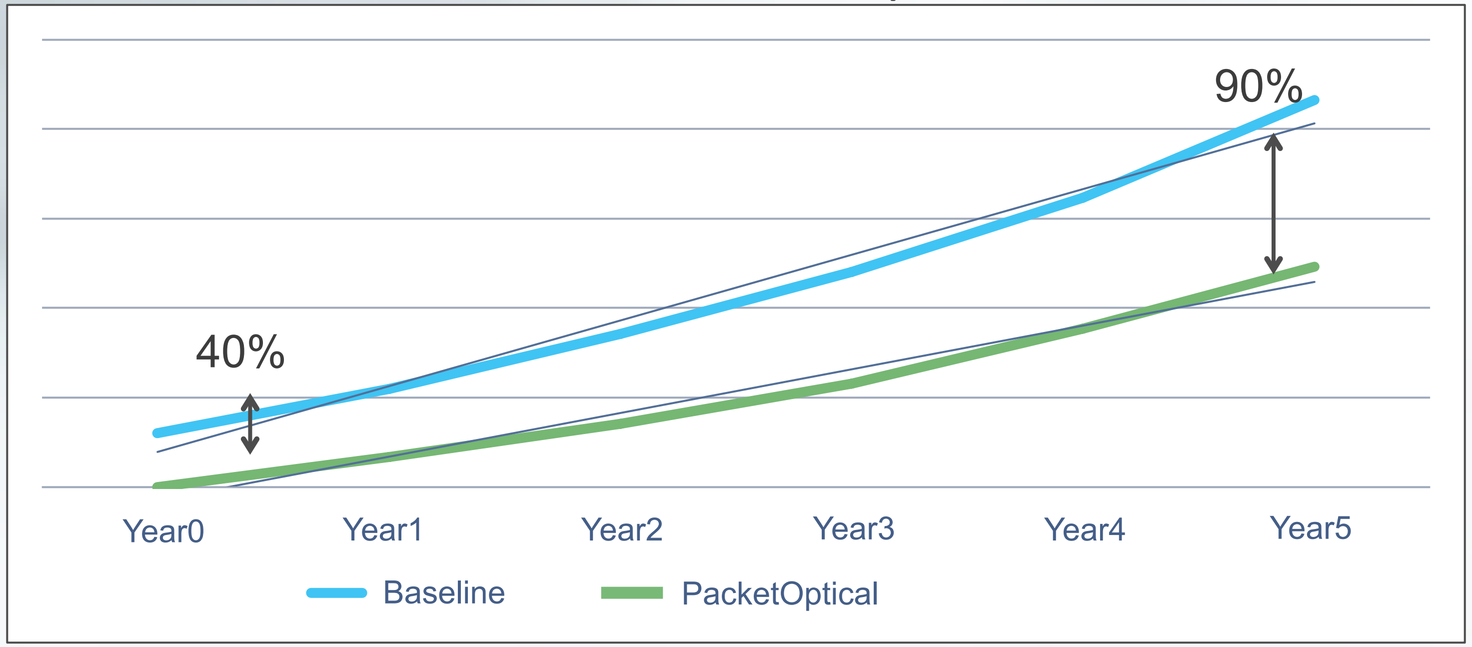
< 24T WC per PoP from year-0 to 2

< 48T WC per PoP from year-3 to 5

5-Year Traffic Growth Rate



5-Year Total CAPEX Comparison



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MLO planning study highlights

- Benefits of packet-optical integration
  - Significant cost savings given an optimium amount of bypass
  - More efficient network
- Importance of taking all layers into account
  - Not only at planning stage, but operations as well

→ Operational challenges towards multilayer optimized IP/MPLS networks

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Challenges for clients of transport networks

Clients of a Transport Network …

- No visibility into the network's actual topology
- No resource availability information
- For good reason:
  - ✓ Security Considerations
  - ✓ Technology Considerations
  - ✓ Scalability Considerations

However, Clients need to influence …

- The way the services provided to them are routed across the transport network
  - ✓ Some services need to be disjoint
  - ✓ Some services need to be co-routed
  - ✓ Some services need to be optimized based on lowest cost criteria, while
  - ✓ Some services need to have the best delay characteristics

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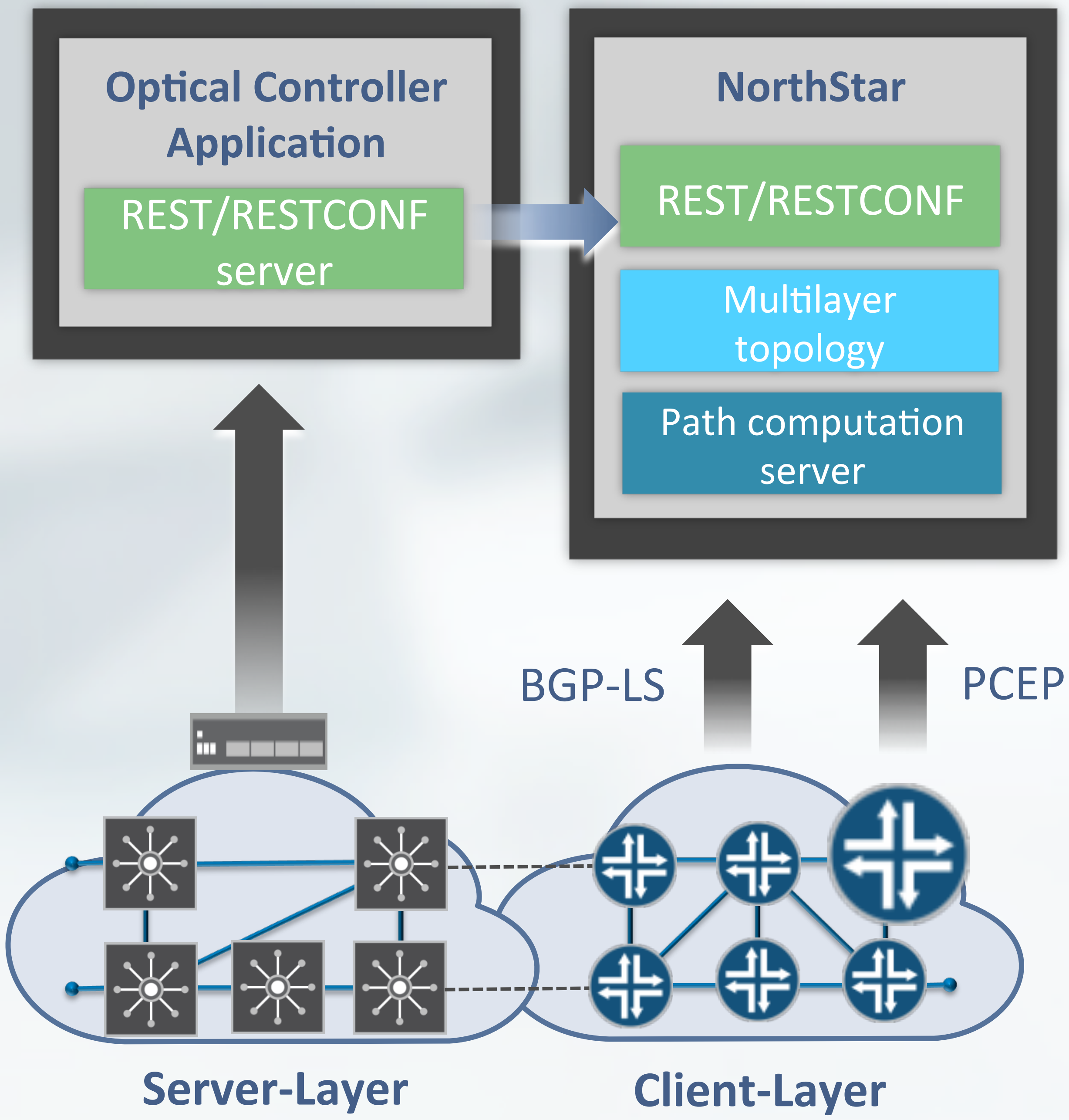
WAN SDN controller with multilayer visibility

- Compute 'optimal' paths for packet (client-layer) LSPs
  - Dynamic SRLGs from transport
  - Latency from transport
  - Optical protection in-use
  - Coordinated multilayer maintenance
- Facilitate multilayer planning & optimization
  - Populate planning tool server-layer topology
  - Populate planning tool traffic-matrix
- Multi-layer provisioning



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Thanks