



# **Next Generation IP over WDM Network Architectures**

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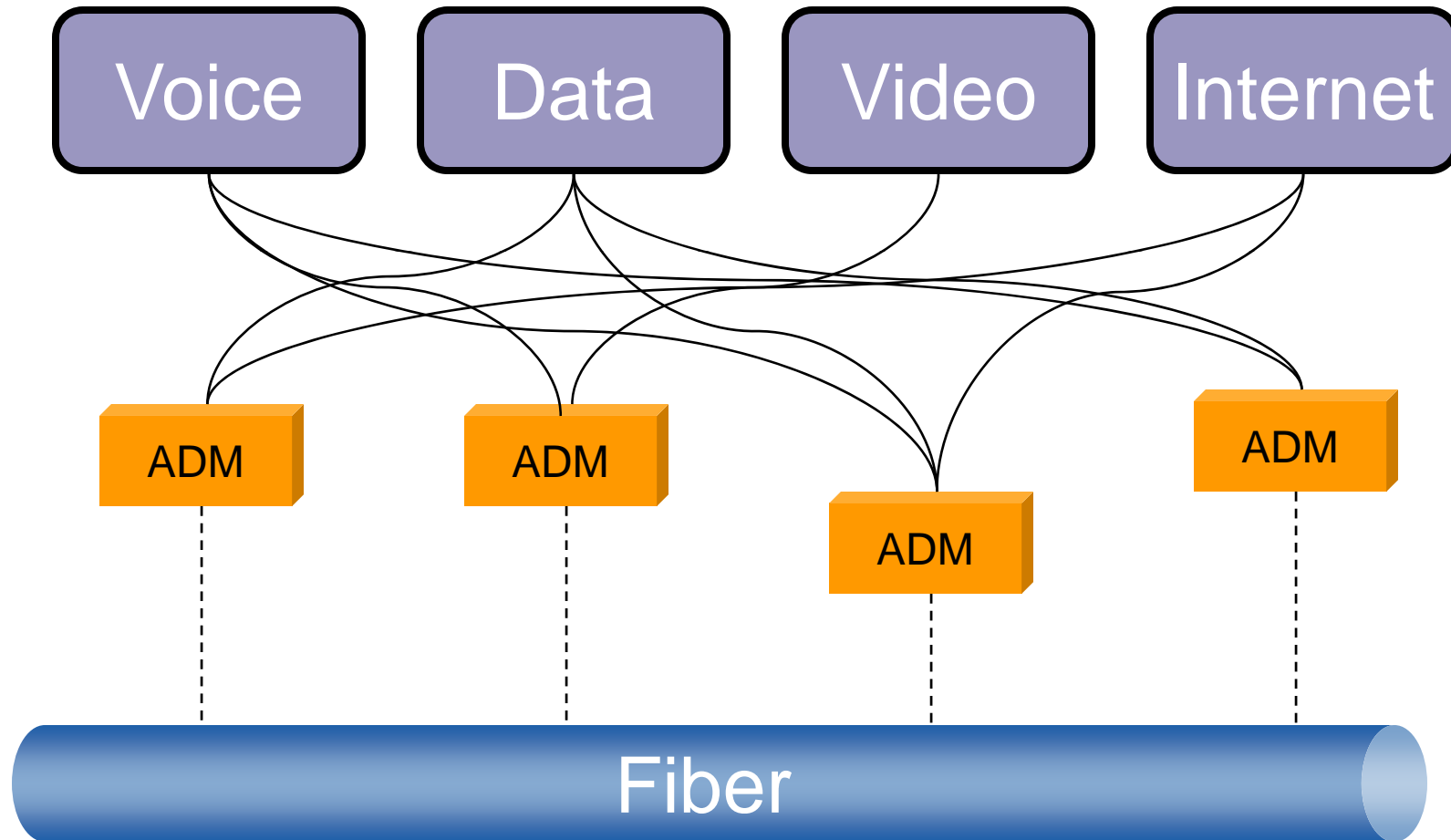
# Acknowledgements

- Curtis Villamizar
- Drew Perkins
- Serge Melle

# Agenda

- Where did we begin?
- Defining the problems
- Solving the problems:
  - Lower CapEx
  - Lower OpEx
  - Faster service delivery
- Examples

# Where did we begin?





# Three fundamental changes

Transmission  
moves to  
“all-optical”

IP  
Convergence

Massive  
Increase  
In Demand

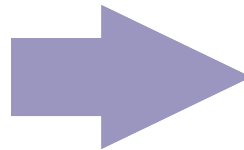
# Implications for IP and Optical Compatibility

- System vendors move to all optical architectures



- Sell off component divisions

Optical systems  
vendors



Component company  
Component company  
Component company

# Defining The Problems

- Need to drive out CapEx
  - Simplify layers?
  - Remove equipment?
- Need to drive out OpEx
  - IP and optical have different skill sets
  - Must reduce the operational burden as new service demands escalate?
- Improve service delivery time
  - Why do I have to wait between 6 and 20 weeks just to get a transponder card?
  - Too many different transponder types!!!



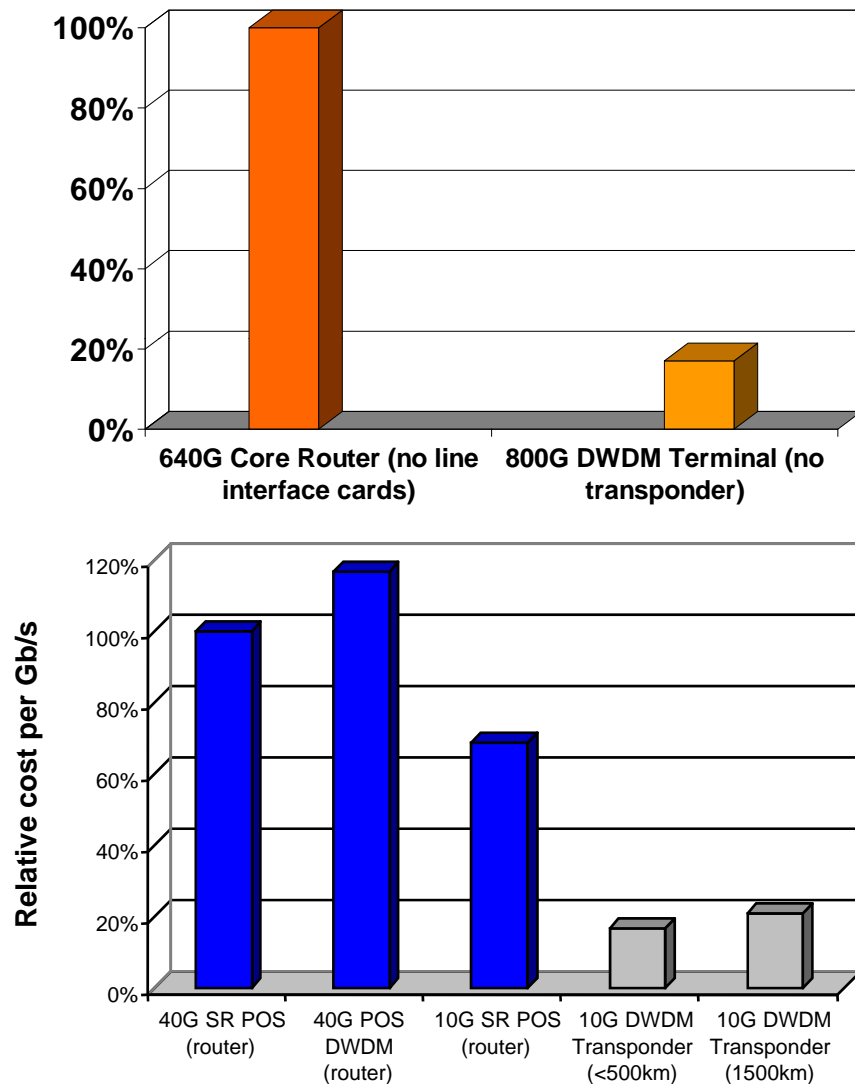
# Lowering CapEx



# Cost Issues in IPoWDM Networks

1. High cost of IP router ports

# Industry Data Points

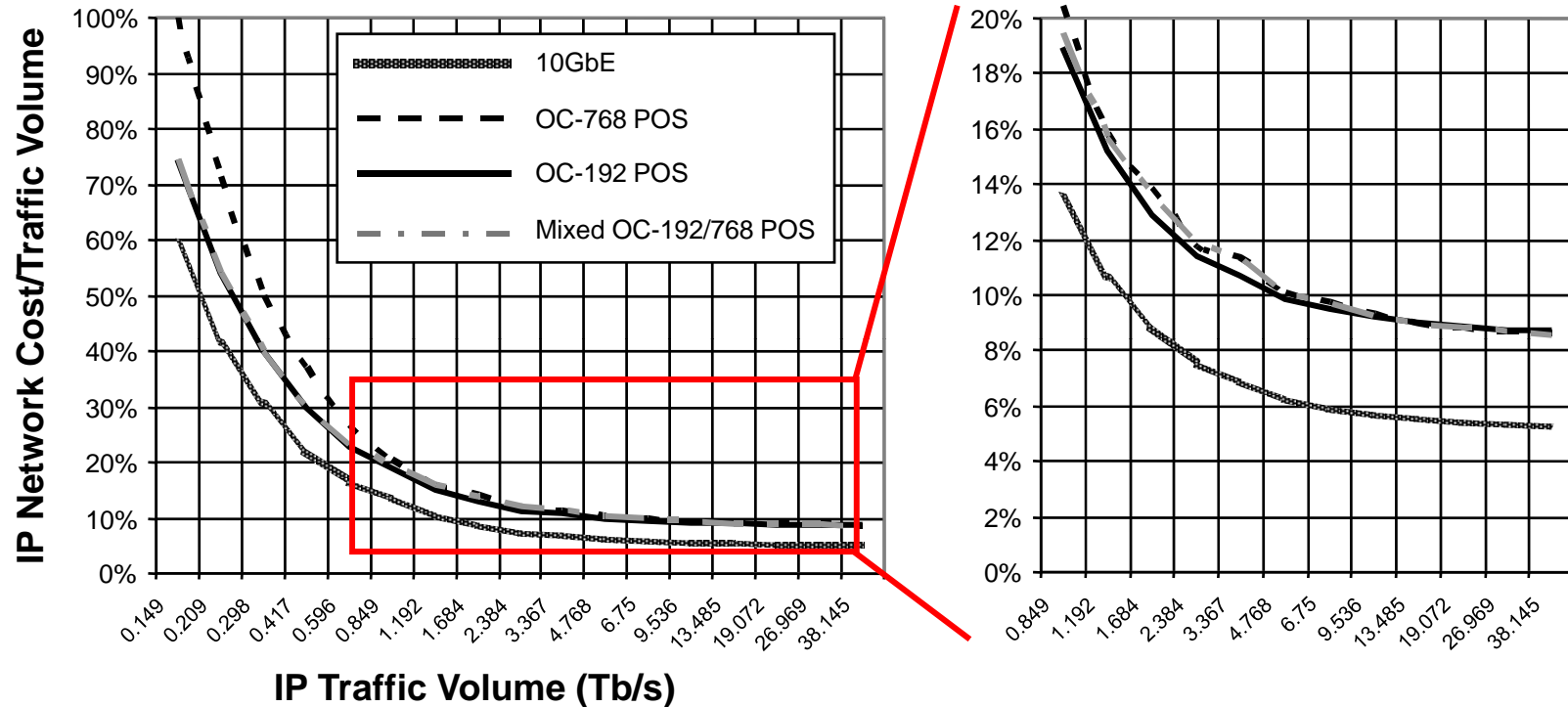


- Significant difference between IP and transport equipment costs
- Up to 5x differential between router & transport DWDM optics
- Opportunity for greatest CapEx savings:
  - Cap or reduce router scaling
  - Cap or reduce number of router ports required
  - Drive functionality into the DWDM transport layer
- Focus should be on minimizing total network cost...
- ...optimizing between IP and transport layers

# Cost Issues in IPoWDM Networks

1. High cost of IP router ports
2. High cost of IP router ports

# Network Cost vs. Interface Type



- High cost of Layer 3 POS router ports
- Historically lower cost points for Ethernet interfaces & switches
- Cost savings from use of converged Layer 2/3 switches (“Ethernet router”)

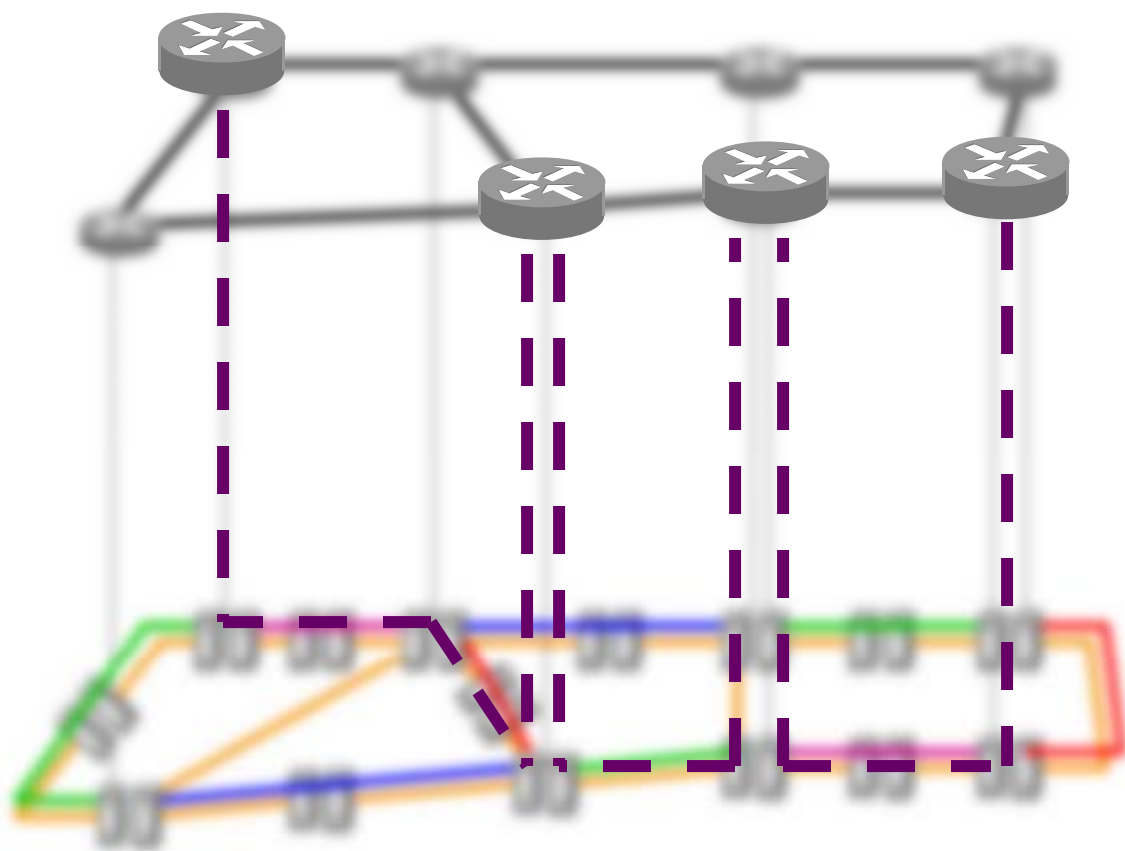
# Cost Issues in IPoWDM Networks

1. High cost of IP router ports
2. High cost of IP router ports
3. High cost of IP router ports



# IP Network Architecture

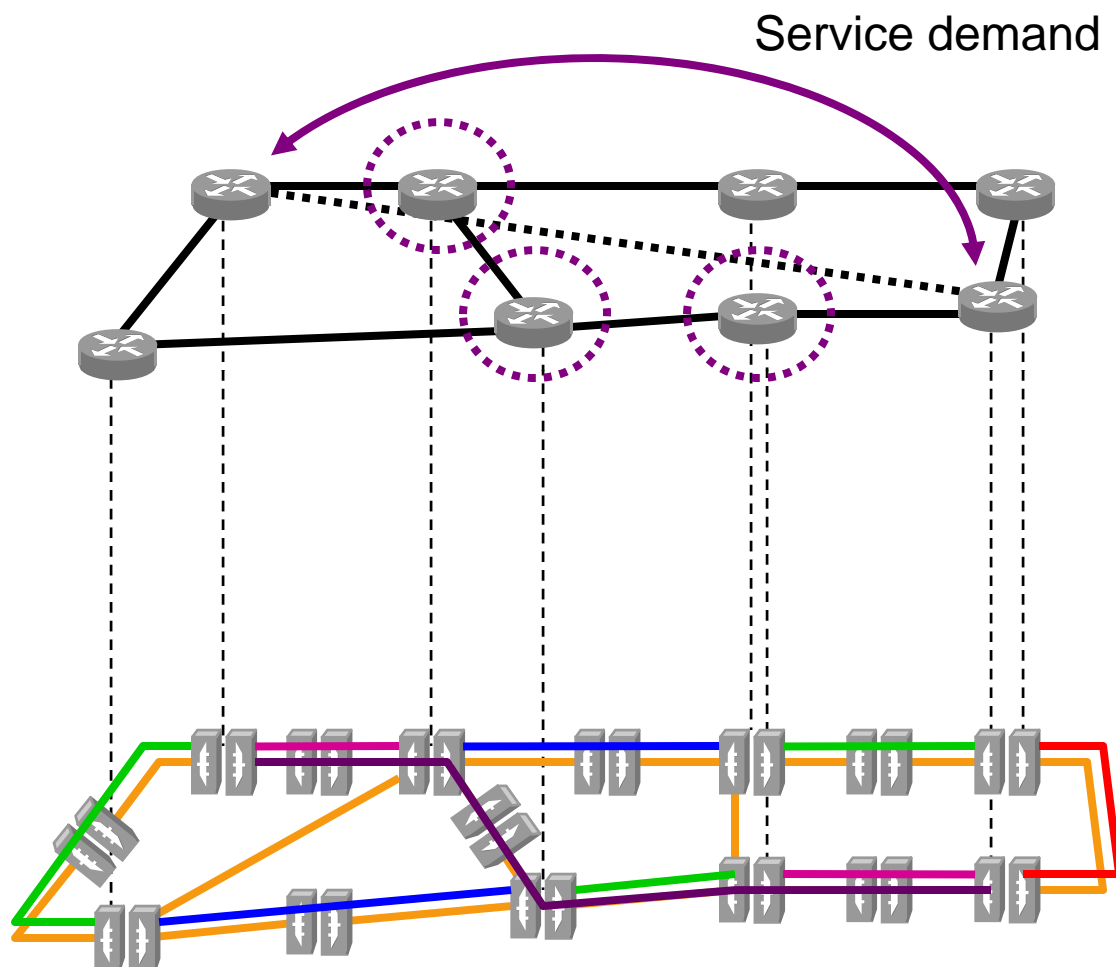
## Present Mode of Operation



- IP core links (router trunks) primarily connected between adjacent router-adjacent router
- IP core links carried over dedicated wavelengths on WDM network
- Little/no router bypass (and thus little pass-through traffic in WDM layer)
- End-end IP demands pass through multiple router hops
  - Consume routing capacity for pass-through demands
- Increasing inefficiency & cost as traffic volume scales

# IP Network Architecture

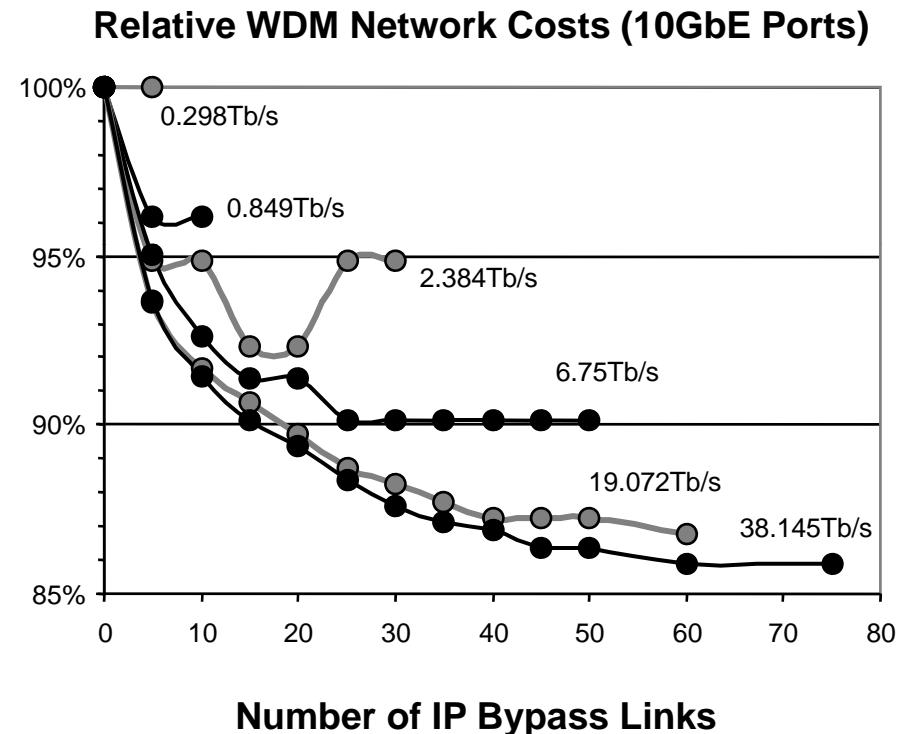
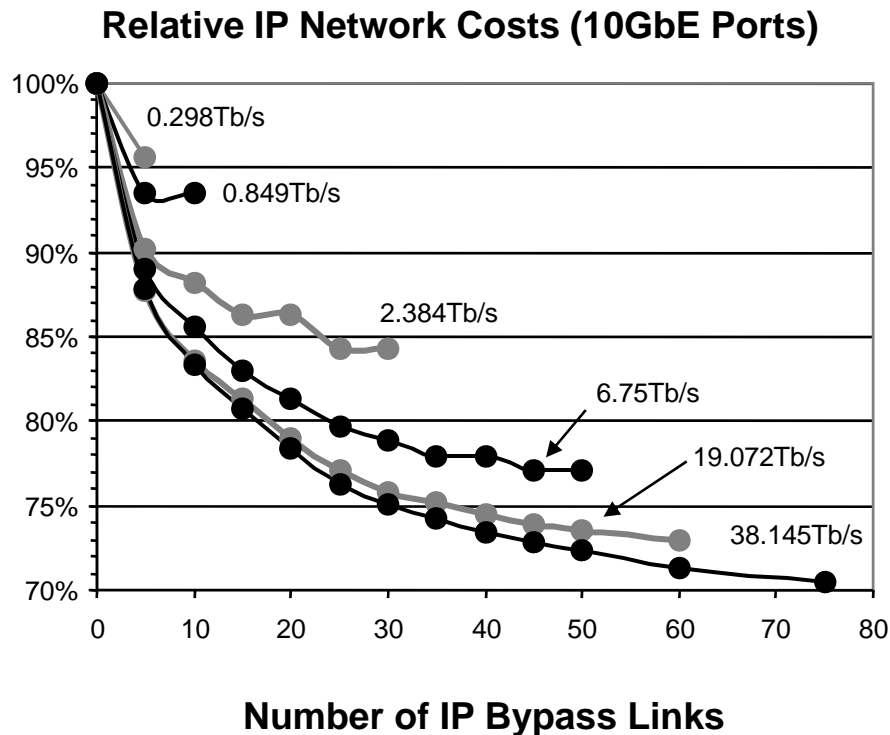
## Future Mode of Operation



- As IP traffic volume grows....
- Minimize end-end IP demands transiting through intermediate router hops
- Increase number of direct router-to-router core links (router trunks)
  - Router “bypass” for end-end demands between nodes

Traffic offloaded  
from three pairs  
of router ports

# Network Cost vs. IP Bypass (10GbE)



Source: ***“Network Cost Savings from Router Bypass in IP over WDM Core Networks”***  
Serge Melle, Drew Perkins and Curtis Villamizar

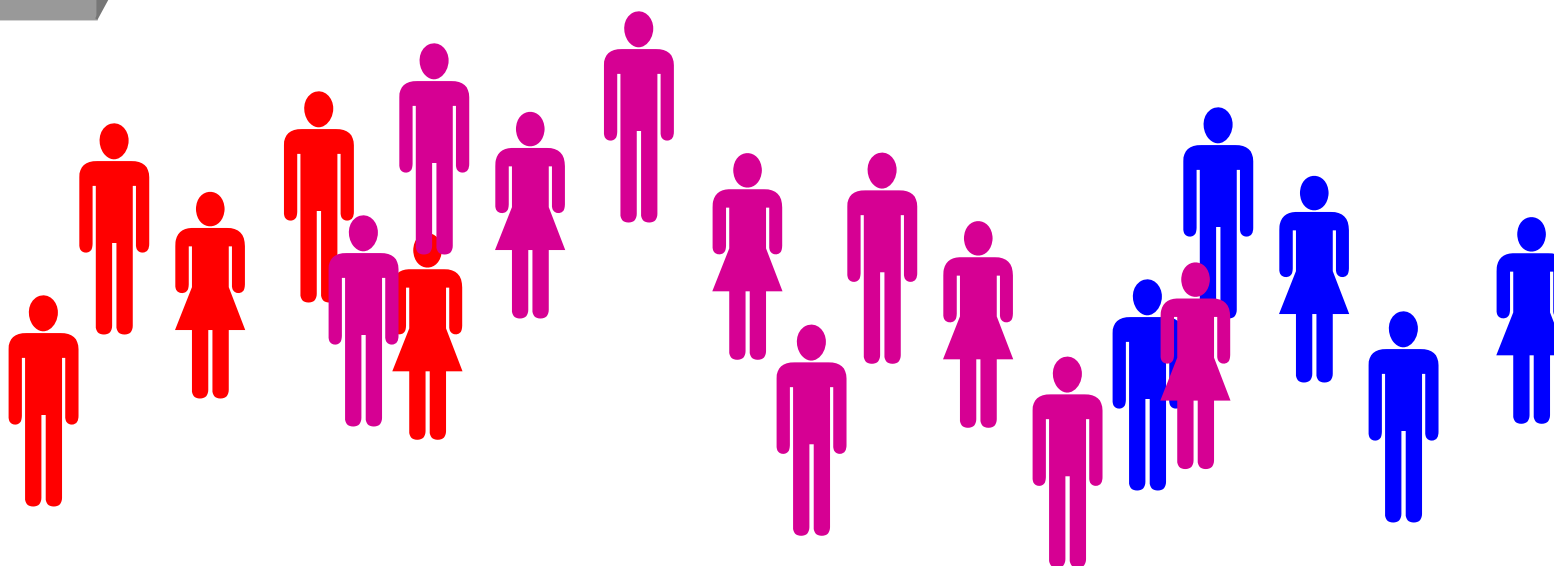
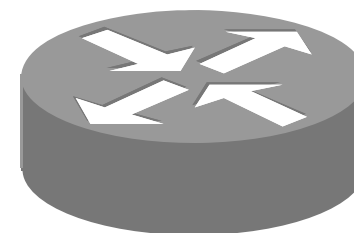
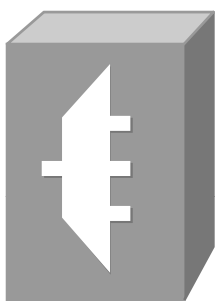
<http://www.infinera.com/technology/techpapers.html>



# Lowering OpEx

# Re-unite IP and Optical

- Make optical more compatible with IP



Optical Network Staff

IP Network Staff




# Re-unite IP and Optical: How?

- Put “digital” back into the optical network
- Hide the “physics” from the network designer
  - Remove the cumulative problems of optics
    - Loss, Chromatic dispersion, PMD, Amp balancing
- Put back “point and click” provisioning
- Put back digital PM and OAM
- Enable GMPLS to reach its full potential
  - Without the crippling cost of external cross-connects



# Faster Service Delivery



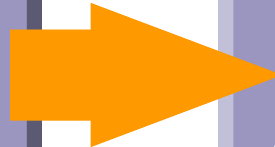
It takes a long time to roll out  
a major optical transmission  
network...

...or does it?

# Forecasting capacity growth...

- ...is one of the biggest problems for the network designer

It takes my optical supplier X months to deliver transponders



My traffic forecasts have to be absolutely accurate!

- With dozens of different transponders and muxponders, how can I keep stocks?

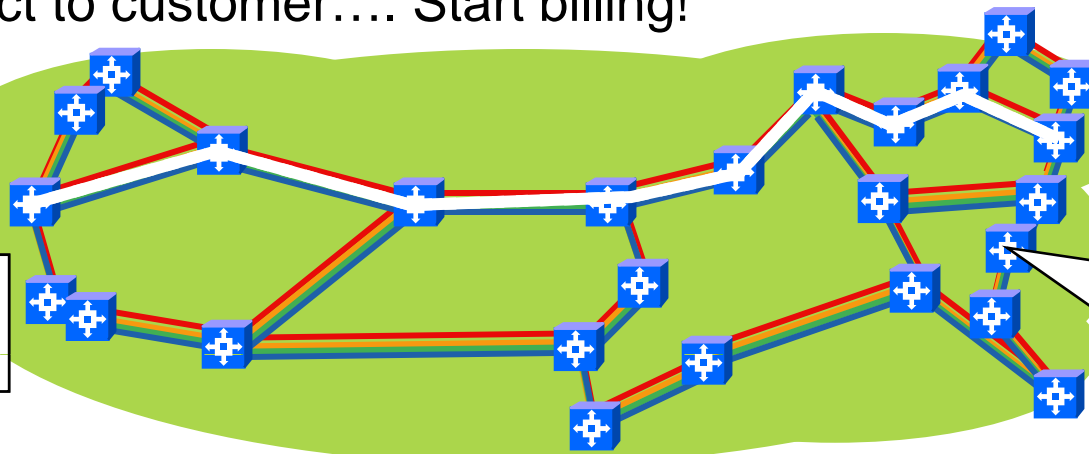
# Just-In-TAM™

These companies can offer the fastest turn-up of high-speed bandwidth in the industry

1. Your Infinera network offers 100G capacity with each DLM.
2. Customer order comes in. Pre-provision and test if desired.
3. Order two Tributary Adapter Modules, one for each end point.
4. TAMs arrive within 10 days of order.
5. Install TAMs, activate, and test.
6. Connect to customer.... Start billing!



Service Order:  
10G wave





# Proving the concept...



**Level3:**  
10GbE LAN PHY



**Interoute**  
10G in 10 Days



**XO:**  
10G in 10 Days



**Cox:**  
Owned backbone



**Carphone Warehouse:**  
Owned backbone

# Solving The Problems

- Driving out CapEx
  - Optimize router ports vs traffic demand
  - Result: cost-optimize overall network
- Need to drive out OpEx
  - Make optical more compatible with IP
  - Put the “digital” back into the optical network:
    - Digital design, digital service provisioning, digital performance monitoring
- Improve service delivery time
  - Rapid network deployment
  - Tolerant to unforecast service demands



# Thank You

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