



Multilayer Design

Grooming Layer + Optical Layer

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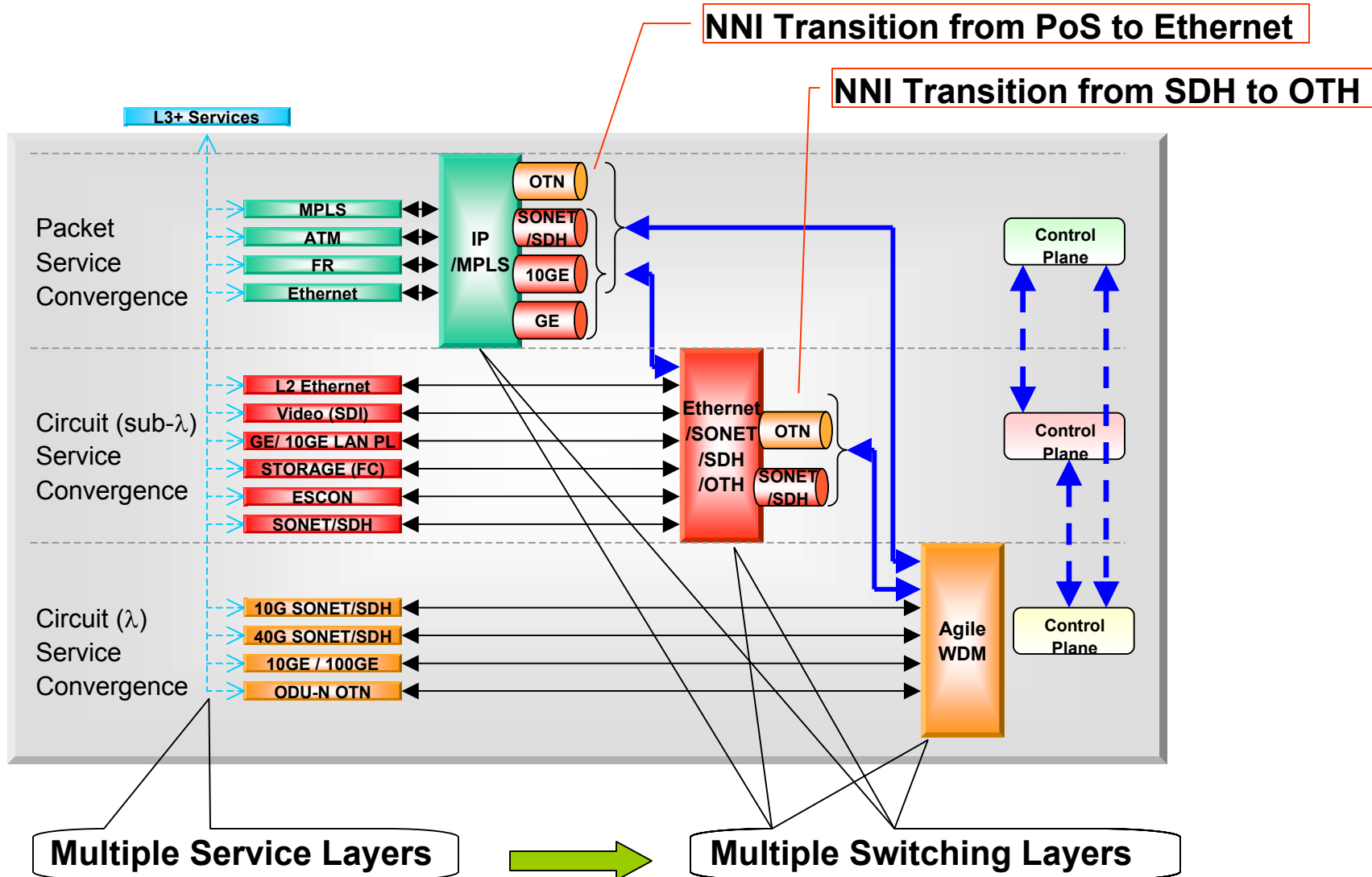
Outline

Challenges

Issues

Solutions

Challenges: Multi-layer traffic engineering



Challenges: Network Architect's view

Architecture: Multiple Service Layers (IP, Ethernet, PDH/SDH, Storage, Video)

- **Traffic Profile:** Static or Dynamic (holding time), SLA
- **Network Connectivity:** Point-Point or Multi-point (V)PN's
- **Network Scope:** Metro/National/Global and Single/Multiple providers

Planning: Multiple Switching Layers (MPLS, Ethernet, SDH, OTH, WDM)

- **Greenfield:** New or overlay with circuit migration
- **Brownfield:** Selective node or network migration

Operations: Sweat current assets

- **Reduce Average Cost (\$ / bit)** : optimizing node, link, network
- **Reduce Marginal Cost ($\Delta\$ / \Delta\text{bit}$)** : scaling node, link, network
- **Reduce Churn Rate ($\Delta\text{subs} / \text{subs}$)** : improving performance (QoS, QoE?)

Challenges: Equipment Architect's view

Complex Switching (Multiple Data Planes)

- **L0 with multi-degree WSS** : multiple hops, multicast, protection, Signal quality
- **L1 migration** : SONET/SDH → OTH ; Rings → Mesh ; Protection → Restoration
- **L2 Ethernet**: Point to Multipoint & Multipoint topologies

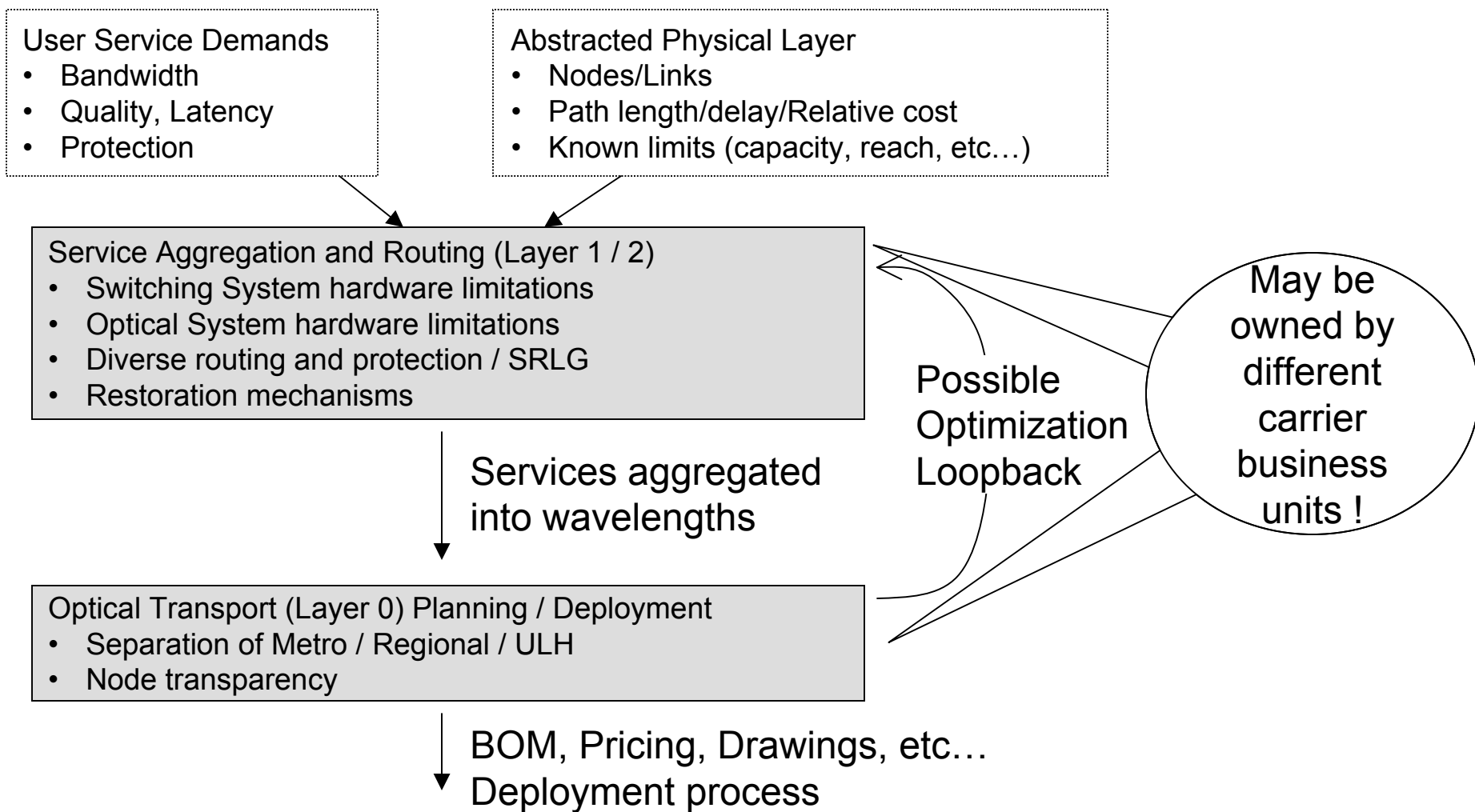
Higher Intelligence (Control/Management Planes)

- **Multi-layer & Multi-domain** : discovery, signaling & routing protocols
- **Management plane Interaction** : path computation, on-demand network state
- **Quality of Service** : Latency, Jitter, Loss, Availability, Restoration Time

Reliable Software

- **Configuration** : Embedded (online) vs Desktop Server (offline)
- **Computation** : Efficient algorithms (Run time vs Optimal Results)
- **Consistency** : Desktop Simulation vs Field Deployment (eg. restoration time)

Challenges: Complex Network Planning

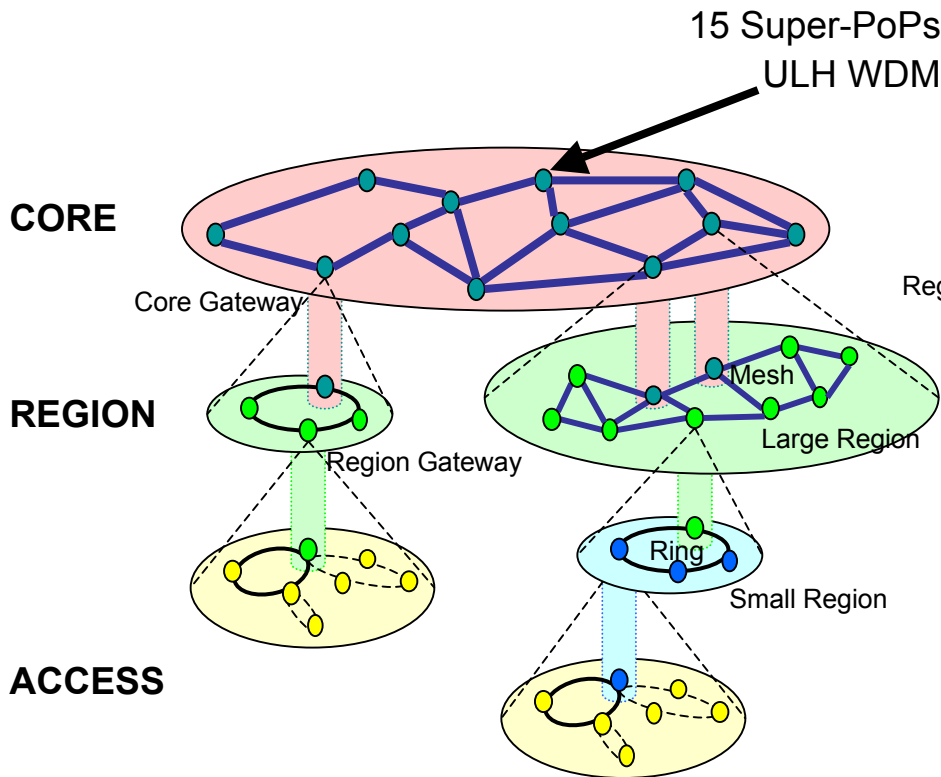


Issues: Network Partition

→ Hierarchical Core Network

- Separate Core & Regional Mesh/Ring
- Multiple OAM/transport routing domains

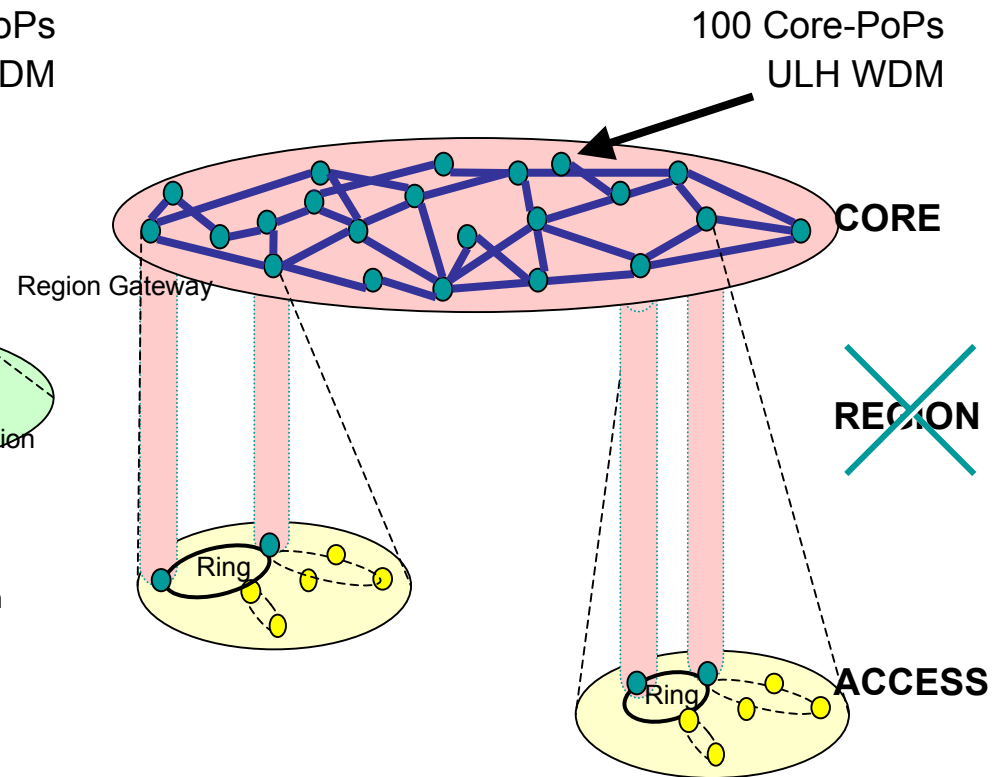
→ Regional Networks for intermediate aggregation



→ Flat Core Network

- Collapsed Core/Regional Mesh
- Single OAM/transport routing domain

→ Access directly aggregate to Metro/Core



Issues: Layer 0 Node Partition

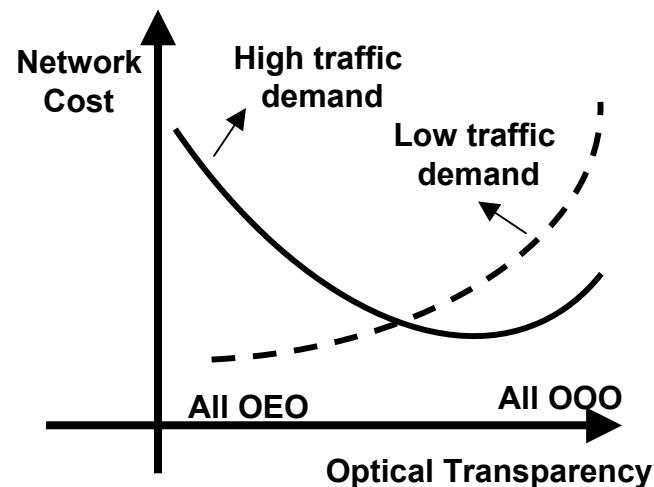
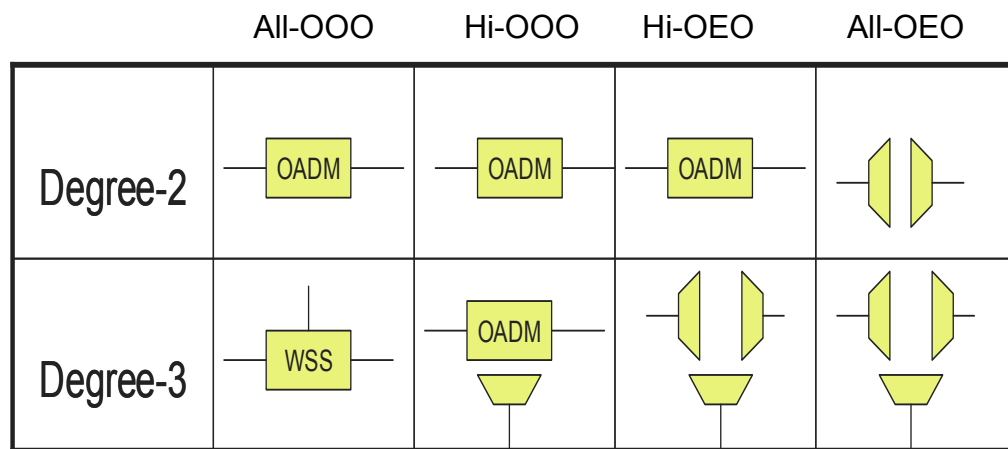
→ Four optical transparency levels available:

→ **All-OOO**: Degree-N transparent at all nodes

→ **Hi-OOO**: Degree-2 transparent as much as possible

→ **Hi-OEO**: Degree-2 transparent, But Degree (N>2) opaque

→ **All-OEO**: Degree-N opaque at all nodes



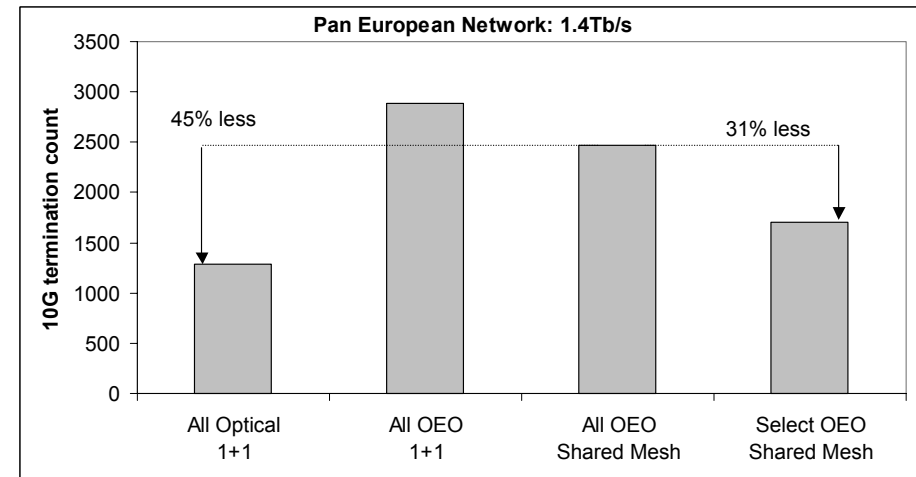
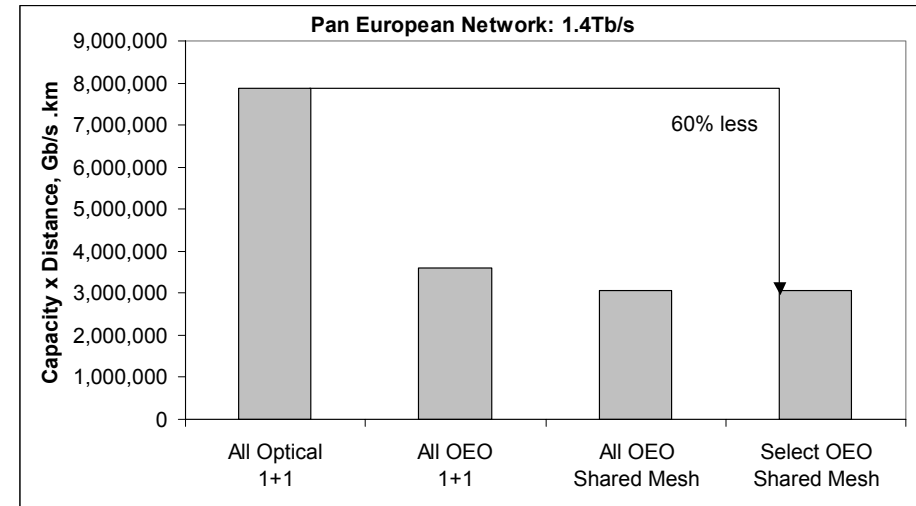
Issues: Operation model vs Mesh networking

Network database has “Home route”

- Home routes are for lifetime
 - Revertive
- Maximize optical transparency
- Design **Express paths**

Restoration capacity is temporary use

- Maximize bandwidth re-use
- Maximize bandwidth sharing
- Design **Non-Express paths**

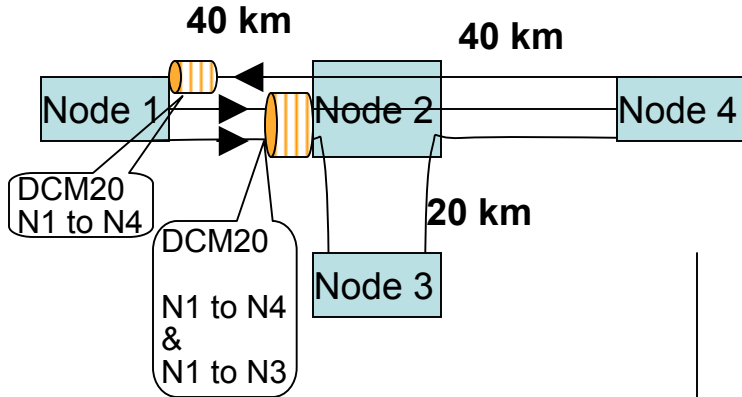


Ref: Ranganathan et.al., ECOC 2002

Issues: Layer 0 design (Metro vs. LH)

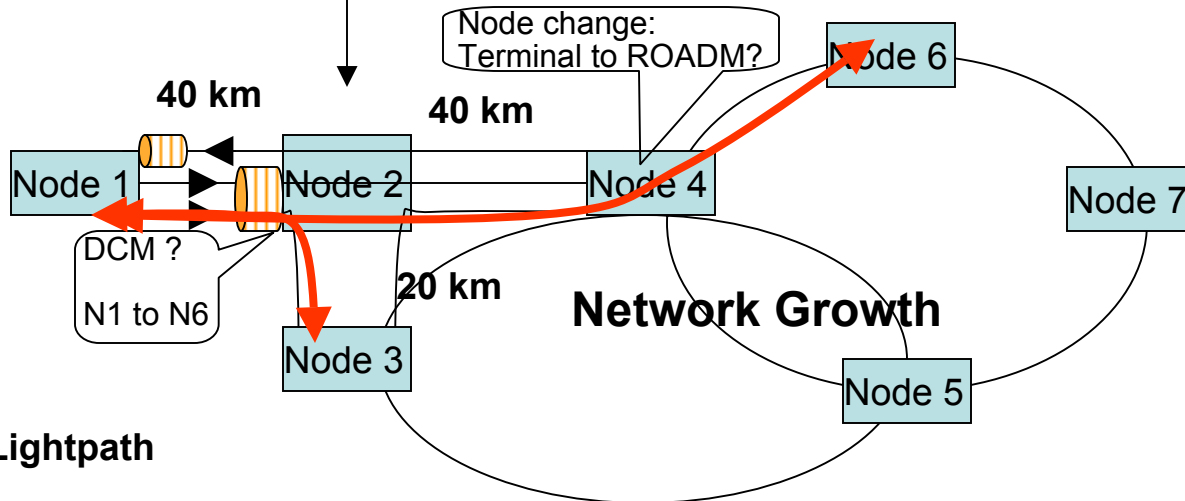
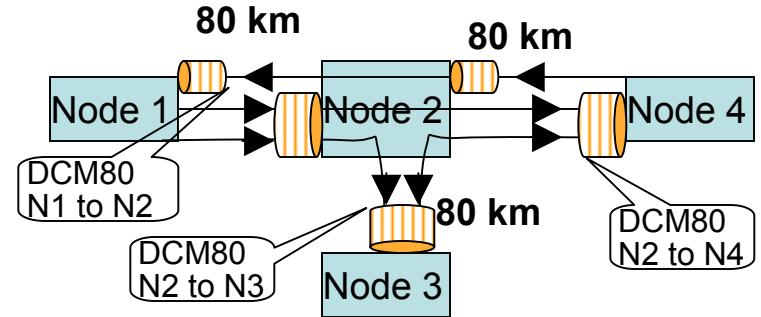
Metro : small inter-node distance

→ based on multi-node decisions



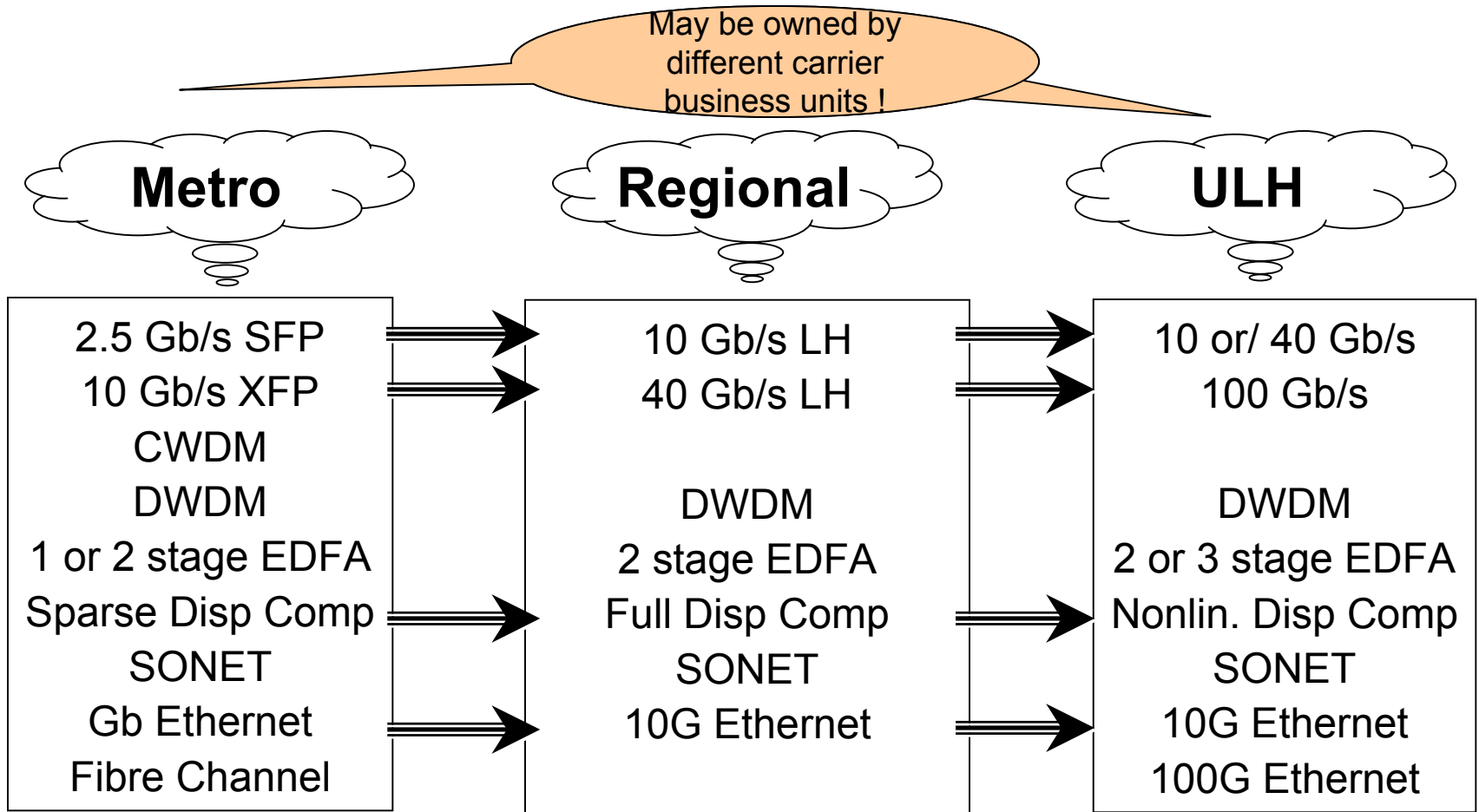
Long-Haul : large inter-node distance

→ based on individual span decisions



Static vs. Dynamic Lightpath

Issues: Physical Layer Convergence -- Maybe



→ **Some technologies are shared, but some are quite different**

Ciena's Optical Transport Design Philosophy

→ Transport layer needs to be Modular and Flexible

→ **Standard:** Multi-sourced components drives cost & risk down

→ **Programmable:** Dynamic traffic flows

→ Help Carriers to improve average and marginal cost

→ **Greenfield:** Introduction of next generation platforms/networks

→ Better, Faster, Cheaper...and, oh yes...Integrated

→ **Brownfield:** Evolution of installed base with improvements

→ Flexible Port : Bit rate (2.5G → 100G), Service (SONET/SDH → OTN → Ethernet → FC)

→ Flexible Node : Amplifier → Traffic drop, Terminal → OADM, Degree 2 → Degree N

→ Be aware of DESIGN PROCESS (i.e. tools) COMPLEXITY

→ **Legacy compatibility:** network scaling optimized AROUND installed gear

Solutions: Multi-layer Design Tool

(Example capabilities: Ciena's Core Director Designer)

→ Intelligence: Control plane capabilities / simulation

- Scale, Scale, Scale...100+ nodes & 10,000+ circuits...in one routing domain
- Routing and Signaling based Capacity Planning
- Mesh Survivability : multi-layer, restoration time, circuit priority

→ Focus: Lowest cost capacity planning

- Re-groom existing circuits & Capacity for new circuits including TE
- Maximize switching at the “cheapest” layer (optical vs. tdm vs packet)

→ Flexibility: User/Management interface

- End-to-End view of Circuit/Node/Network across domains
- Live Network Import
- Export to offline computing - Layer 0 WDM Model

Solutions: Layer 0 considerations

→ Simplify

- Laptop based software for offline Layer 0 network design.

- Post-processing to get accurate BER calculations

→ Automate

- Network partitioning, equipment placement, and regeneration

- 95% optimal solution within 5 minutes on a standard laptop computer

- Link to back end servers for inventory / pricing

- Bill of Materials (BOM) and Excel design reports

- Documentation for Greenfield and Brownfield deployment / turn-up

Conclusions

→ Identified challenges, issues and some solutions

Multi-layer design tools can help answer key questions

→ **Coupling between layers**

→ MPLS LSP's over OTN/WDM mesh network?

→ **Determine lower cost designs**

→ Sparse vs Dense Layer 0 topology?

→ Complex Layer 0 but efficient Layer 1?