Can Optical Channel Margins Help Alleviate Congestion at the IP Layer?

Cengiz Alaettinoglu

Leader, Architecture and Strategy,
Network Control and Planning, Ciena

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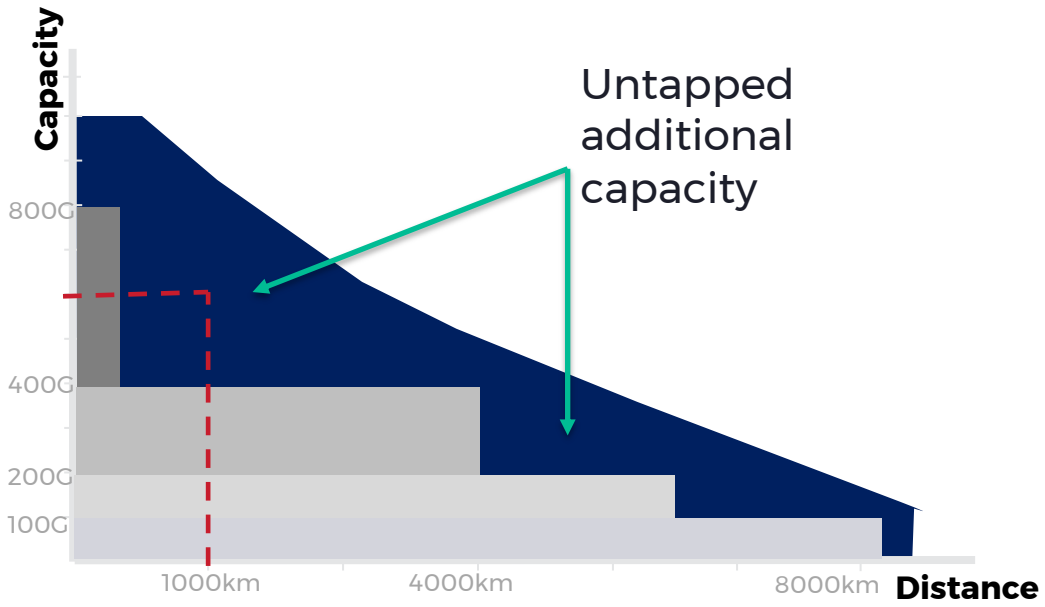
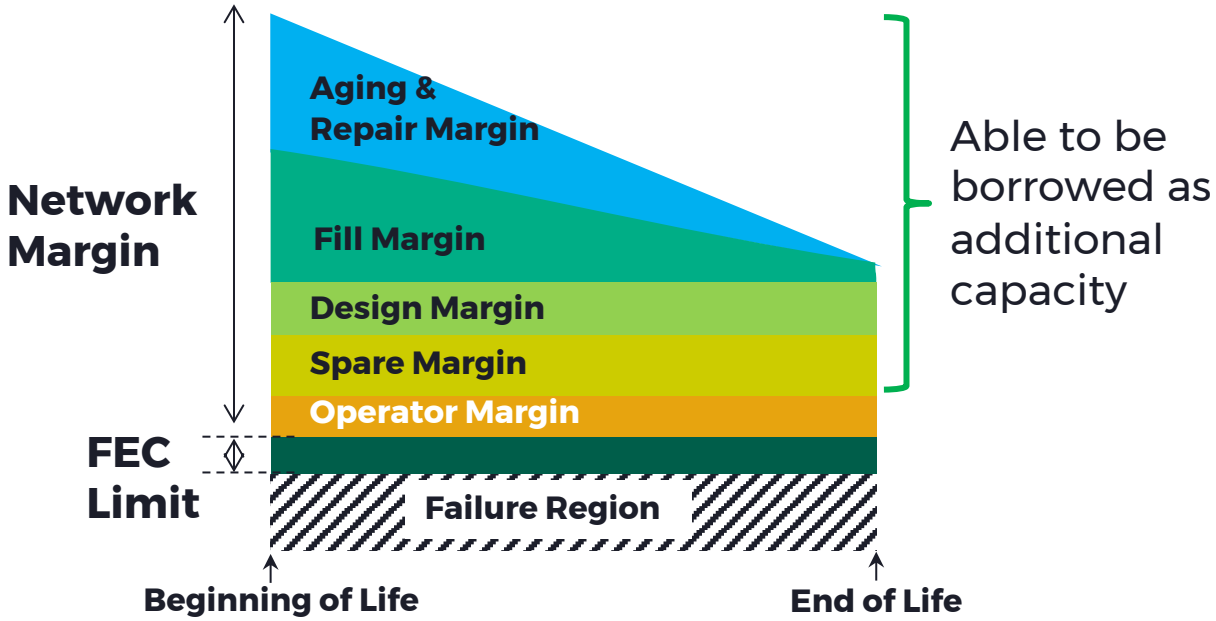
Optical Channel Capacity and Margin



Shannon Channel Capacity Limit



Channel Margin

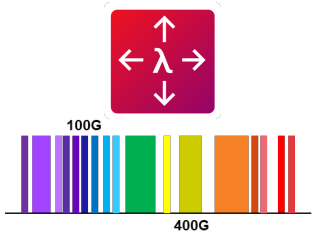
FEC = Forward Error Correction

SNR Telemetry Allows More Optimistic Margins and Higher Capacity

Performance Telemetry
- ESNR and SNR_{EXT}, SNR_{ASE}, SNR_{TNLE} ,…
- Pre-FEC BER and latency…

gRPC

Service Path



Programmable Coherent Optics

Maximum Capacity

- Mine SNR margin to enable maximum traffic across any available path
- Based on real-time telemetry, network topology, and service paths
- Useful as short- to mid-term capacity
- Long-term, telemetry values will change due to environmental issues

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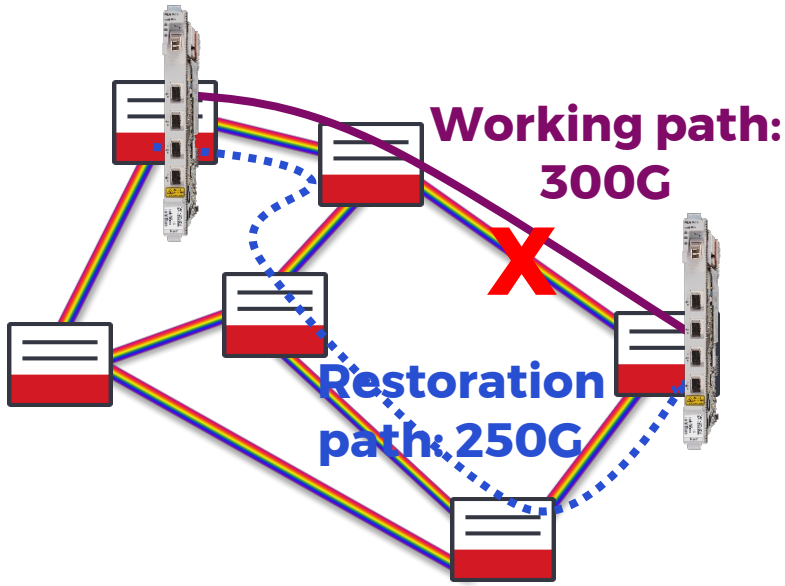
SNR = Signal to Noise Ratio
eSNR = effective Signal to Noise Ratio
FEC = Forward Error Correction
BER = Bit Error Rate

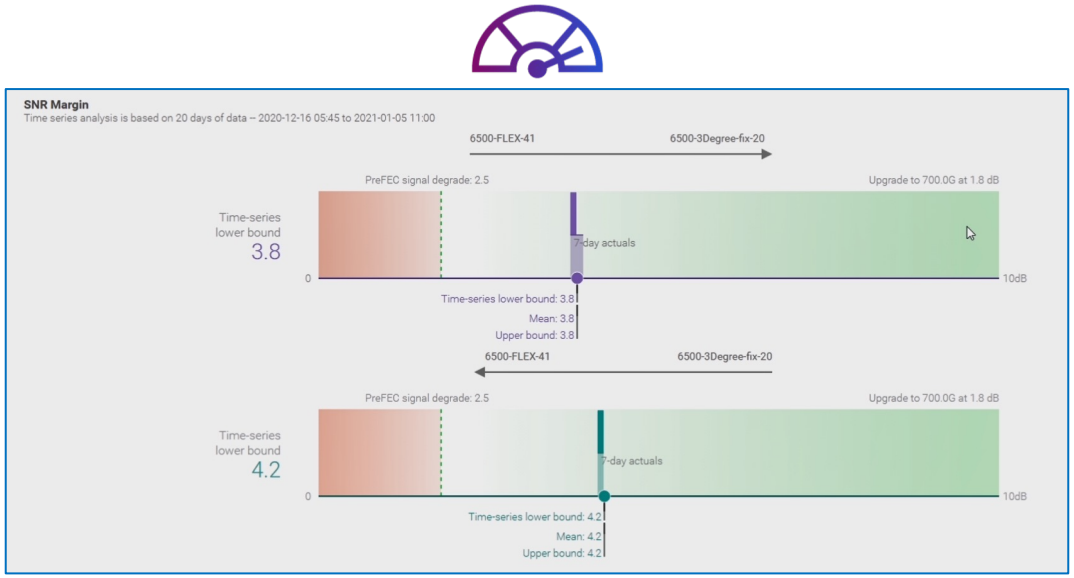
Applications of SNR Telemetry

Partial Capacity Restoration



- Restores optical services (i.e., IP links) at partial-capacity when full-capacity restoration is not possible

Channel Margin Gauge Based Viability

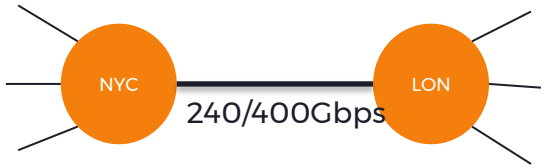


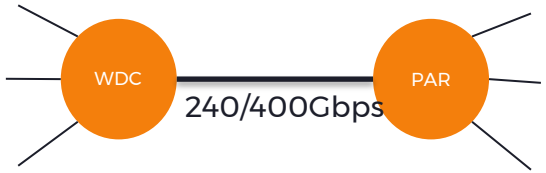
- Increases capacity of existing services (i.e., IP links) over their current paths

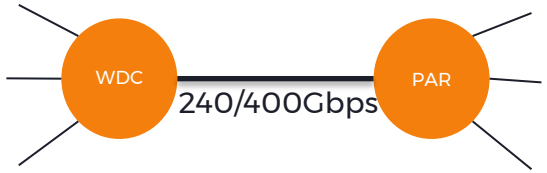
Benefiting from Additional Capacity with Converged IP/Optical Automation

- Most IP networks will tolerate single fiber cut
  - IP networks are often run under 50% link utilization
  - Traffic engineering will use shortest and non-shortest paths and tap into unused IP capacity
- Optimizing at the IP/MPLS layer alone is not always sufficient
  - Multiple fiber cuts often cause congestion and packet drops
- Converged IP/optical automation can help
  - Full-capacity or partial-capacity restoration after fiber cuts
  - Capacity of congested IP links may be increased
  - Create new IP links by repurposing router ports

Converged IP/Optical Traffic Engineering with Partial-Capacity Restoration







Before cut
50%-50% split

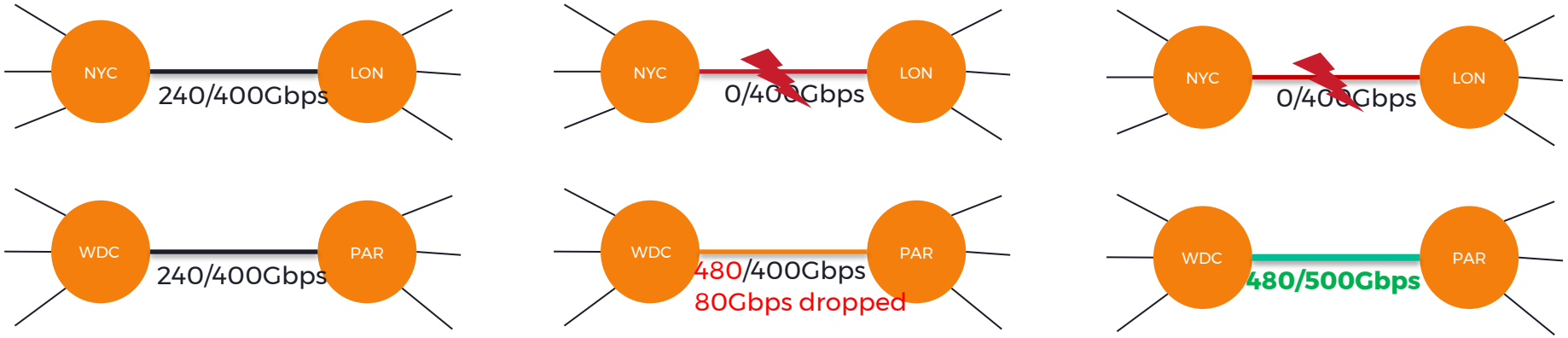
Fiber cut
0%-100% split

Partial restoration
50%-50% split

Partial restoration + TE
20%-80% split

- Optical restoration may take longer paths
  - This results in partial-capacity at the IP layer and may cause packet drops
- Partial capacity restoration and IP traffic engineering needs to be coordinated:
  - Adjust IP link capacity, metrics
  - Adjust SR-TE policies, RSVP-TE tunnels

Converged IP/Optical Traffic Engineering with Capacity Increase



Before cut
50%-50% split

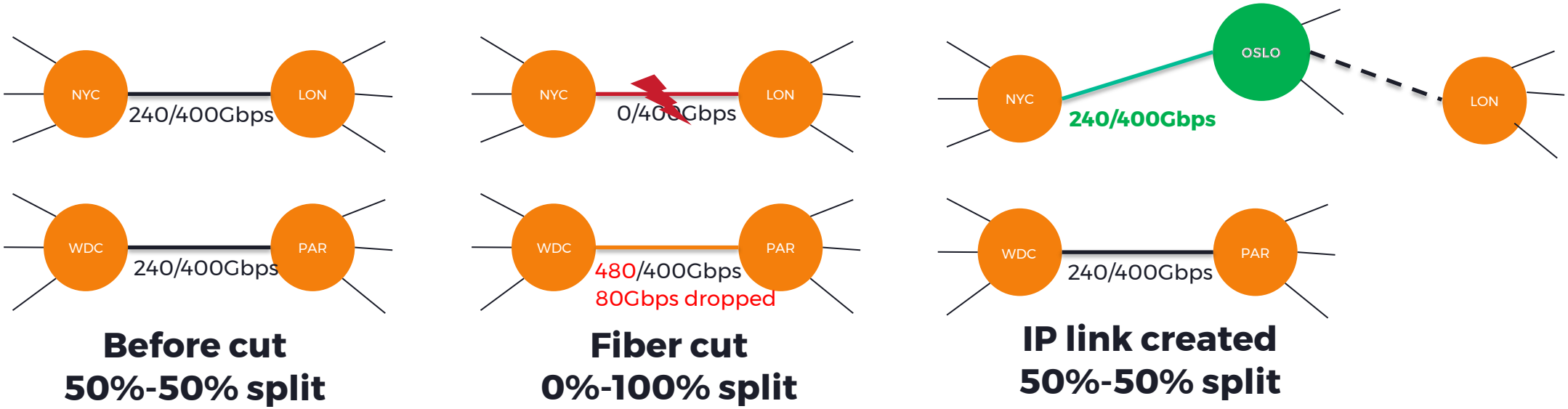
Fiber cut
0%-100% split

Increased capacity
0%-100% split

- A simpler alternative is to increase the capacity of the Washington DC - Paris link
  - Only if Channel Margin Gauge indicates this is feasible
- Issues
  - Re-tuning lasers is destructive and needs to be coordinated with IP layer to avoid packet drops
  - 500Gbps is not a standard ethernet rate; an additional port in LAG would be required

LAG – Link Aggregation Group

Converged IP/Optical Traffic Engineering with New IP Link



- The long and partial restoration path from New York to London goes via Oslo
  - Can the traffic be taken to the IP network at Oslo?
  - Optical path would be shorter and can support higher rate
- Issues
  - Needs an available router port and a DWDM add/drop structure at Oslo

Converged IP/Optical Traffic Engineering

Essential Components to Drive Optimization Decisions

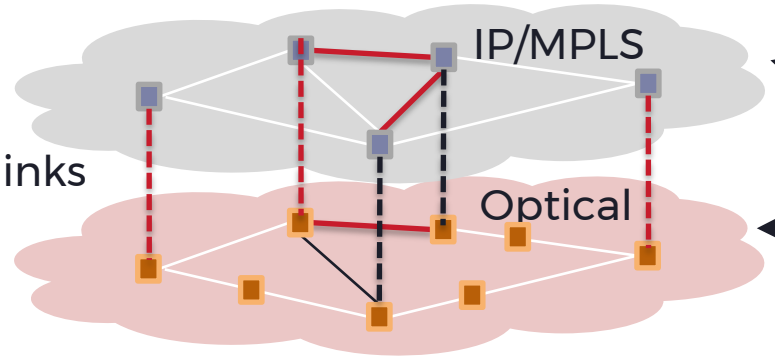
Network Model
- IP topology
- Optical topology
- Transitional (inter-layer) links
- Transitional link capacity flexibility

Traffic Matrices
- Service-aware
- Peak or current traffic levels
- Full-mesh or tactical

Network Policies
- Under/over-provision
- Optimization criteria
- Resiliency requirements
- Cost of change

Coordinated Route Optimization
- Optical telemetry-based capacity and restoration
- IP TE with Segment Routing

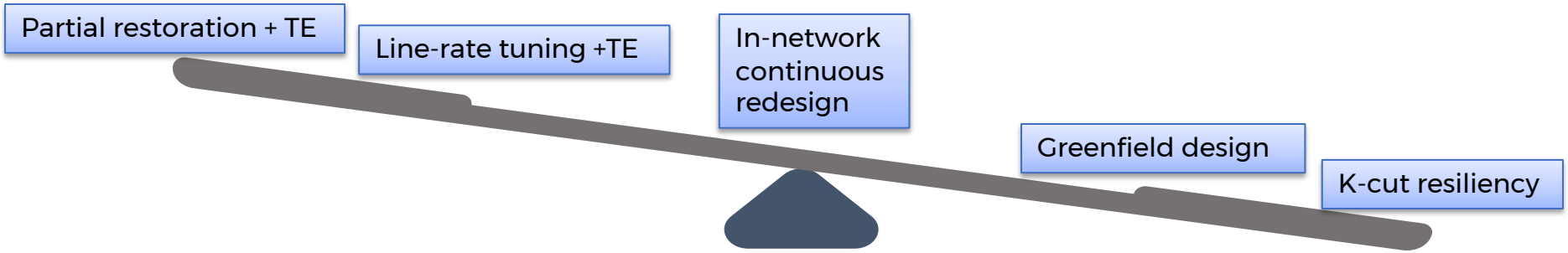
Network State and Telemetry



Configuration Commands

Programming with multi-layer SDN Controller

Spectrum of Multi-Layer Network Optimization



SDN Control

- Reactive/predictive: fiber cuts, congestion
- Suitable for closed-loop automation
- Real-time traffic demands
- Local search and heuristics
- Quick run times and congestion alleviation

Results

- Prioritizes non-destructive solutions
- Leverages ports of down links
- Looks for underutilized LAG ports

Network Planning

- Proactive: k-cut resiliency
- Equipment refresh, disaster recovery, …
- Forecasted traffic demands
- Global search, linear/integer programming
- Long run times and global optimum

Results

- Any port can be taken for a more optimum network
- Network topology evolves with traffic demand

Key Takeaways

1

Dynamic optical layer enables maximum traffic across any available path by mining SNR statistics and borrowing from channel margins

- ✓ Full-capacity or partial-capacity restoration after fiber cuts
- ✓ Short-/mid-term additional capacity using channel margins

2

IP traffic engineering can take advantage of this additional capacity when IP TE alone is not sufficient

- ✓ Congestion after multiple fiber cuts
- ✓ Congestion due to traffic surge at the IP layer

3

Visibility and coordination between layers allows optimized capacity engineering

- ✓ A converged IP/Optical SDN controller is necessary for automating complex workflows

Thank you

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