

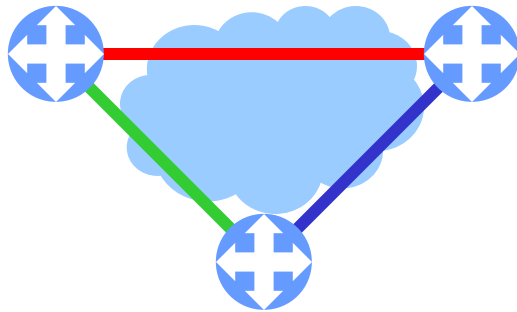


Taking IP Layer Needs into Account during the Optical Layer Planning Process



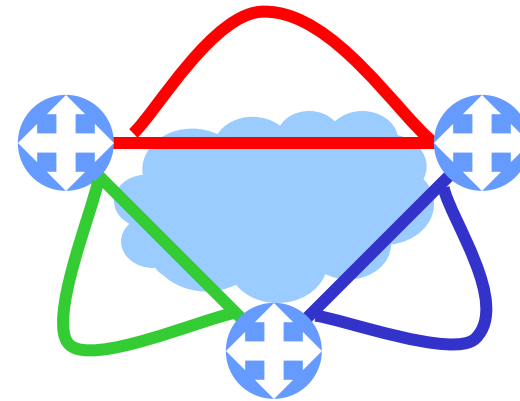
Ori Gerstel, IPoDWDM Architecture, Cisco

Two Fundamental Models for Protecting an IP Core



IP over unprotected links

- IP links run at < 50% load
- L0 unprotected – L3 protects against all failures

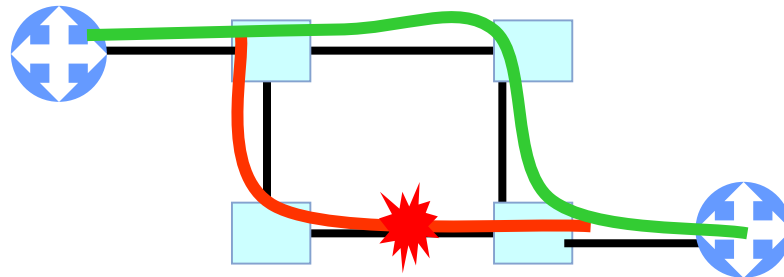


IP over L0 protected links:

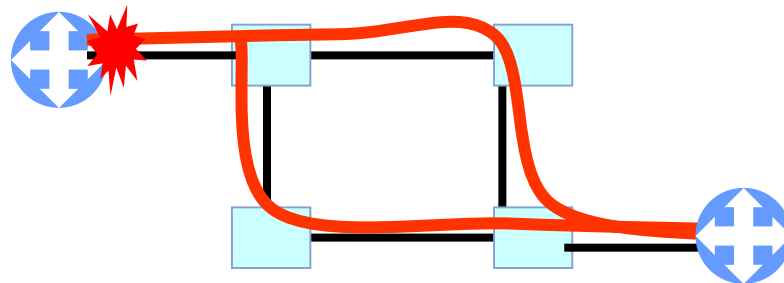
- IP links run at < 50% load
- L0 layer protects each IP link (typically 1+1 for DWDM)
- Hold-off at L3 to wait for L0

Observation: L0 protection adds cost to L0 but does not save cost in L3 layer

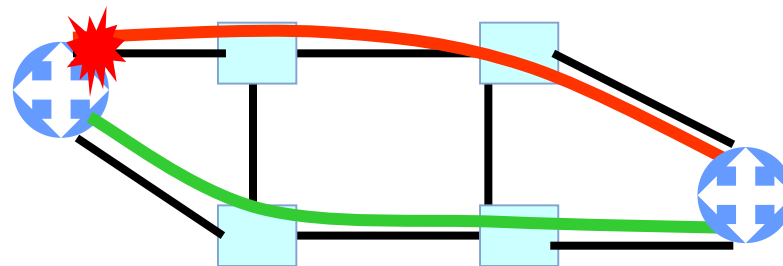
Optical protection works for optical failures



But fails when a router interface fails – L0 cannot protect



Router protection works well against both optical failures and router failures



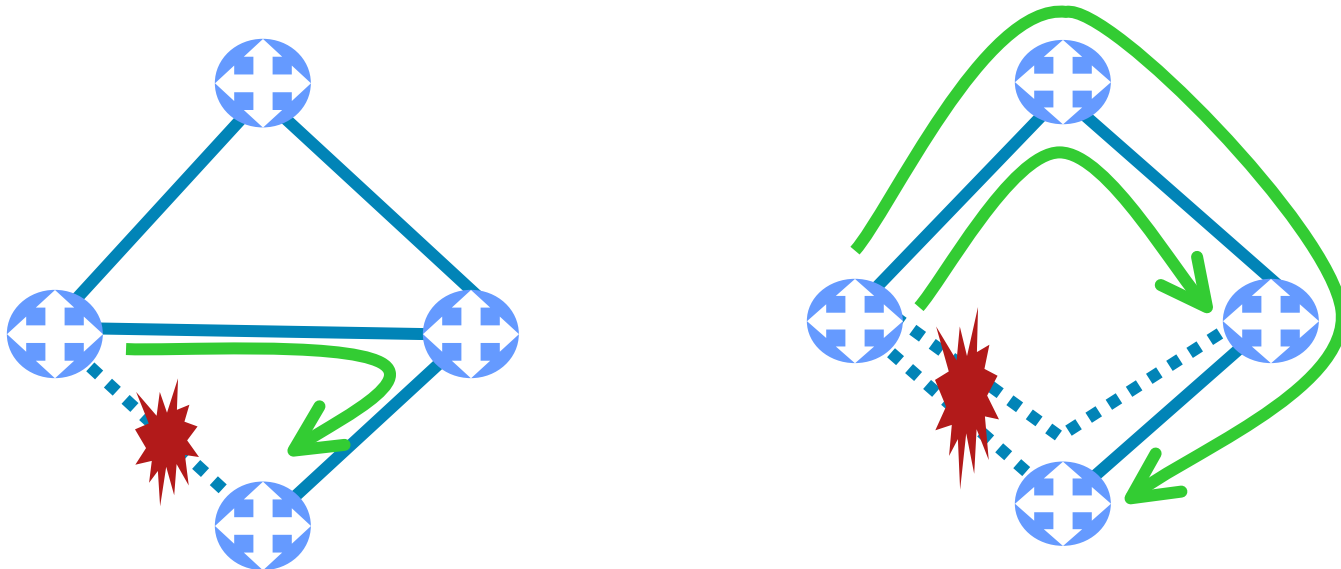
Therefore optical protection is no substitute for IP protection but a potential addition

Additional reasons why most large SPs run IP over unprotected wavelengths

- **L3 can deal with multiple failures gracefully:** use QoS to temp drop low priority traffic → much higher available protection bw
- **L0 protection requires hold-off at IP layer:** to avoid race conditions. → reaction to pure IP faults slower than needed
- **L0 protection is bandwidth consuming:** $> 2x \text{ wavelength} \cdot \text{km}$ → less than 25% of the bits on the fiber are revenue generating
- **L0 protection is expensive if using 2 TXPs/end:** especially for 40G transponders
- **L0 protection not robust enough if using 1 TXP/end:** does not work if the failure is induced by noise or PMD
- **Shared L0 protection is slow:** can't upset optical power mgmt
- **Dedicated L0 protection slow at 40Gbps:** modulation format & TDC devices react slowly
- **L0 protection is less flexible:** protects pt-pt link. L3 can protect via 3rd router or dual homing

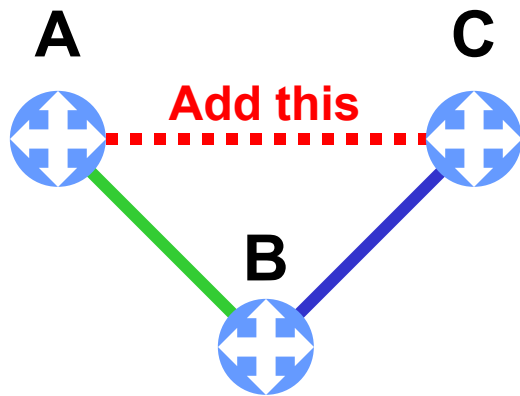
...But this implies more careful planning

- Single optical failure → multiple IP links fail
- L3 protection plans should be aware of L0 routing
 - Share SRLG data
 - need to simulate all L0 failure modes and provide enough bandwidth at L3 for each

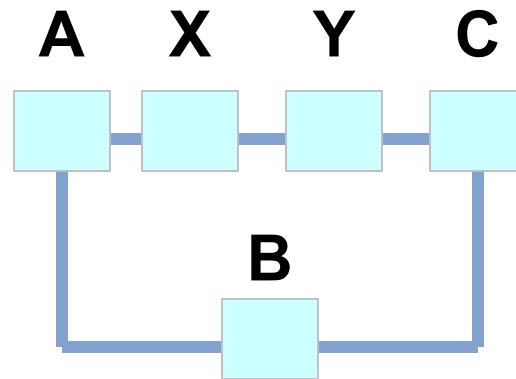


Also L0 routing should be aware of IP protection needs

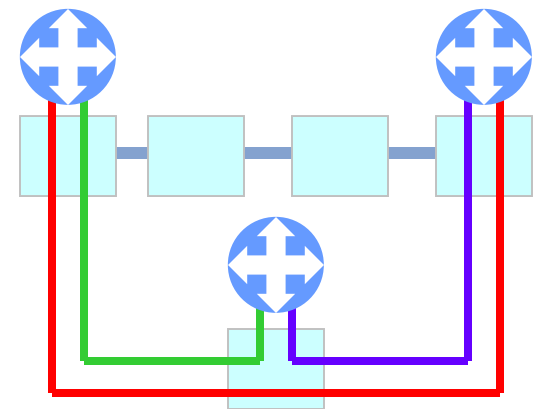
L3 topology



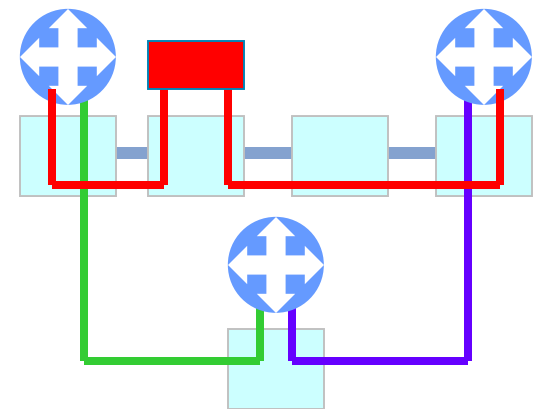
L0 topology



(a) Bad Mapping



(b) Good Mapping

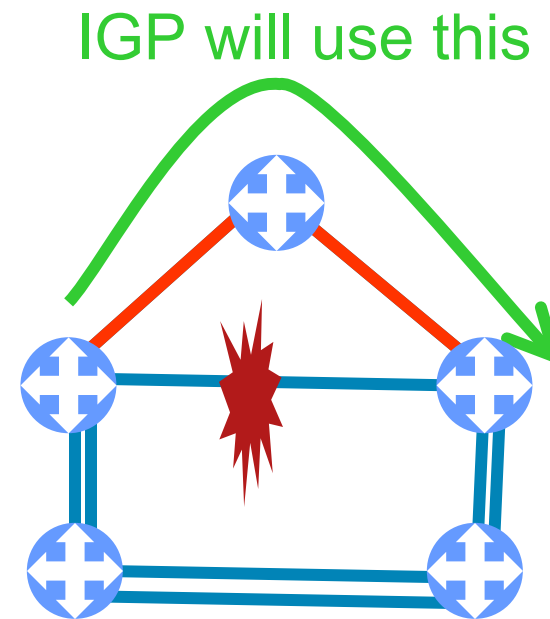


- Optimal L0 routing for A-C w/o considering L3 → mapping (a)
- Single fiber cut results in failure of FRR
- Using a longer optical route (even extra regens) provides lower overall cost

Note: L3 planning not just a Max Flow Problem

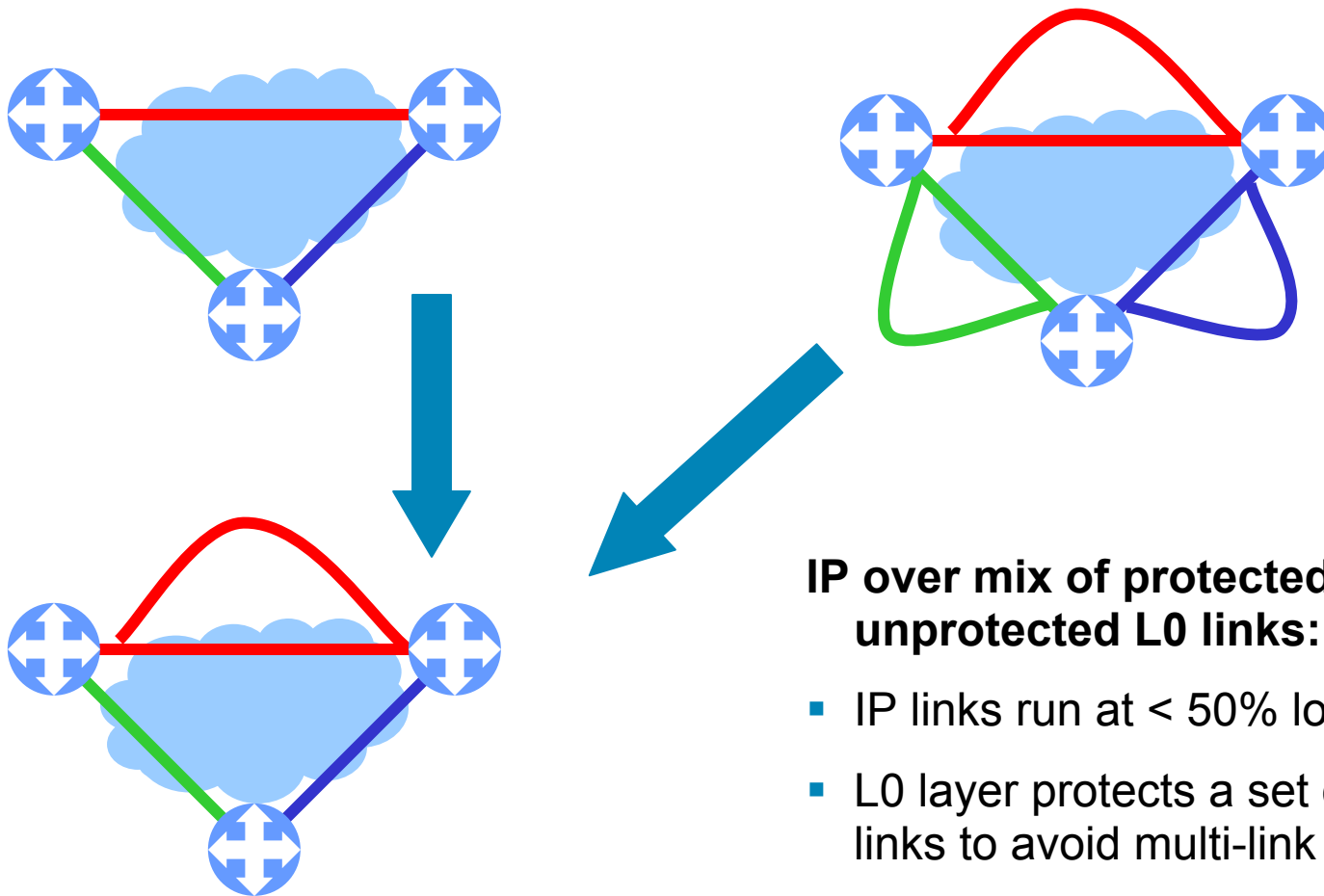
Need to Take into Account IP Routing Behavior

- If IP layer protection is based on topology convergence (ISIS or OSPF), then IP will route along shortest (weighted path)
- Need the capacity in the right place – not just anywhere



Combined L0 + L3 Design

Does a Hybrid Protection Model Provide Benefits?



IP over mix of protected and unprotected L0 links:

- IP links run at < 50% load
- L0 layer protects a set of key IP links to avoid multi-link L3 failures
- Other links rely on L3

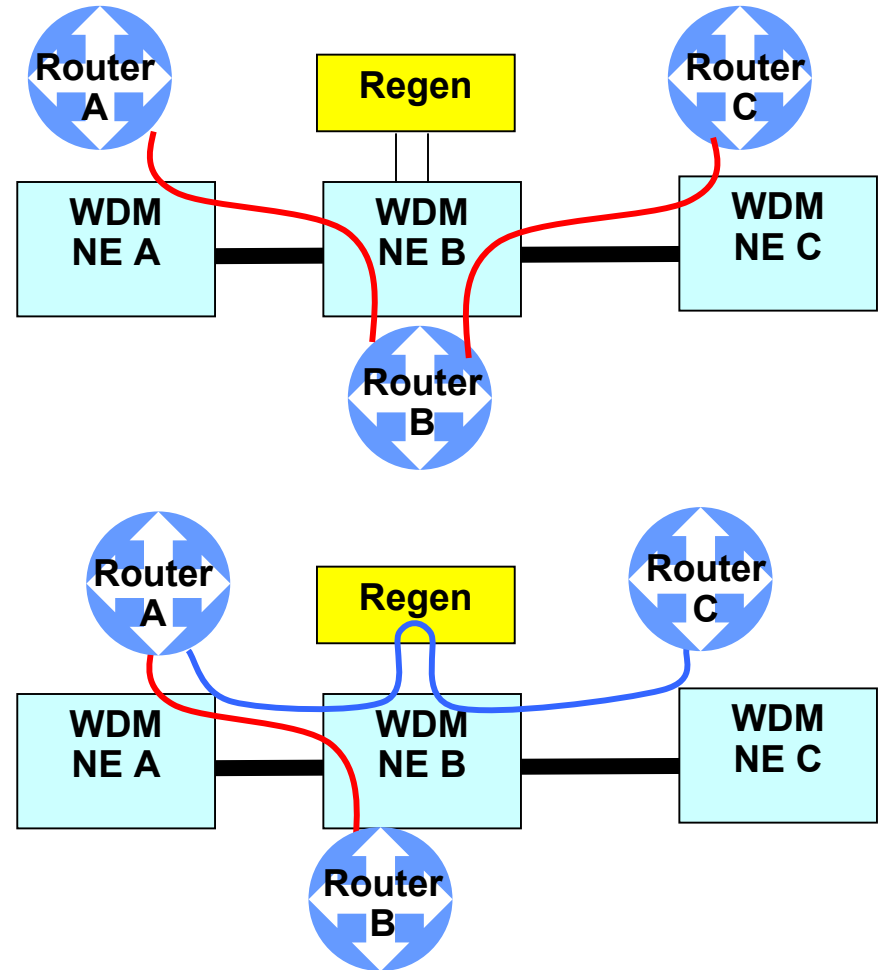
Combined L0 + L3 Design

Should L3 Topology be Influenced by L0 Considerations?

- **Example: consider 2 possible network expansion options →**
- **If separate L0/L3 planning:**

The IP group may choose option (2) – it's equivalent from an IP cost perspective

However, from an optical perspective, link A-C is more expensive & labor intensive
- **If both layers are planned together, option #1 is better**



Further Reading

- O. Crochat, J-Y. Le Boudec, O. Gerstel, “Protection interoperability for WDM optical networks”, ToN, 2000
- C.-F. Su and G. Sasaki, "Survivable IP Over WDM: Guaranteeing Minimum Network Bandwidth," Proc. IASTED Conference, 2002
- F. Giroire, A. Nucci , N. Taft, C. Diot, “Increasing the Robustness of IP Backbones in the Absence of Optical Level Protection”, Infocom 2003
- C. Rozic and G. Sasaki, "Cost Efficient Survivable IP over WDM with Dual Homing", OFC'08

Summary

- Most core networks are opting for IP protection over unprotected wavelengths
- L0 planning must be aware of L3 needs
- L3 planning must be aware of L0 routing (SRLGs)
- At a minimum need exchange of data between 2 separate planning processes
- Even better – common design tool that considers both layers to come up with an optimal design
- Challenge: organizational “wall” between L0 and L3 in many SPs
- Need to break wall due to mounting price/bit pressures

