Complexity in Multi-level Restoration and Protection Strategies in Data Networking

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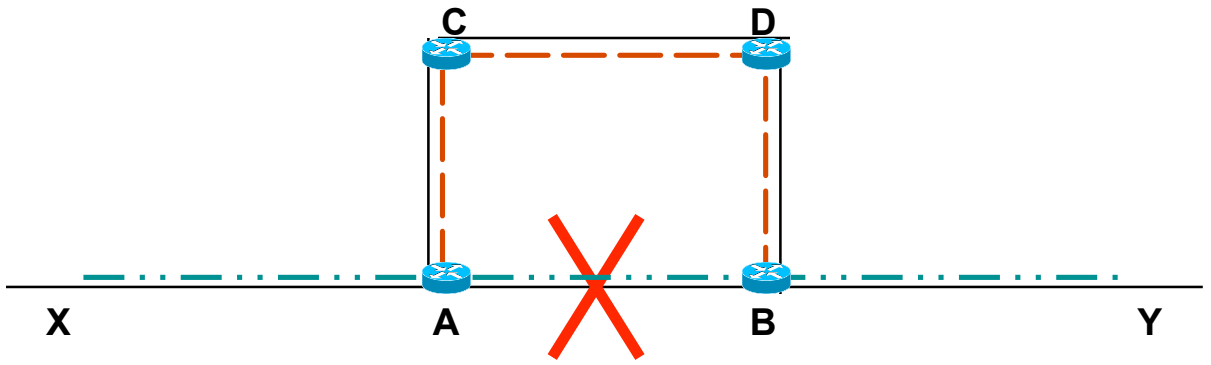
October, 2002

What makes it complex?

- **Multi-technology network *viewed as a stack* of single-layered networks**
- ***Contention* between different single layer schemes**
- ***Lack of sharing* of spare resources between layers**
- **Natural evolution has resulted in *new survivable layers* and restoration techniques**
- **Differentiation of *service reliability requirements* and recovery for target failures**
    - **Attempt restoration at traffic injection layer**
    - **Granularity of recovery scheme: lambda, LSP, prefix**
    - **Lower layers for cable cuts**
    - **Higher layers (ATM, IP) demands different recovery**

Restoration basics



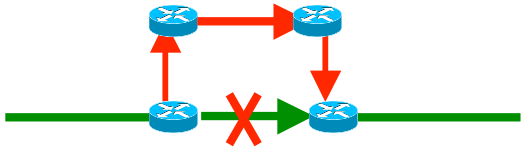
Restoration Requires:

- **Fault detection**
- **Spare capacity**
- **Router or Switch to put failed service on this capacity**
- **Control protocols to reroute failed circuits**

Effect of topology on required overbuild

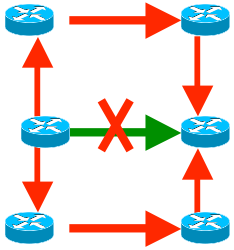
Capacity overbuild
(Protection Capacity/Service Capacity)

Connected 2



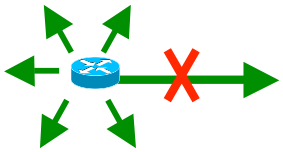
100%

Connected 3



50%

Connected N

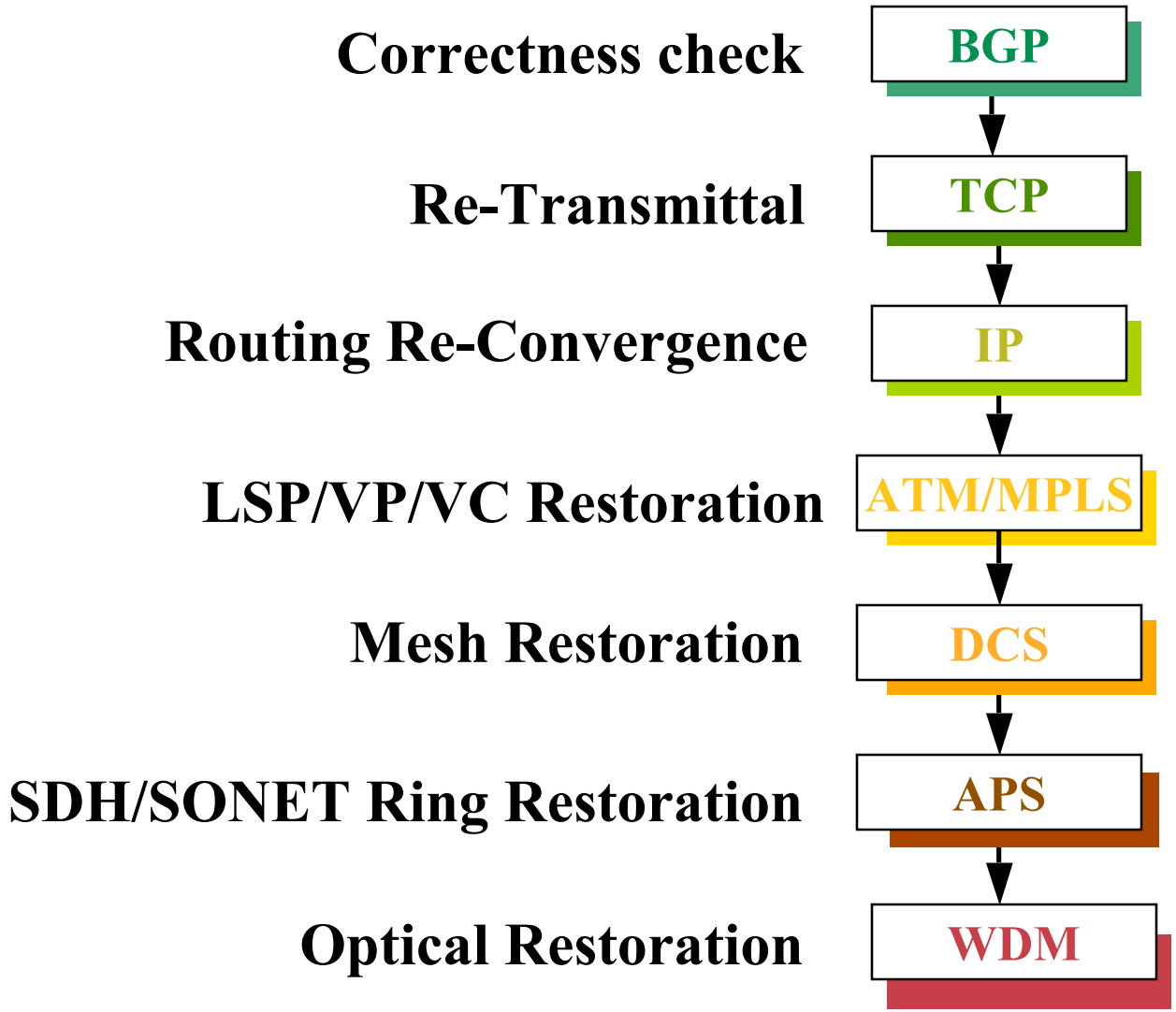


1/(N-1)

Connected = # Of Physically Diverse Routes that can restore at granularity of interest

Effect Of Layering

Current stack



Building networks out of “boxes” aka protection at the lowest layer

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- Each **survivable layer** in the overall recovery process has to be **managed**
  - ***Goal***: one layer is not activated for a failure that is supposed to get resolved at another layer.
  - ***Problem***: end nodes of disrupted network connections at a higher layer can generally not distinguish from a lower layer failure.
- Multi-layer ‘activation’ may result in **competition for network resources**
  - The only coordination point available today is inside a router
  - Manage alarm messages that are passed up to higher layers
  - Network congestion and **flap and burn**
- **Spare resources required** in every layer where a recovery scheme is active,
  - Few ways exist to combine the spare capacity pools in different layers.
- The **spare capacity** pool of a higher layer has to be supported through lower layer paths
  - If the network is designed in a negligent way, may require a serious amount of resources.

Building networks out of encapsulations aka protection at the highest layer

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- A higher layer recovery scheme **resolves all layers below**
- Advantages:
  - Easier to manage with the survivability scheme in higher layer
  - The operational **complexity can be avoided**
  - Granularity of the higher layers is finer, less spare capacity is needed
  - This does **not imply highest layer recovery is cheaper**
- Disadvantages:
  - May **complicate the rerouting** in event of lower layer failures
  - When lower layers are really hosed, may involve **reconfiguration in network elements** far away from the original failure cause
- Special precautions given the desired level of granularity.
  - Assemble LSPs sharing physical routes into aggregate groups to reduce the recovery „efforts“ in case of physical failures.
- Ensure that the spare and working resources are physically disjoint.
  - The routing constraints of higher layers are more severe than lowest layer approach: **May create higher capacity requirement**

Building networks with ‘converged restoration’ strategies

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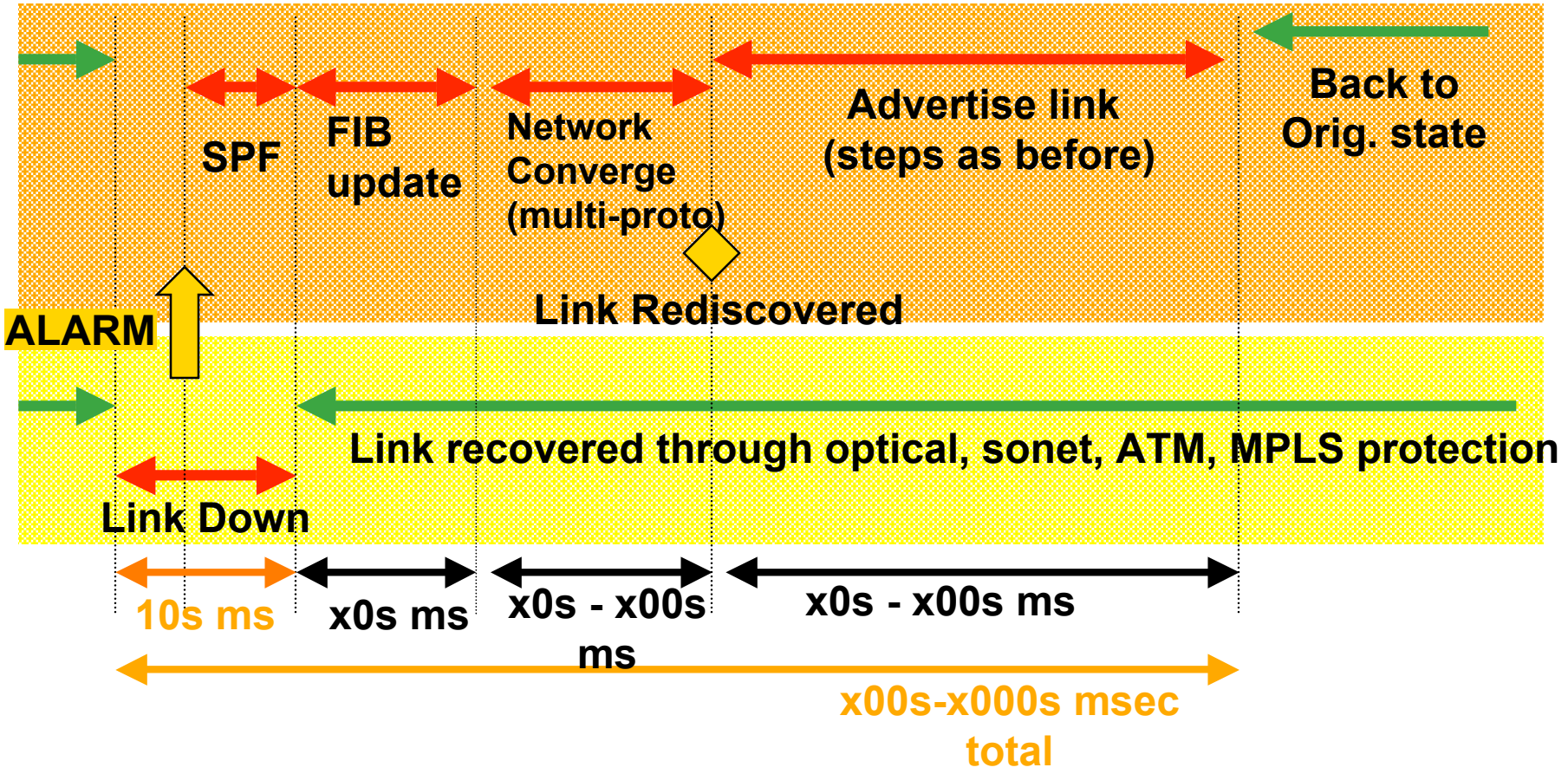
- Converged scheme **recovers disrupted traffic at multiple layers**
  - The joint optimization of spare capacity of may lead to some distributed (between the two layers) capacity allocation.
  - **Eases operation** of different service types and needs.
  - Attempt to have **restoration at multiple layers in parallel**
- One drawback is the **increased complexity**
  - Lower layer will recover most of the disrupted traffic
  - The affected paths/LSPs/VCs are then recovered
- **New protocols** required to activate the appropriate network layer
  - **All devices in path have to be engineered the same way**
    - OSI, PNNI, GMPLS
- The complexity and the bottom-up, multilayer activation **may require forklift of equipment** in all layers

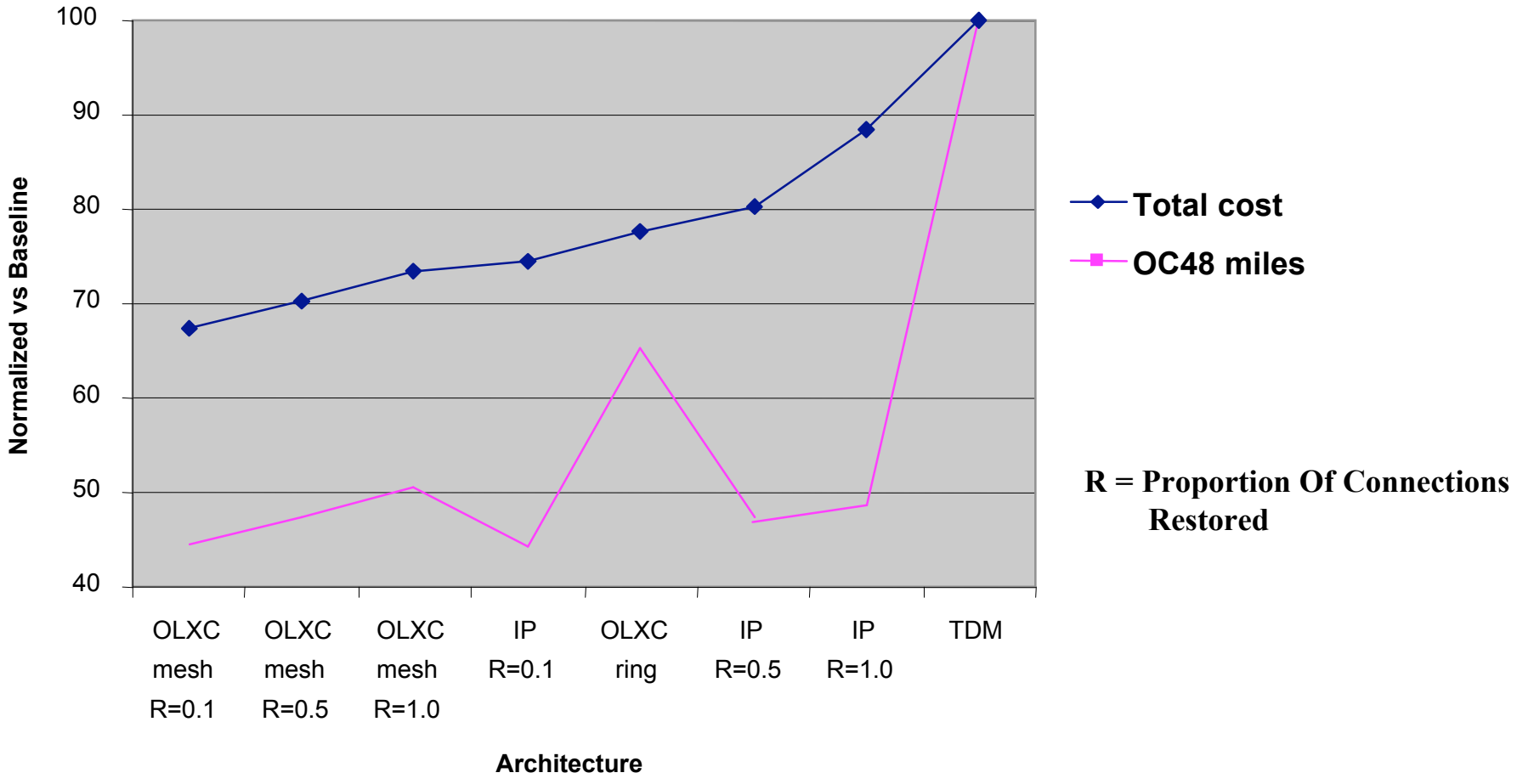
Counter-Productive Protection Behavior: Need Hysteresis between layers



- **Instant response to Level 1 alarms in routers causes unnecessary routing activity, routing instability, and traffic congestion if there are lower layers involved in recovery strategy**

Modified from Source: RHK

Restoration Economics



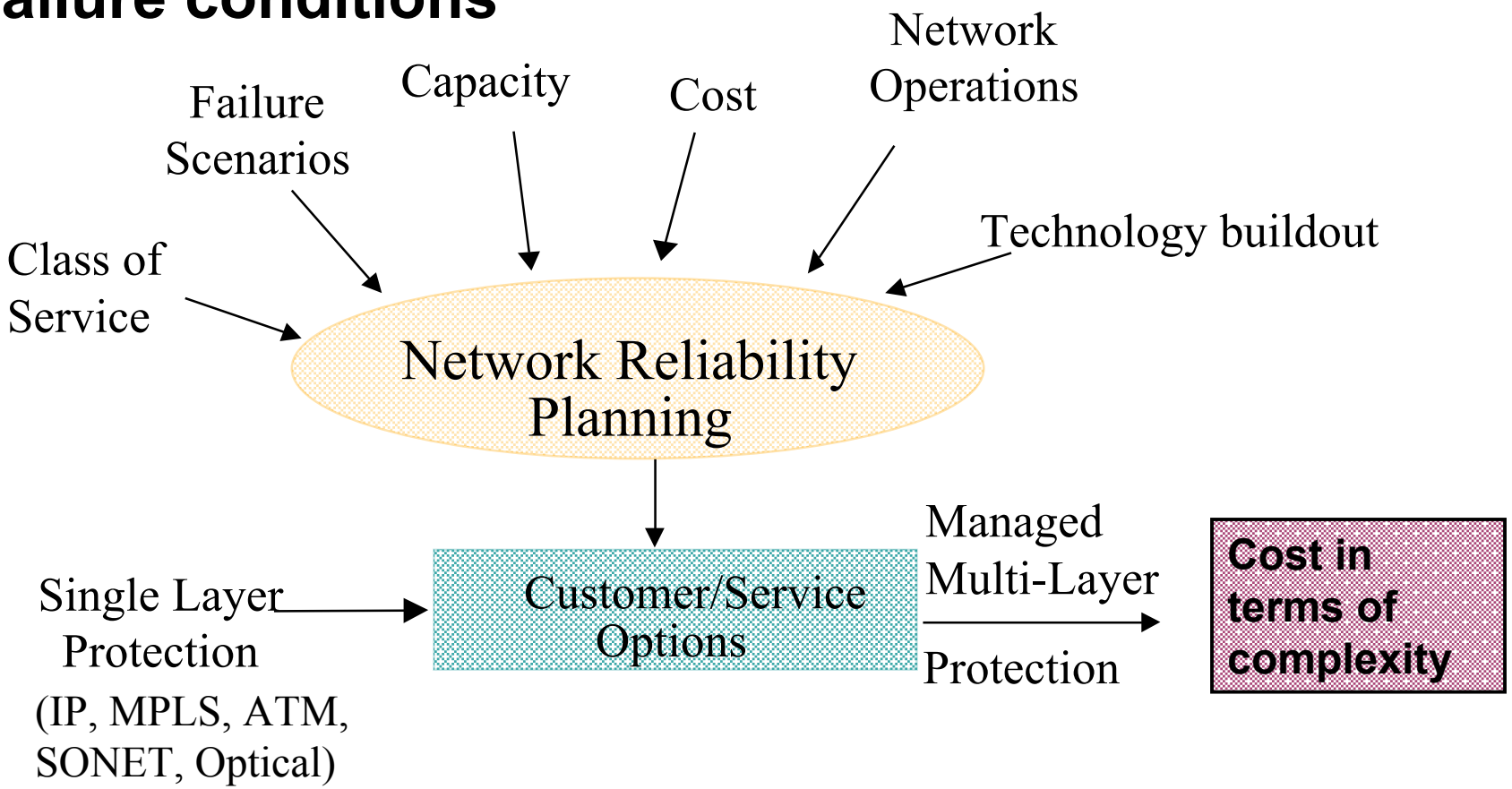
References:. R. Doverspike et al, **"Transport Network Architectures In An IP World"**, Infocom 2000.

Network Restoration Layer Characteristics

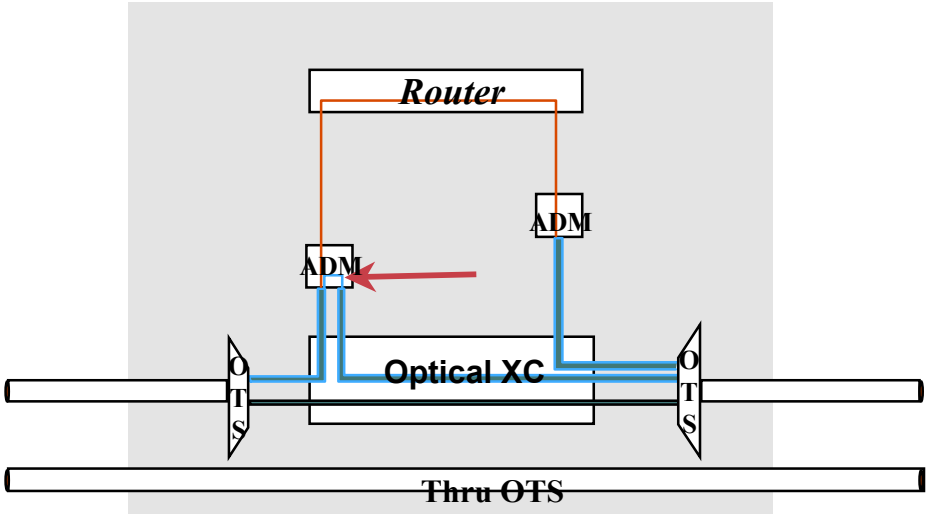
Network → / ↓ Variables	Fiber	Optical	Sonet/SDH	ATM	IP/MPLS
Restoration Technique	Simple switch	APS, mesh	APS, DCS	VC switch	Route
Cost Gbit/$	Lowest	→	→	→	Highest
Granularity	Coarsest X00s lambdas Tbit	Lambda <= 10 Gbit	Medium	VC	Finest: LSP prefix
Restoration Speed	X00s msec	X00s msec	X0s msec	msec to sec	msec to sec
Independent Control plane	NO	YES	YES	YES	YES

Network Survivability planning

Definition: an aspect of network reliability that quantifies the performance of a network under failure conditions



Optical Layer Restoration Motivation
Reducing Switching Costs - lowest layer with control plane



Location Of Cross-Connect Function	Relative Cross-Connect Cost
Router	7
ADM (SDH RING)	5
Thru Wavelength	1.0
Thru OTS (No XC)	0.0

Inefficient If Only A Small Proportion Of Traffic Really Needs Restoration

Trade-Off: Granularity vs Switch Cost/Gb Restored

Modified from Source: John Strand

Most recent multi-layer convergence attempt: Generalized MPLS

- **Utilize the common suite of protocols for setting up, maintaining, and restoring lightpaths in Optical Layer**
- **Provide extensions to address Optical Layer unique features and requirements**
- **Provide potential to integrate protection/restoration in MPLS, IP and Optical Layers**

Challenges:

- **Managing shared restoration capacity**
- **Timely and reliable failure detection and notification**
- **Coordination between different layers in protection/restoration**
- **Deployment (operations) and technology**

Remain calm at all times

- Even with this level of complexity, many networks continue to function
- Is there a limit to the complexity after which we cannot manage it?
- Is there a limit after which we cannot afford the cost?
- Can devices, protocols and networks be engineered for converged solution?
- It only makes sense to pay for and engineer the level of restoration you require
  - *If x00 - x000 msec is good enough, why add complexity/cost to get to 50 msec?*

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