

Physical Layer Network Survivability

Rajesh Jagannathan

Rajesh Jagannathan

Survivability – An Introduction

What is it?

- An OSI layer1 system of equipments, protocols, network design that provides robustness in the event of some failures. Usually guards against single failure.

Why layer1?

- Higher layer survivability mechanisms get overwhelmed
- Simplicity / Scalability / Cost-effectiveness
- Solution for higher layers without survivability mechanisms

Failures:

- Fiber cut, distortion
- Component failure (laser, chip, inter-connection etc..)
 - Loss of Signal (LoS),
 - Unacceptable Bit Error Rate (BER)

• Protection

- Pre-determined survivability schemes with rigid topological structure
- Fast
- More spare capacity

• Restoration

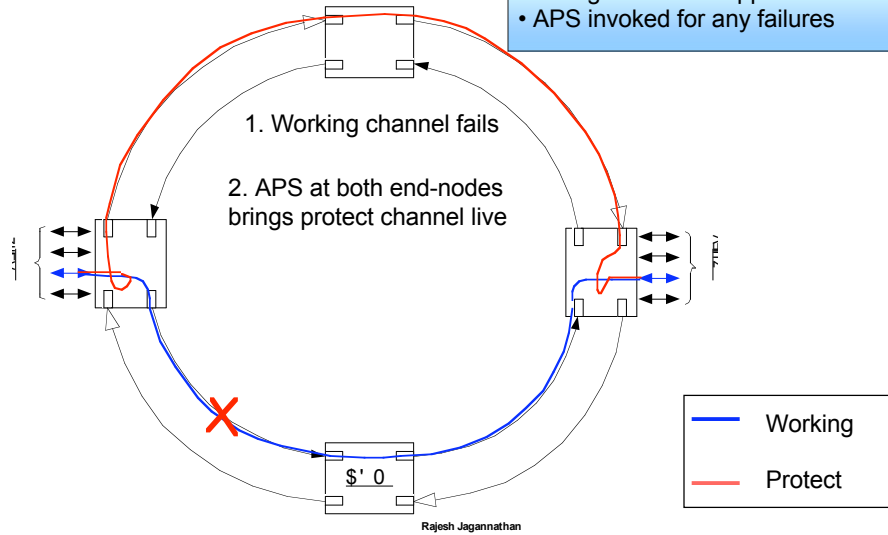
- Dynamic survivability schemes with flexible topological structure
- Slower
- Lesser spare capacity

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Rings - Path Protection

UPSR : Unidirectional Path Switched Ring

- Two Rings circulating opposite directions
- Protect channel corresponding to a working channel in opposite direction
- APS invoked for any failures



UPSR Design Issues

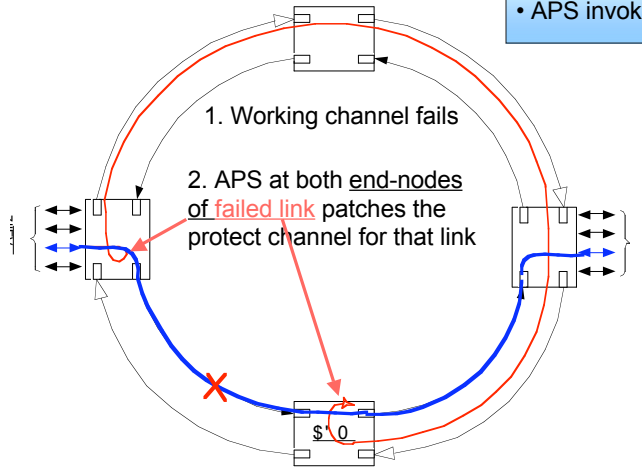
- Preferred for simplicity
- Straightforward Routing
 - Each demand unit consumes one unit of capacity in the entire ring
 - Dedicated Capacity

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Rings - Link Protection

BLSR : Bidirectional Line Switched Ring

- Two Rings circulating opposite directions
- Protect channel corresponding to nodes of a failed link
- APS invoked for any failures

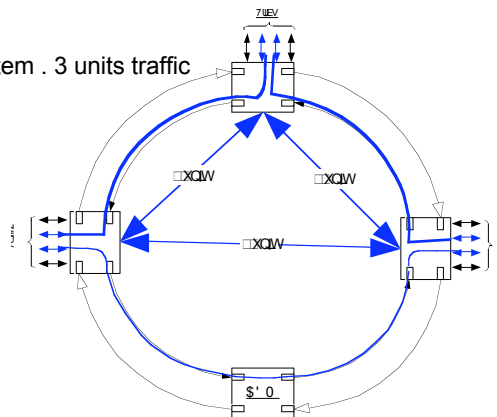


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BLSR Traffic Packing Issues

- 1 unit of ring capacity could serve multiple non-overlapping demands
- Stacked rings

Example : 1 channel system . 3 units traffic



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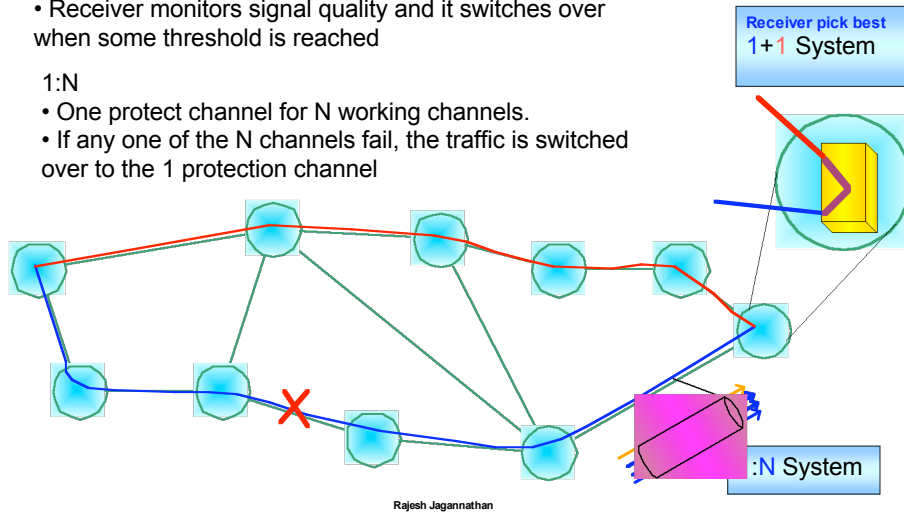
Linear Systems (1+1, 1:N)

1+1

- Both Working and protect channels transmit at the same time in diverse paths
- Receiver monitors signal quality and it switches over when some threshold is reached

1:N

- One protect channel for N working channels.
- If any one of the N channels fail, the traffic is switched over to the 1 protection channel



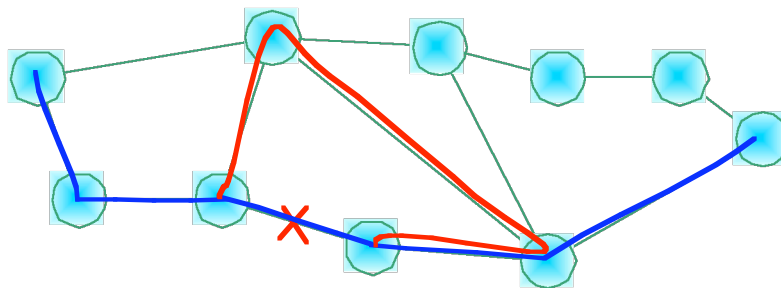
Linear System

- 1+1
 - Dedicated capacity, therefore inefficient use of resources
 - Simple, eliminates the need for complex switches
 - Shortest cycle, 2 disjoint paths
- 1:N
 - Used for systems that have lesser failures
 - Systems that require less reliability
 - Widely used for servicing & upgrades

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Link Restored Mesh Network

- Arbitrary mesh topology
- When a link fails, alternate path is set up to patch up the end-nodes of the failed link. All failed traffic is re-routed through this patch.
- Switches and protocols enable new path set-up
- Spare capacity for restoration provided on links to enable restoration of all traffic affected by any single link failure



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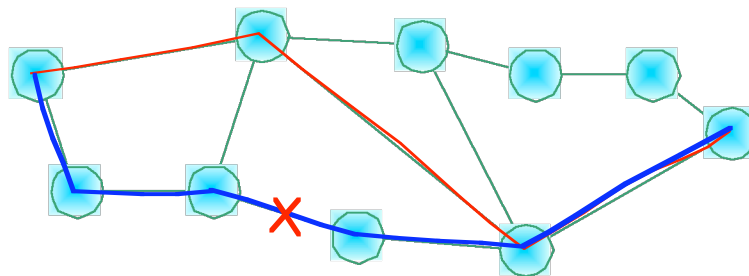
Link Restoration Issues

- Backhauling
- Shared Vs Dedicated capacity
 - All-optical restoration may use dedicated capacity
- Dynamic Vs Static
 - Capacity allocation
 - Cut N' Restore
 - Shortest path, Least spare capacity miles etc..
- Better utilization of capacity

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Path Restored Mesh Network

- Arbitrary mesh topology
- When a link fails, alternate paths are set-up between end-nodes of all failed traffic
- Switches and protocols enable new path set-up
- Spare capacity provided on links to enable restoration of all traffic affected by any single link failure



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Path Restoration

- No backhauling
- Shared capacity
- Dynamic Vs Static
- Capacity allocation
 - Cut N' Restore
 - Shortest path, Least spare capacity miles etc..
- Best utilization of capacity

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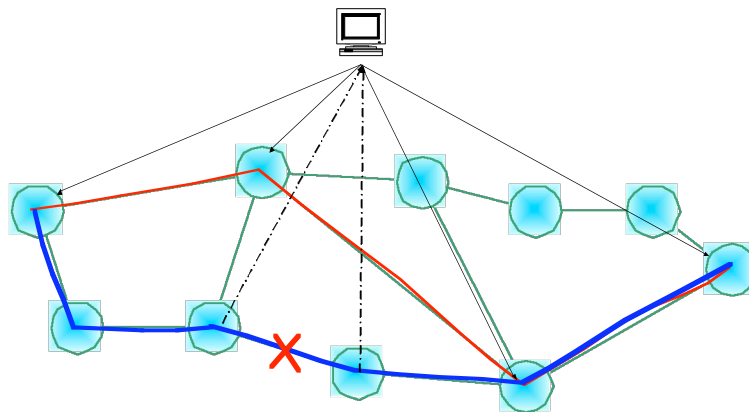
Cut and Restore

Pathfinder(P_{ab}, L_{xy}) : Method that finds a path between end-nodes a & b without using the link $x-y$. $x-y$ is the link that has failed. Any rerouting policy could be embedded into Pathfinder().

1. For all links in network, fail a link $x-y$ that has not been failed before
2. Find alternate paths using Pathfinder() for all traffic that was affected by this failure
3. Note down the spare capacity $Sp(L_{mn})$ needed on each link $m-n$ to accommodate this rerouting.
4. Repeat steps 1-3 updating $Sp(L_{mn})$ in any pass n iff $Sp(L_{mn})_{pass(n)} > Sp(L_{mn})_{pass(n-1)}$
5. $Sp(L_{mn})$ represents the capacity needed in each link $m-n$ to guarantee availability of restoration path according to policy implemented in Pathfinder().

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Centralized Restoration



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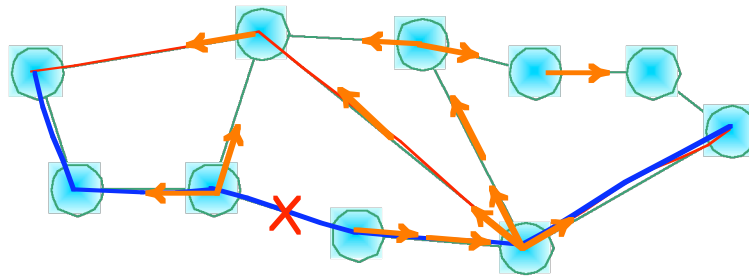
Centralized Restoration

- Shared capacity
- Scalable networks
- Restoration scalability
 - Signal propagation
 - Processing speed
 - Routing table access and structure
- Simple switches

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Distributed Restoration

- Each node is aware of the network neighborhood (layer 3 example is a router)
- Messaging protocols allow network self-discovery
- The end nodes corresponding to a failure propagate the messages and queries to other nodes to discover a restoration path.
- A path set-up protocol is followed by the nodes to provision the restoration path.



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Distributed Restoration

- Shared capacity
- Scalable networks
- Restoration scalability?
 - Sniffing algorithms
 - Processor speeds
 - Routing table structure and access
- Complex switches to implement protocols

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Hybrid Networks

- Rings, Linear Systems, WDM, Zoned restoration to capture desirable qualities for different parts of network
- Layer3-Layer1 interwoven restoration for faster stabilization
- Ringed-mesh
 - A mesh topology is covered with rings
- UPSR-BLSR combinations

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References & Conclusion

Papers & Articles

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Multiwavelength Optical Networks: A Layered Approach, T. E. Stern and K. Bala, published by Addison-Wesley

Mesh-based Survivable Networks, Wayne D. Grover

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Standards:

[Synchronous Optical Network \(SONET\) - Automatic Protection T1.105.01-2000](#)