



UNIVERSITE DE RENNES 1



Network Survivability

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Outline

- Introduction to Network Survivability
- Types of Network Failures
- Reliability Requirements and Schemes
- Principles of Network Recovery
- Performance of Recovery Mechanisms
- Characteristics of Recovery Mechanisms (single layer)
- Conclusion

Network Problem

- Failures
 - Unintentional
 - Natural disasters, software bugs, human errors, etc.
 - Intentional
 - Maintenance action, sabotage, etc.
- Nodes or links
 - Physical or logical
- Disruption of communication services
 - Loss of revenue for business consumers
 - Social unrest, or human lives could be in danger when critical distributed applications stop
 - The provider's operations rely on its provider's own network

Reliability Definition

- **Reliability**: probability of a network element to be operational during a certain time frame [E800]
- **Availability**: probability of a network element to be operational at one particular point of time
- Numerical example:
 - If probabilities are mutually independent
 - Availability of a path = <product of> availability of all network elements along the path
 - Path_availability = 0.9996. 0.9997. 0.9998. 0.9999. 0.9995 = 0.9980
 - If probabilities are not independent then, overall availability is lower

Network Survivability

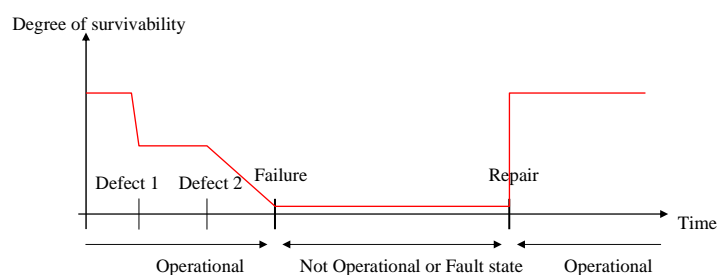
- **Network survivability**: ability to recover the traffic in the event of failure, causing few or no consequences for the users
- Impossible for a network to be completely survivable in case of dramatic events
 - For instance major earthquake
- **Degree of survivability**
 - Capacity to recover from single and multiple network failures (considering the probability of each type of failure)

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Failure Terminology



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MTBF

- **Mean Time Between Failures:** average time interval between two subsequent failures on the same network element
- **Mean Time To Repair (MTTR):** average time needed to repair a failed network element
- **Availability of a network element:**
 - $A = 1 - \text{MTTR}/\text{MTBF}$ (MTBF \gg MTTR)

Type of network element	MTBF range (h)	typical MTTR range (h)
Web server	10^4 - 10^6	1
IP interface card	10^4 - 10^6	1
IP router	10^5 - 10^6	2
SONET/SDH DXC	10^5 - 10^6	4
1000 km of cable	10^4 - 10^5	10^3

Types of Network Failure

- **Single-link failure**
 - The link between two adjacent network elements
 - Either one direction of a bi-directional link (broken laser equipment), or both (cable cut)
- **Single-node failure**
 - All links attached to the node are out of service
- **Focus on single failure scenarios**
 - The probability that two or more faults are overlapping in time can be neglected, if they are statistically independent, and MTTR/MTBF very low

Types of Network Failure

- When considering logical network layer, one failure in the lower network layer can lead to multiple link failures in the upper network layer
 - For instance:
 - one cable cut => several TCP connection interruptions
- **Share Risk Group** concept (SRG):
 - A group of resources that are affected by the same failure
- **Share Risk Link Group** (SLRG):
 - A group of upper layer links that are affected by the same lower-layer failure

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Reliability Requirements

- Depend of the application services
 - need for recovery (social expectation or tolerance)
 - speed of the recovery process (delay sensitivity)
- **Service-Level Agreements (SLA)**
 - Minimal availability of the service
 - five 9 : 99,999%
 - Maximum down-time:
 - half an hour
 - Financial compensation when engagements are not met
 - X % of the monthly charge

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Reliability Schemes

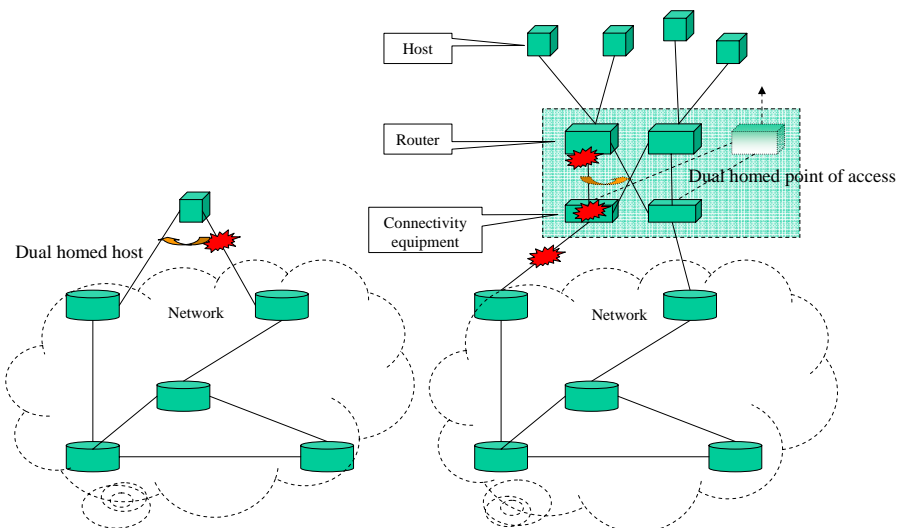
- Prevention
 - Putting cable deeper in the ground, fire security plan, limited access to the building, etc.
- Duplication
 - Terminal network element
 - Dual homing: when a failure occurs, the terminal element can still access via the unaffected network access link
 - Network element redundancy: In the case of cross-connect failure, all traffic can be switched to an identical hot standby cross-connect.
 - Network resilience
 - Automatically divert the traffic streams affected by the failure to another (fault-free) path in the network

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Reliability of Network Terminal Element



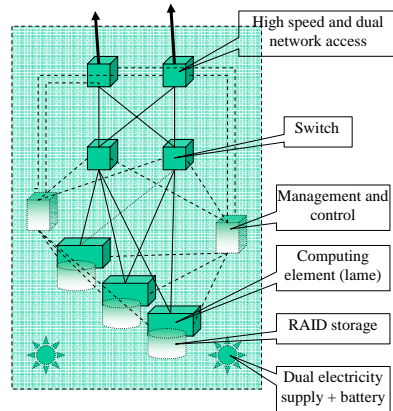
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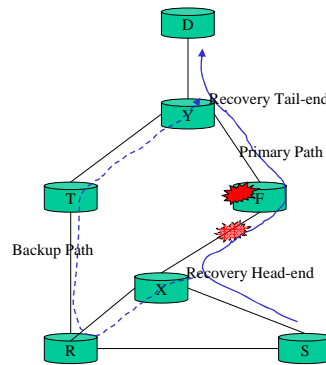
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Reliability of Host or Server

- Survivable service == survivable host or server
- Host redundant architecture
 - Server farm, warehouse, blade center, etc.
- Multiple powerful computing elements
 - Resilient to load and failure
 - With data storage (RAID 5)



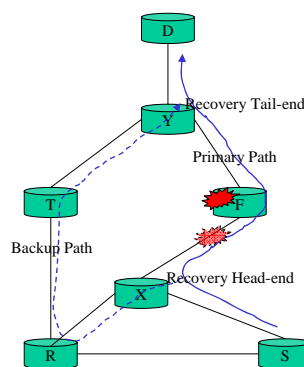
Principles of Network Recovery



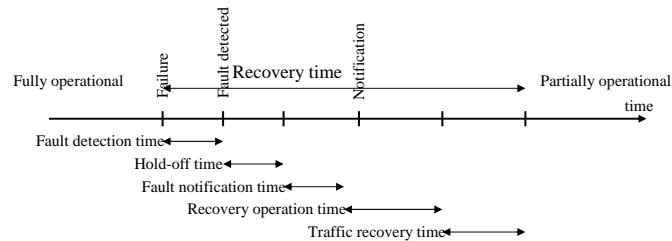
- The backup path is usually resource disjoint (link and/or node disjoint) from the primary path

Principles of Network Recovery

- No single point of failure in the network
 - For instance Y and D-Y are single points of failure !
- Enough available bandwidth along the backup path (spare capacity)
- Tolerant to the rise of the propagation delay



Recovery Cycle



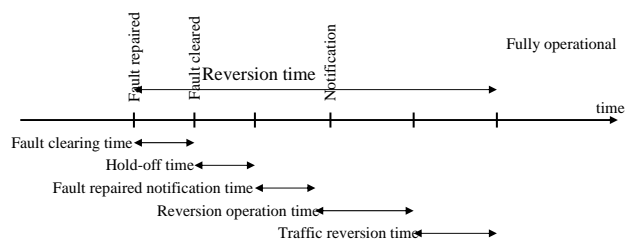
- Fault detection time = data gathering and diagnosis
- Hold-off time = allow lower layer to repair the fault
 - for instance, route dampening (timer duration is variable)

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Reversion Cycle



- The new routes along the backup path may be less ideal than before the failure
 - Dynamic rerouting protocol
 - Wait for repair, and switch back
- Hold-off time : too quick reaction may lead to unstable network conditions

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Criteria for Recovery Performance

- Scope of failure coverage
 - Failure scenario :
 - single-link failure, single-node failure, double-link failure, SRLG failure, etc
 - Percentage of coverage
 - Recover only a certain percentage of the traffic volume, traffic coming from or terminated in the failing node can never be recovered by network recovery
- Recovery time
 - Usually an important criterion for recovery mechanism
- Backup capacity requirements
 - Network capacity requirements may depend on algorithms selecting the backup paths, traffic characteristics and layer
- Guaranteed bandwidth
 - Some recovery mechanisms inherently guarantee the full bandwidth of the affected traffic to be rerouted along the backup paths (other don't)
- Reordering and duplication
 - Reversion operation (from backup to working path) may lead to duplication and reordering
- Additive latency and jitter
 - When backup path is longer than the primary path

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Criteria for Recovery Performance

- State overhead
 - State = information stored in the individual network element about the primary or backup paths and their management
 - Limited storage capacity or delayed lookup
- Signaling requirements
 - Some recovery scheme might require a significant number of signaling messages (=> bandwidth, CPU usage)
- Scalability
 - State or signaling overhead may increase faster than network or traffic sizes
- Stability
 - Timers must be tuned:
 - small values speed up the recovery, but may lead to never-ending switch-over and switch-back and may produce larger signaling bandwidth
- Notion of class
 - Some recovery classes distinguish between different classes of traffic, and may take appropriate recovery actions
 - For instance, one traffic class may have a fast recovery scheme whereas another class gets a slow recovery mechanism but at a lower cost

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Recovery Mechanisms

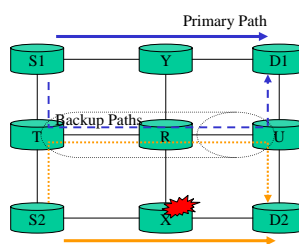
- Shared backup capacity
- Proactive or reactive recovery
- Protection or restoration
- Global or local recovery
- Centralized or distributed control of recovery
- Ring or mesh networks

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Backup capacity: Dedicated versus Shared



- Dedicated backup capacity : one backup resource corresponds to one particular primary path
- Shared backup capacity : one backup resource is shared between several primary paths
 - More complex (only some segments are shared), but more efficient if single failure assumption is confirmed

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Backup Paths: Preplanned versus Dynamic Computation

- When are the backup paths computed ?
 - Preplanned (proactive):
 - The path is computed **in advance**, for all accounted failure scenarios (before any failure occurs)
 - Lack of flexibility for unaccounted failure scenarios
 - Many backup path computations need at every network topology change
 - Reactive (dynamic):
 - The path is computed **on the fly** once the failure is detected
 - Reaction slower than preplanned recovery scheme
 - No guarantee to find an appropriated path

Protection versus Restoration

- Protection:
 - The backup paths are preplanned and fully established (some resources are reserved) before the failure. No additional signaling is needed
- Restoration:
 - Either preplanned (without resources reservation) or reactive, but when failure occurs additional signaling will be needed to establish the backup path
 - Restoration is slower than protection
 - But use less backup capacity

Protection Variants

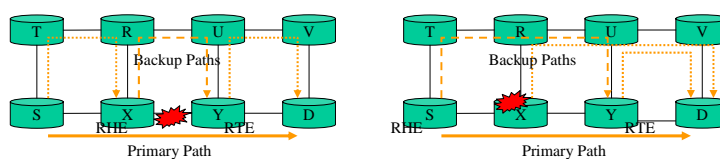
- 1+1 Protection (Dedicated protection)
 - One dedicated backup path protects exactly one primary segment
 - The traffic is permanently duplicated at the RHE on both paths, and the RTE selects the working path
 - Double bandwidth/resource consumption
- 1:1 Protection (Dedicated protection with extra traffic)
 - One dedicated backup path protects exactly one primary segment
 - But in failure free condition, the traffic is transmitted over only one path, and extra traffic can use the backup path
 - The extra traffic is preempted when a failure occurs
- 1:N Protection (Shared recovery with extra traffic)
 - One backup path is shared to protect several known primary segments
 - In failure free condition, extra traffic can use the backup path
- M:N Protection ($M \leq N$)

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Global versus Local Recovery



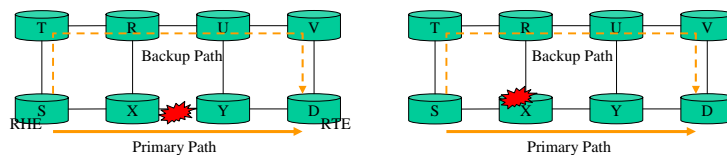
- Length of the protected segment on the primary path?
- Local recovery:
 - Only the local network elements, affected by the failure, are by-passed
 - For instance:
 - Single link failure: the backup path is set up between the nodes adjacent to the link failure
 - Single node failure: the backup path is established between the two neighbor nodes of the failing node
 - Every node which is upstream a point of failure could be a RHE (recovery Head-End)
 - Many backup paths

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Global versus Local Recovery



- Global recovery:
 - The complete primary path is protected by one backup path
 - The RHE and RTE coincide with the source and destination
 - The backup path must be completely disjoint from the primary path
 - For single link failures, the backup path must only be link-disjoint
 - Else, it must be node-disjoint, except for the RHE and RTE (Recovery Tail-End)

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Global versus Local Recovery

- Pros and Cons:
 - Local recovery detects fault rather quickly
 - Quick detection and quick (local) recovery operation
 - Local recovery produces suboptimal results
 - The same traffic may cross a particular link twice (*back hauling*)
 - Failure coverage is different
 - For instance, if two successive nodes fail along a primary path, global recovery could still resolve this double failure
 - The number of backup paths are larger with local recovery, but the global recovery may generate more state and message overhead.
- => **Segment recovery !**
 - A valuable intermediate option between local and global recovery

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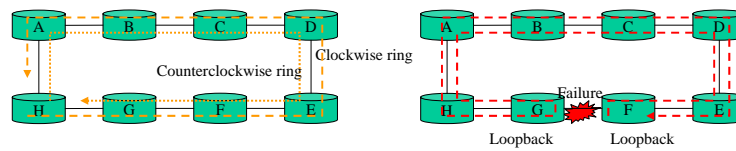
Control Recovery Mechanisms

- Which entity controls the recovery process?
 - Centralized recovery:
 - The central controller has a global view of the network status
 - It determines where and when a fault has occurred and how to reconfigure the network elements involved in the recovery process
 - For instance: Telecommunications Management Network (TMN)
 - Distributed recovery:
 - The control is distributed over the network elements
 - Network element may have partial view of the network status
 - Coordination is more difficult to achieve
 - For instance : IP or GMPLS control planes
- Note: backup path computation can be decorrelated from recovery operation
 - Hence a recovery mechanism can combined both centralized and distributed aspects

Control Recovery Mechanisms

- Pros and Cons
 - Centralized systems are in general simpler to supervise and to implement
 - Centralized systems tend to have a better global view, whereas distributed systems is typically more local
 - Centralized recovery is generally more efficient in terms of required capacity
 - Decentralized systems are more scalable
 - Decentralized systems are less vulnerable

Ring Networks versus Mesh Networks



- A ring : a set of nodes where each node is connected to exactly two adjacent nodes in a connected graph
 - Simple connected topology
- Double ring
 - One clockwise ring and one counterclockwise ring
 - Each traffic flow may use one of the ring
 - The nodes adjacent to a failure loop back the traffic around the opposite side
- Ring networks
 - Ring-based SDH networks or SONET self healing ring techniques
==> if generalized: a Mesh network

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Some other points

- Connection-oriented versus connectionless
- Revertible or non-revertible mode
- Unidirectional or bidirectional traffic

- Multilayer recovery

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Conclusion

- Recovery from link failures in traditional IP can take a long time.
 - IP routing protocols were not designed to ensure that network users would not experience significant outages
 - E.g. several tens of seconds
 - Understanding some of the underlying dynamics
 - Primary and backup path
 - Preplanned or reactive recovery schemes
 - Path or local protection
- => tradeoff between recovery time and resource consumption

Bibliography

- J-P. Vasseur, M. Pickavet, P. Demeester, "Network Recovery", Morgan Kaufmann, 2004.
- I. Hussain, "Fault-tolerant IP and MPLS network", Cisco Press, 2005.
- [E800], ITU-T Recommendation E.800, "Terms and definition related to QoS and network performance including dependability", August 2004.
- Alex Raj, Olivier Ibe, "A survey of IP and MPLS fast reroute schemes", Computer Networks, 2006.
- Jack Foo, "A Survey of Service Restoration Techniques in MPLS Networks", ATNAC, 2003.