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QoS-Aware Fault Tolerance in Grid Computing

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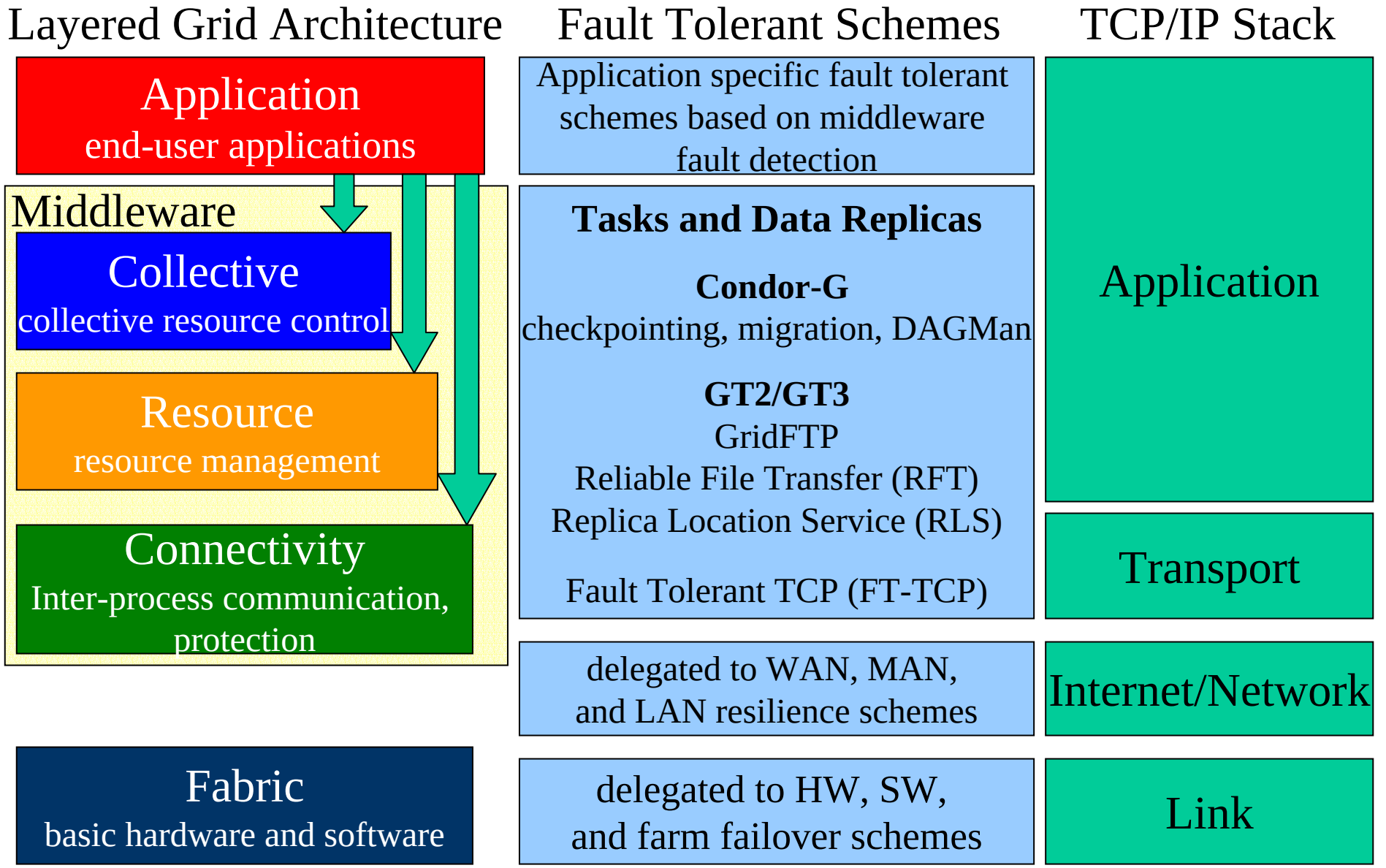
Outline

- Grid fault tolerance
- Quality of Service (QoS) aware fault tolerance
- Integrated QoS aware fault tolerance
- Performance evaluation
- Conclusions

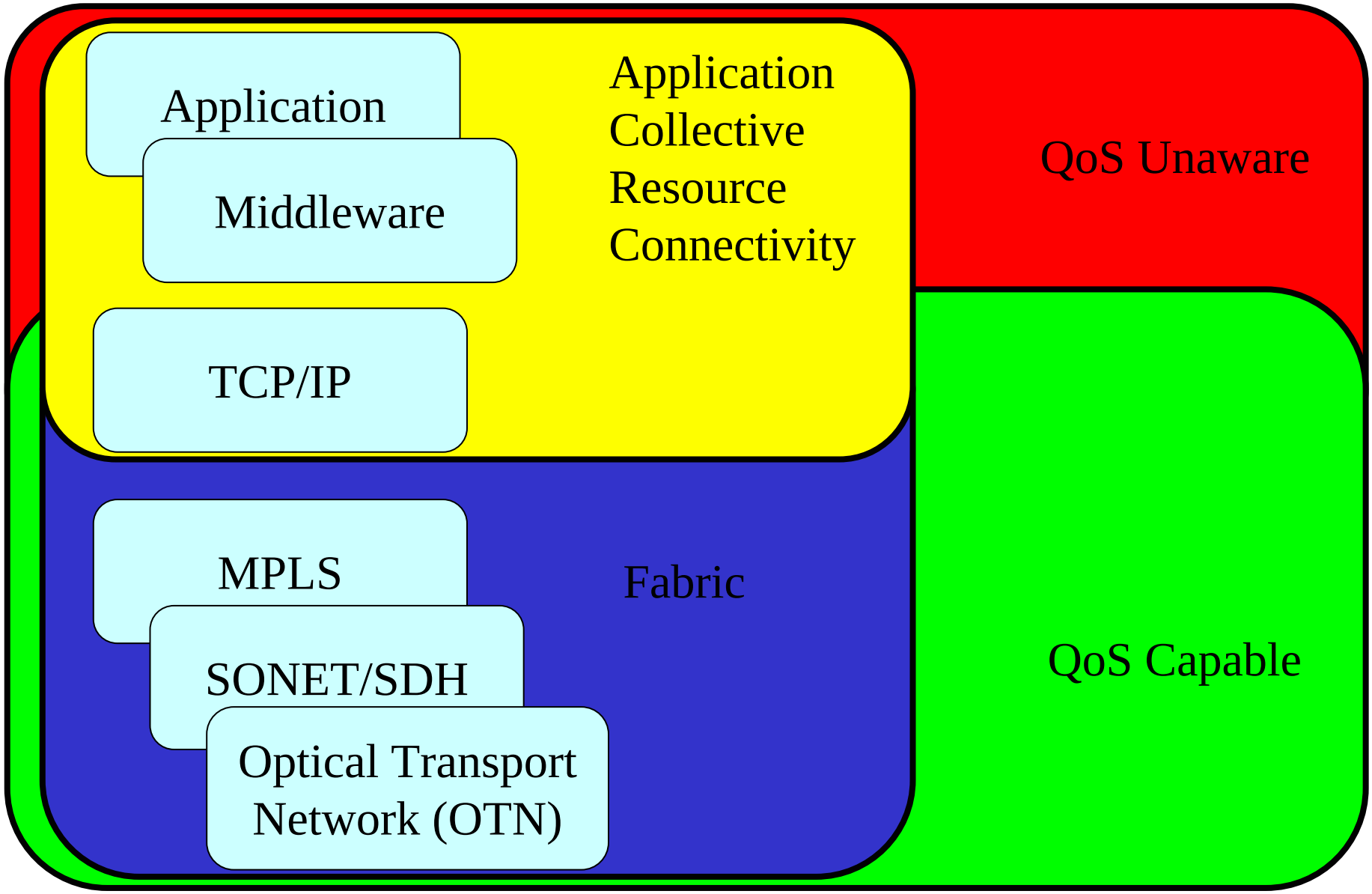
Approaches for Grid Fault Tolerance



QoS-Aware Fault Tolerance

- Def. QoS-Aware Fault Tolerance:
  - Capability of overcoming both hardware and software failures while maintaining communication QoS guarantees
- Def. QoS-Capable Layer
  - Grid layer capable of guaranteeing communication QoS
- Example:
  - Upon failure of main data center bandwidth guaranteed connectivity must be guaranteed to data replica center

QoS Awareness in Grid Fault Tolerance



Application/Middleware Fault Tolerance

- Advantages
  - Network layer independent
  - Flexible (e.g., degree of failover dependent on application)
- Drawbacks
  - Application dependent
  - User driven
  - Need for TCP synchronization
  - Slow reaction to failures
  - Not scalable (e.g., CPU and storage)
  - No communication QoS guarantees

QoS Capable TCP/IP

- Dynamic rerouting with Diffserv
- Advantages
  - Pervasiveness
- Drawbacks
  - No Traffic Engineering
- Example
  - After rerouting, packets with the same Type of Service (ToS) compete for the same insufficient resources along the shortest path

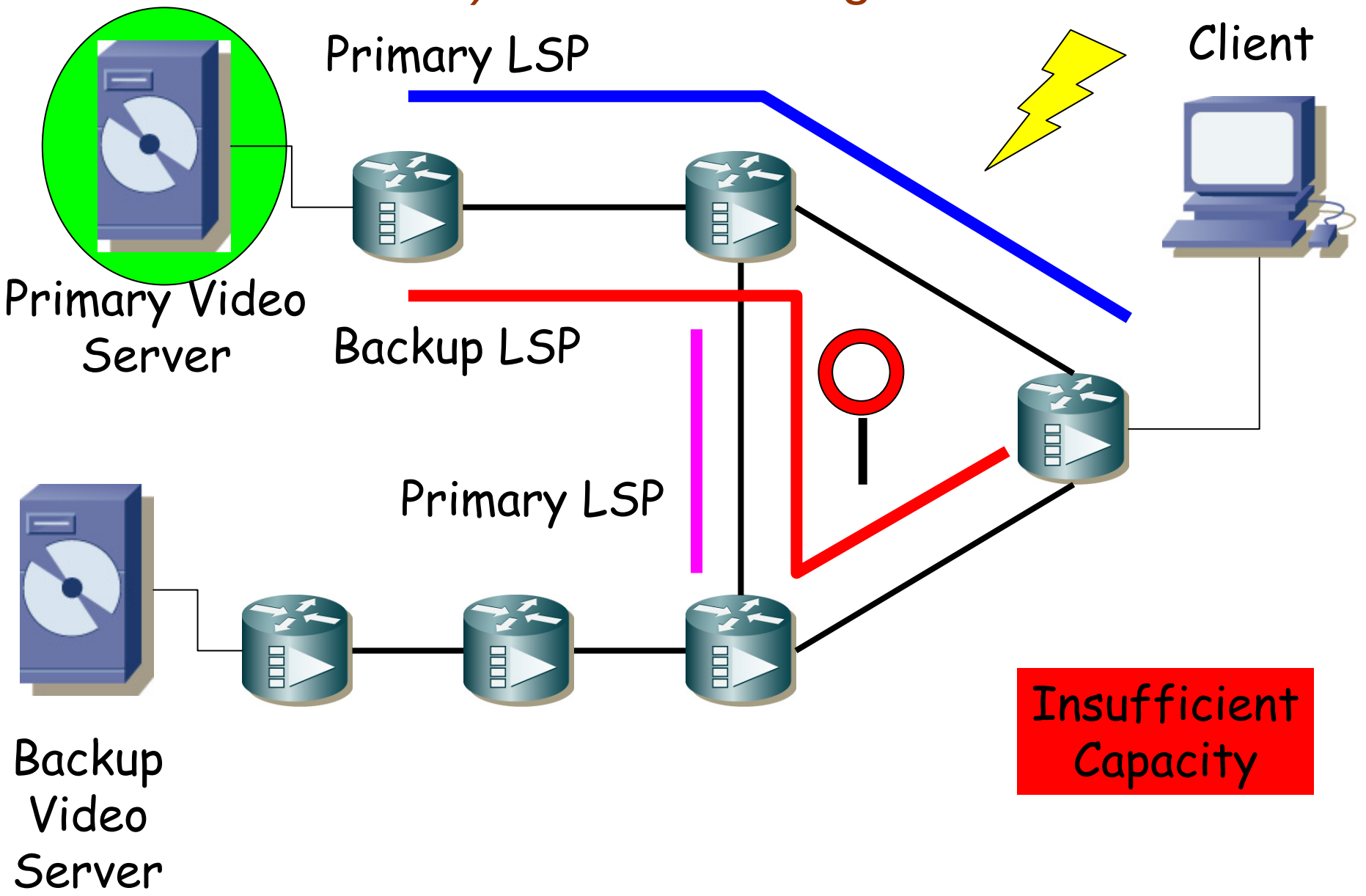
QoS Aware Fault Tolerance Below Layer 3

- QoS aware fault tolerance through connection oriented communication in QoS capable layer
  - Multi-Protocol Label Switching (MPLS):
    - Label Switched Paths (LSPs)
  - SONET/SDH
    - SONET/SDH Path
  - OTN
    - Lightpath (i.e., wavelength channel)

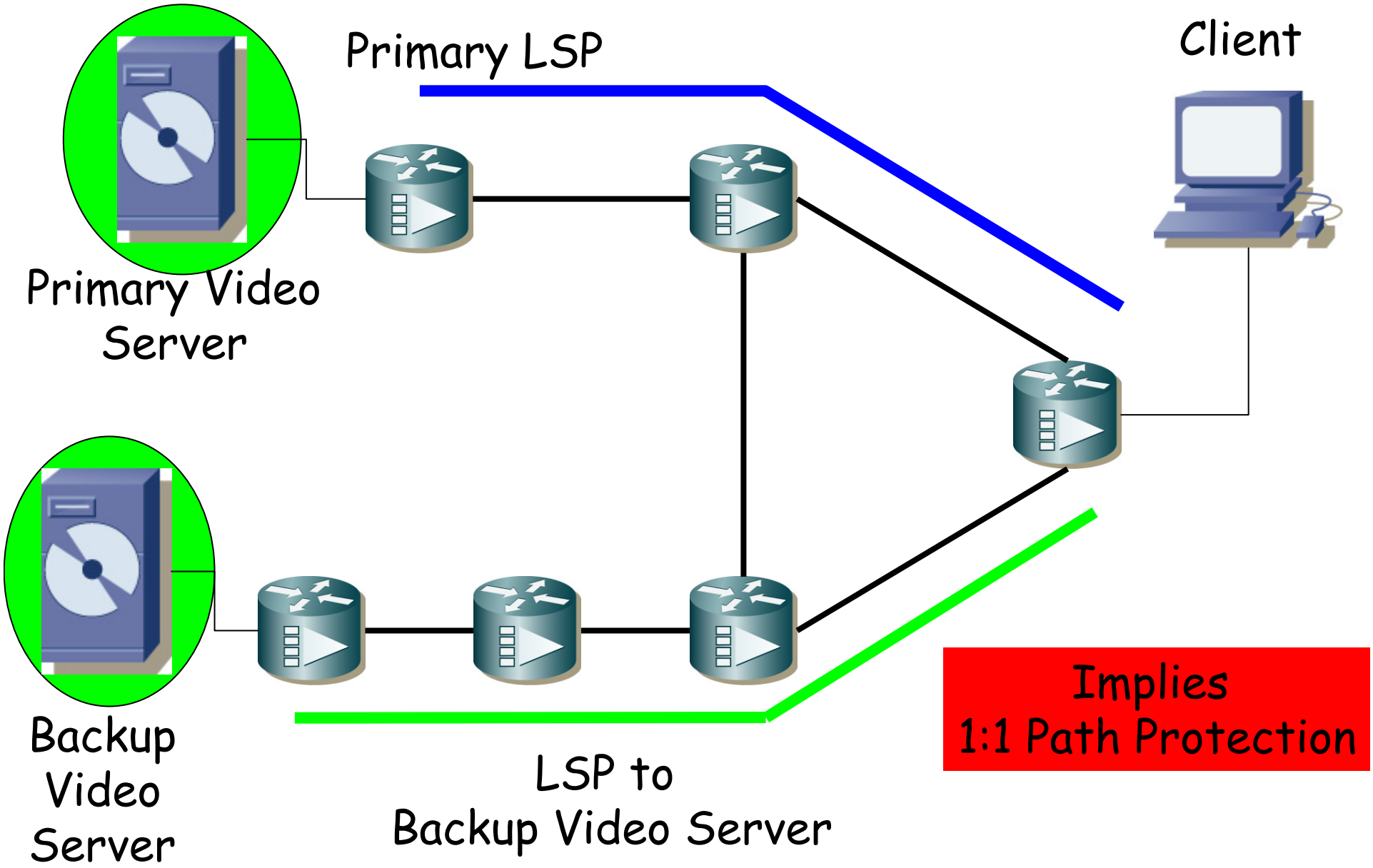
Implementing Multi-layer QoS Aware Fault Tolerance

- Assumption
  - Grid computing services requiring communication QoS guarantees (e.g., collaborative visualization)
  - QoS parameter
    - minimum bandwidth
- Objective
  - Maximize recovered connections and minimize required network resources upon network link failure
- Proposed approach
  - Integrating QoS unaware layer and QoS capable layer fault tolerance ⇒ QoS aware integrated fault tolerance
    - QoS capable layer fault tolerance
      - (G)MPLS path restoration
    - Software layer fault tolerance
      - Service replication (server migration)

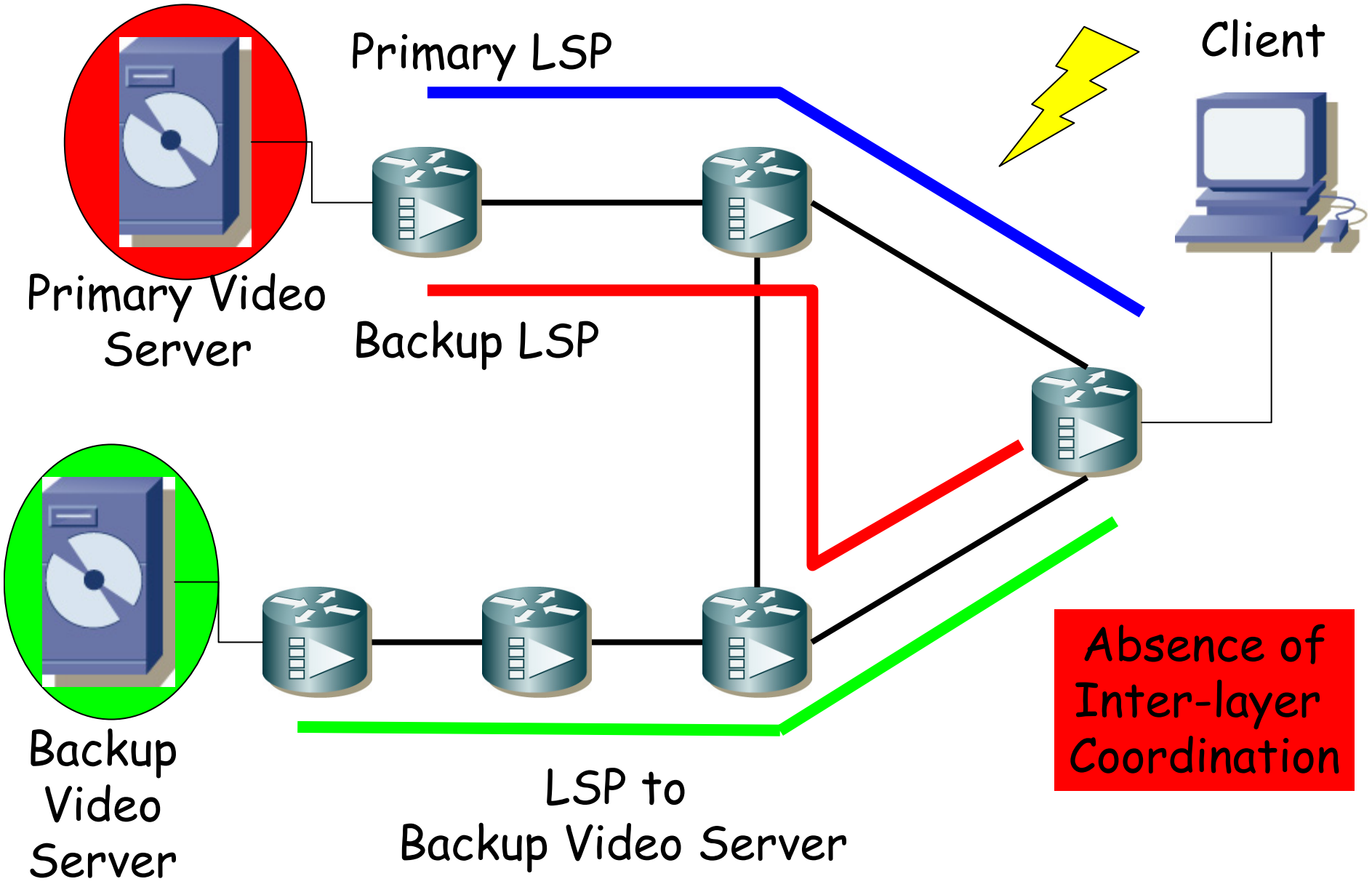
Network Layer Fault Tolerance (Path Restoration) Issue: Blocking



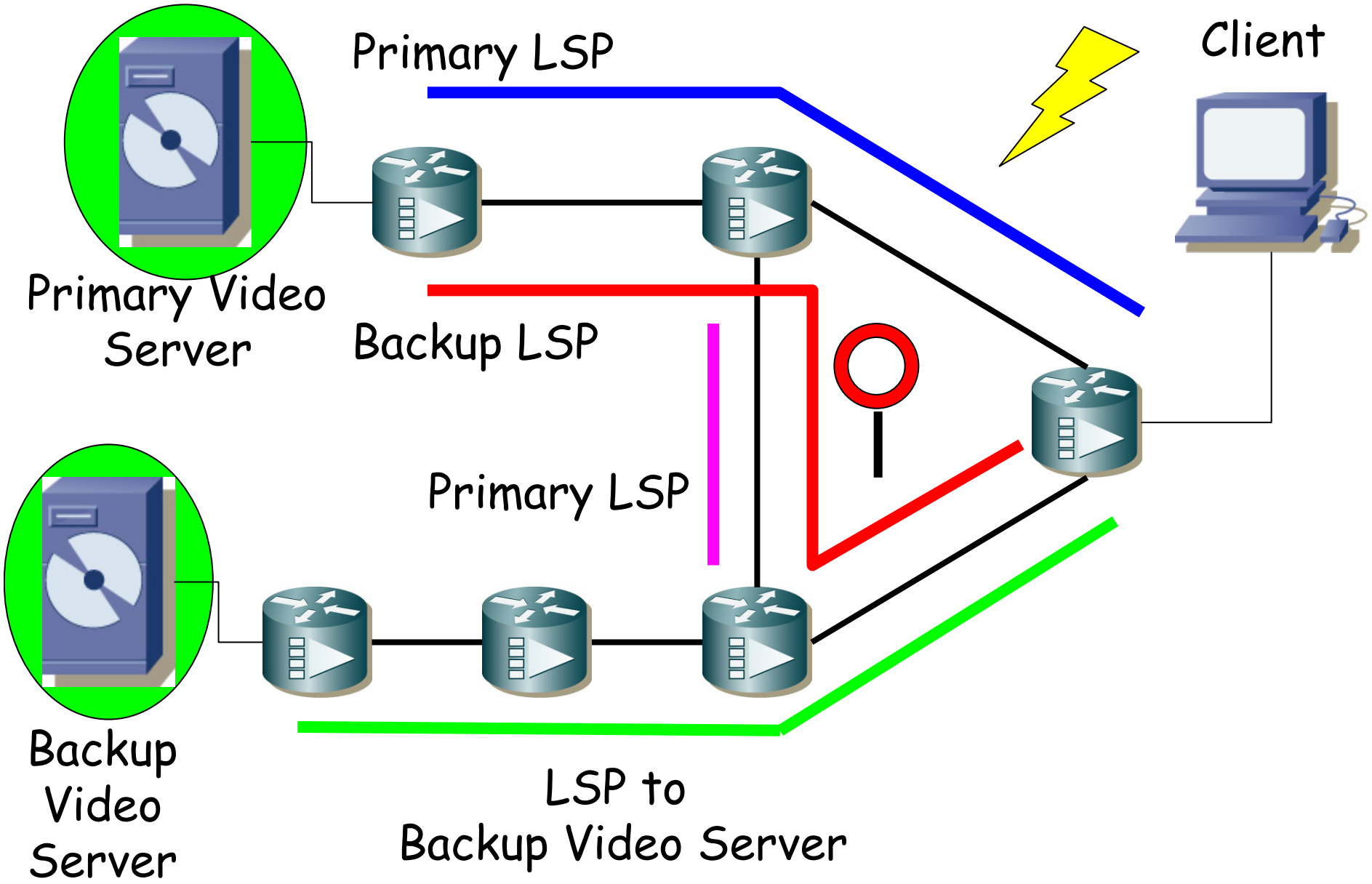
Software Layer Fault Tolerance Issue: Wasted Network Capacity



Non Integrated Fault Tolerance Issue: Unnecessary Server Migration when Backup LSP is available



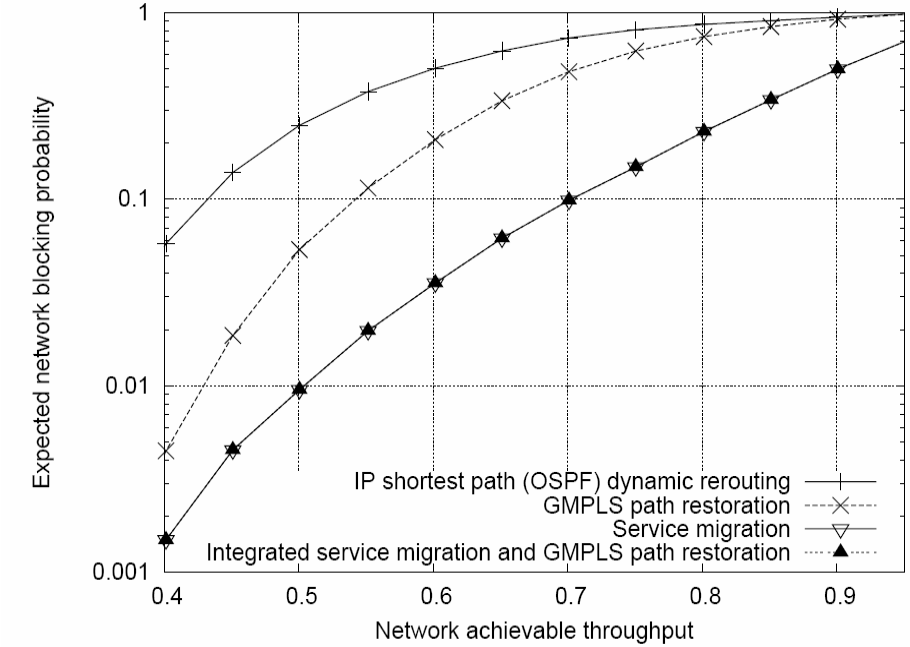
Integrated Fault Tolerance Advantages: Path Restoration + Service Replication

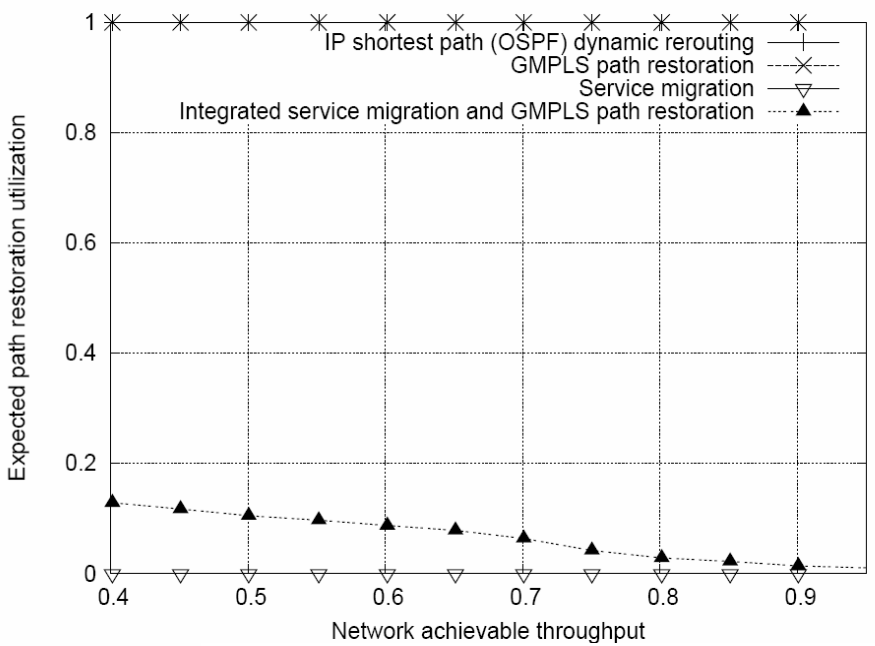


Simulation Scenario

- Physical network
  - 100 randomly generated connection matrices
  - Bidirectional connection generation
  - Bidirectional connection rerouting
- Expected network blocking probability
  - average ratio between number of unrecovered connections and failed connections
- Expected replica utilization ratio
  - Average ratio between the number of locations utilized for service replication and number of locations allowed for service replication
- Expected path restoration utilization
  - Average number of times the original server location node is utilized as replica location normalized ot the number of replica locations utilized
- Expected connection path length
  - average length of connection paths to reach replica location
- Evaluation scenarios
  - Limited number of replicas
    - per location
    - per failed connection between (s,d) pair
  - Limited distance (hop) of allowed replica locations
  - Minimum required replication flow

Integrated Restoration Performance



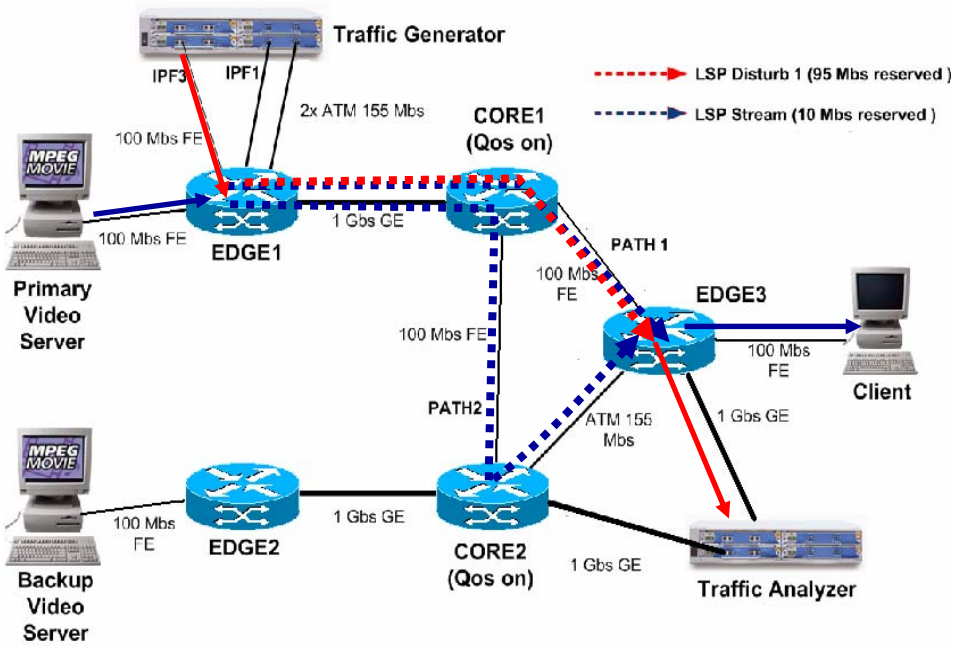


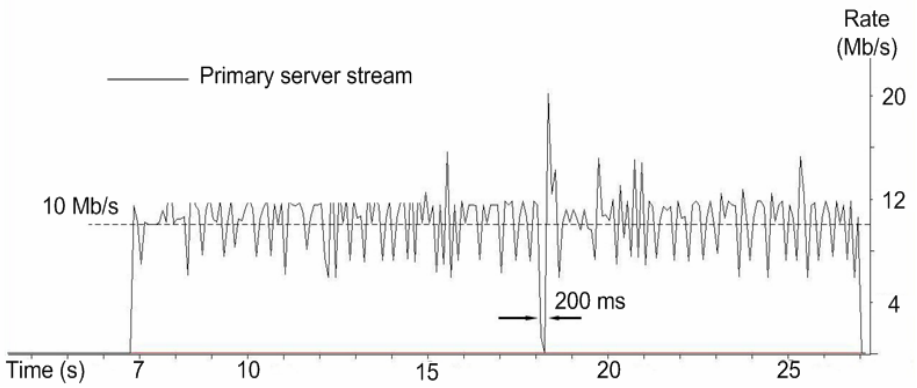
- Integrated restoration outperforms OSPF dynamic rerouting resilience
- Integrated restoration performs as well as service migration resilience but by utilizing path restoration decreases the need for service synchronization and restart

Integrated Multi-layer QoS Aware Fault Tolerance

Network restoration	Integrated Server Migration
Connection tear down by transit router	Connection tear down by Ingress router
Notification to the ingress router	Notification to Service Agent
Connection rerouting	•Service Agent setup a new connection from another server •Client switches-over

Rerouting after connection preemption





Stream carried on a guaranteed bandwidth LSP

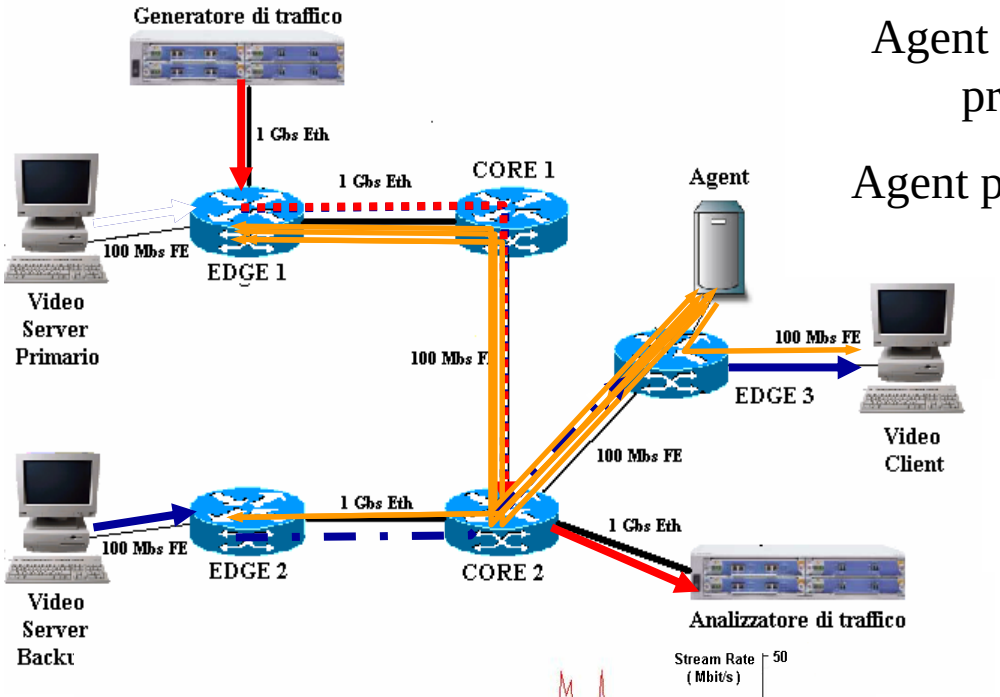
New LSP at higher priority set up

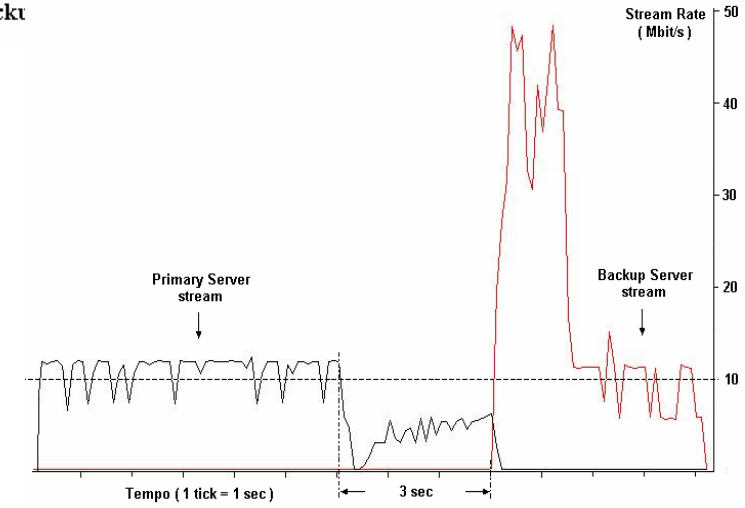
LSP carriyng the stream is prempetd and rerouted on a new path

Throughput at the client falls during LSP rerouting (100 ÷ 900 ms interruption)

Migration is not needed because LSP rerouting is fast enough

Migration after connection preemption 1 (Integrated scheme)





Agent sets up LSP from primary server

LSP carrying the stream is prempted

Agent periodically checks LSP status

Premption is detected by the agent

Agent provides to setup an LSP from backup server

As soon as LSP is up Ingress router notifies the Agent

Agent then notifies the client server migration

Recovery takes **about 2-4 seconds** to complete:

- Less than 1 second (polling period) for fault detection
- 2-3 seconds for network reconfiguration
- Network latency negligible

Replica Placement Problem

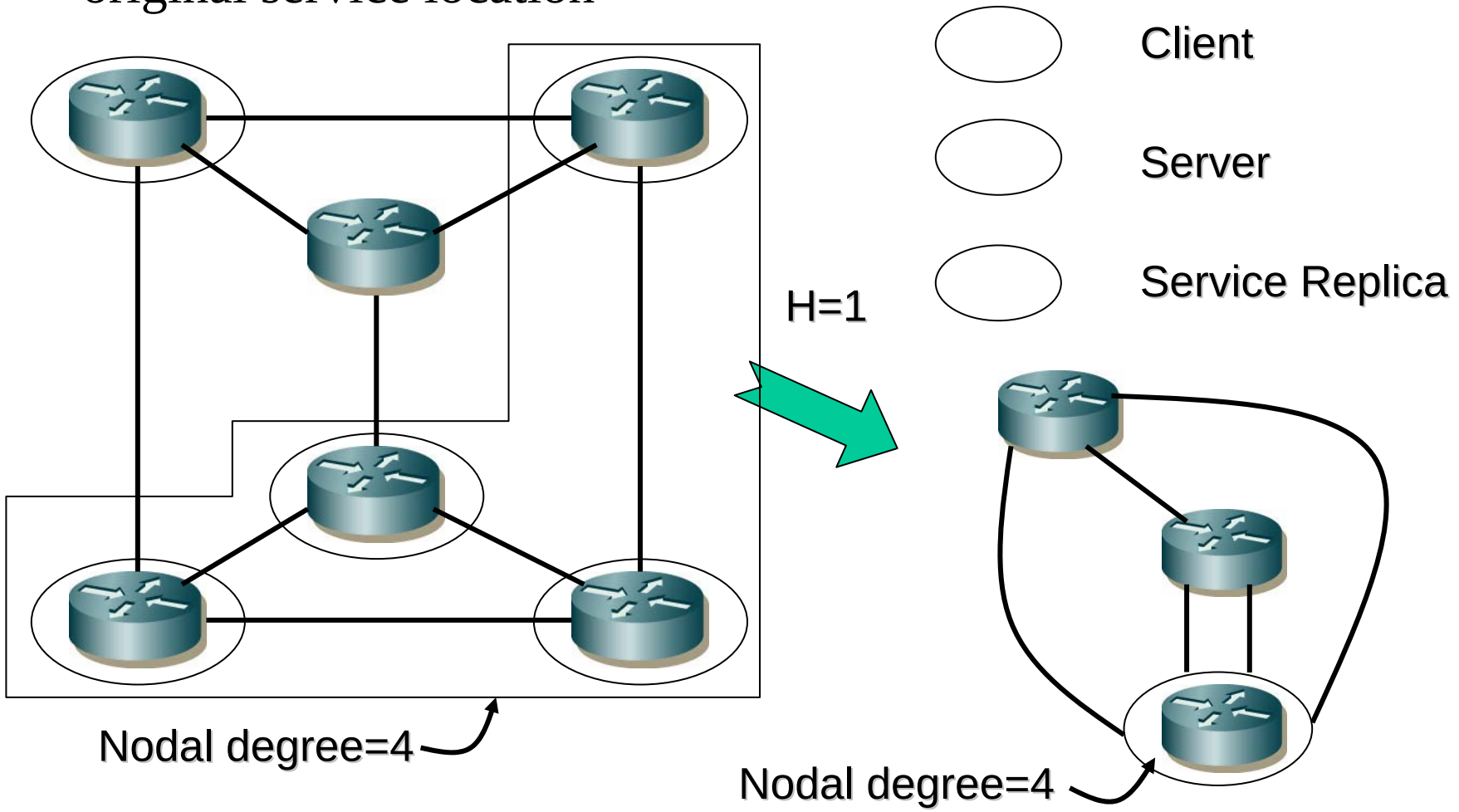
Objective

- Utilize service replication for guaranteeing high percentage of recovered inter-service connections
- Limit number of allowed replica locations to optimize utilized computational resources
- Utilize simple and efficient heuristics for replica placement

- Proposed Approach
  - Place replicas in nodes adjacent to original service location
  - Form cluster of nodes with same service replicas (i.e., service islands)
- Expected results
  - Improve service inter-connectivity recovery
  - High replica utilization ratio

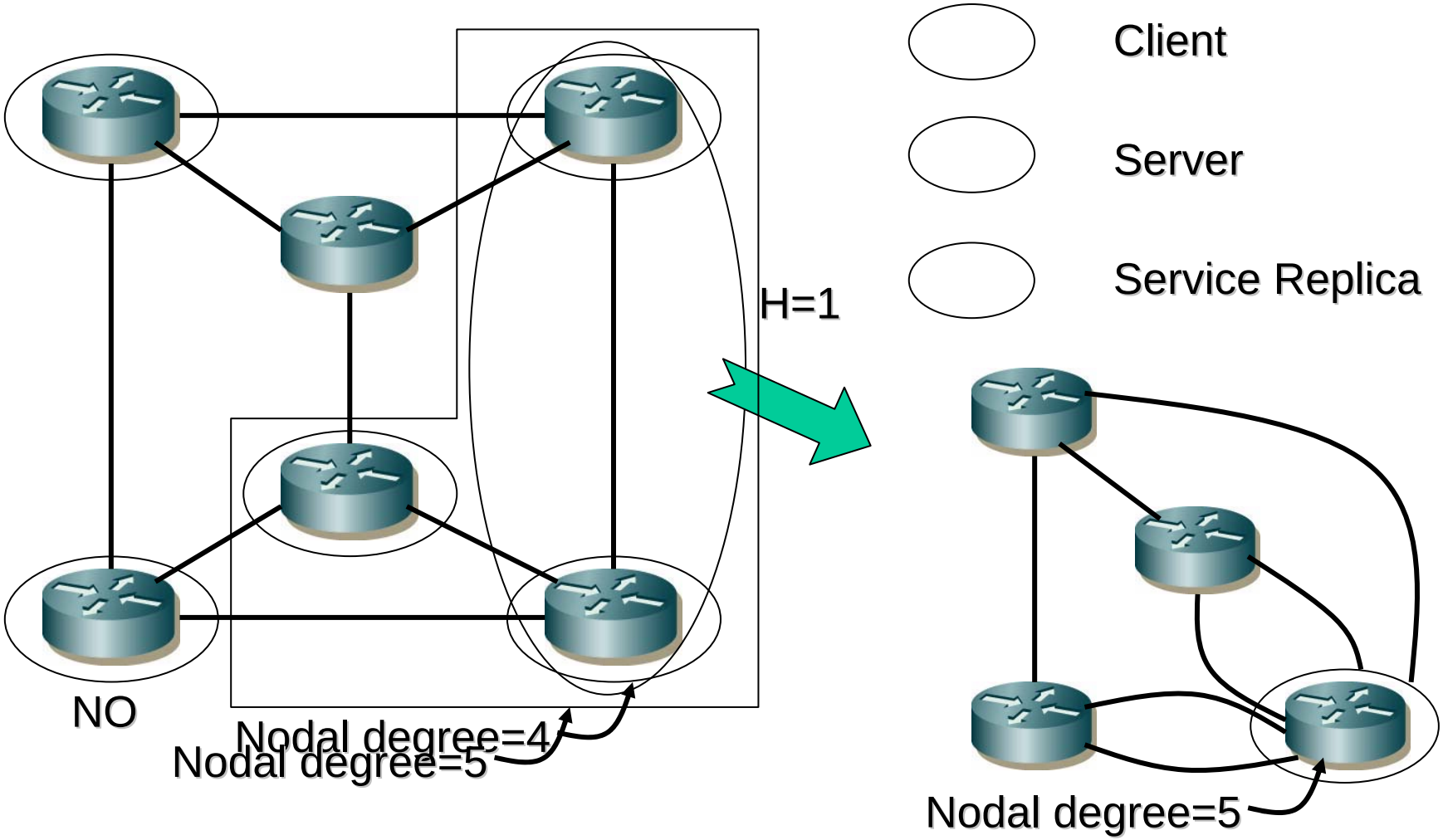
HOP Heuristic

- Place replica in all the nodes reachable in H-hop from the original service location

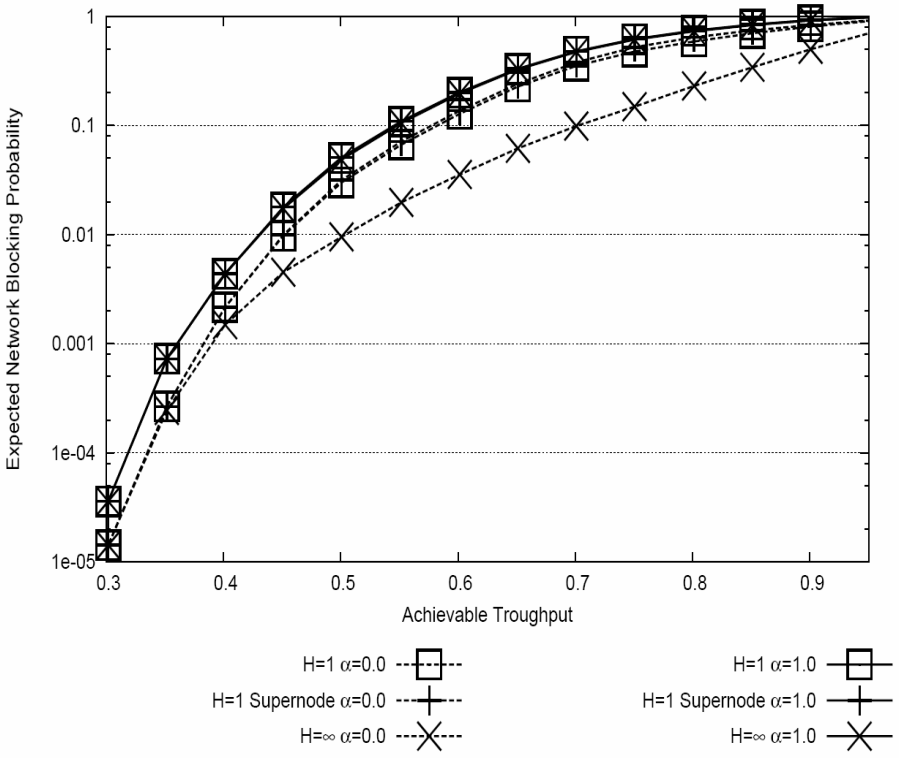


Super-Node Degree Heuristic

- Place replica in all the nodes reachable in H-hop from the original service location and incrementing the previous step super-node nodal degree

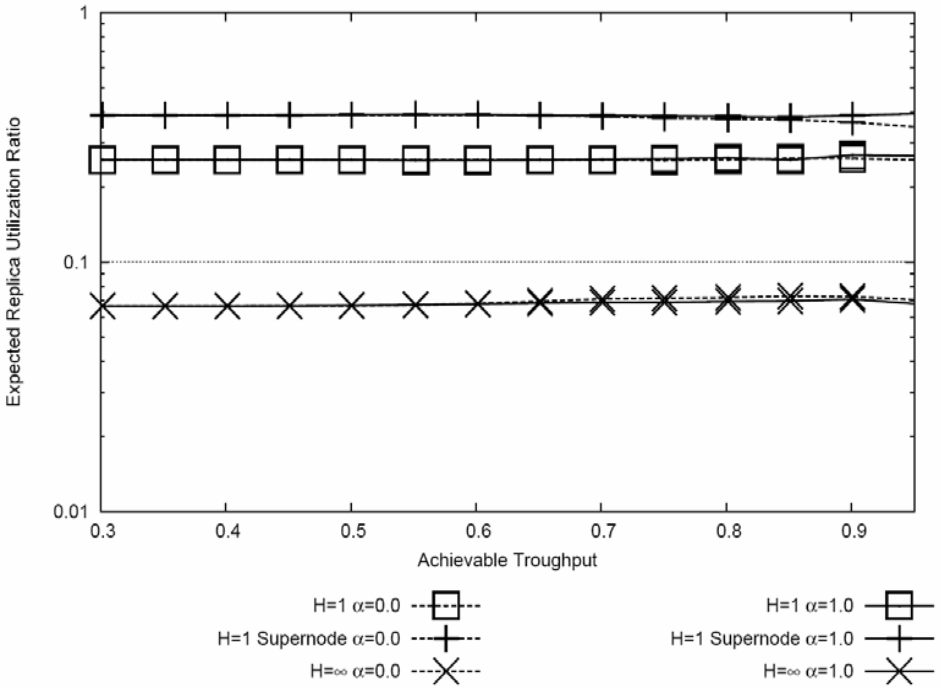


HOP and Super-node Degree



- H=∞ and α=0 expected network blocking probability lower bound
- For both α=0 and α=1
  - Super-Node degree and HOP heuristic similar expected restoration blocking probability
  - Super-node degree better expected replica utilization ratio

- H, number of hops from destination to consider candidate service island nodes
- α=0, no capacity need for replica update (static replica placement)
- α=1, full capacity (same as client-server) capacity for replica update (dynamic replica placement)



Summary

- Need for QoS aware fault tolerance in Grid Computing
  - Not only recovering connectivity but also maintaining communication QoS parameters
- Proposed implementation
  - Integration of application/middleware fault tolerant schemes (e.g., replication) with QoS capable layer (i.e., below layer 3) fault tolerance (e.g., LSP restoration)
- Further work
  - QoS aware fault tolerance as grid service
  - Other QoS parameters

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