MPLS / GMPLS

Generalized multi-protocol label switching

Ali Ahmad

February, 2012

Articles

Generalized Multi protocol Label Switching: An Overview of Signaling Enhancements and Recovery Techniques

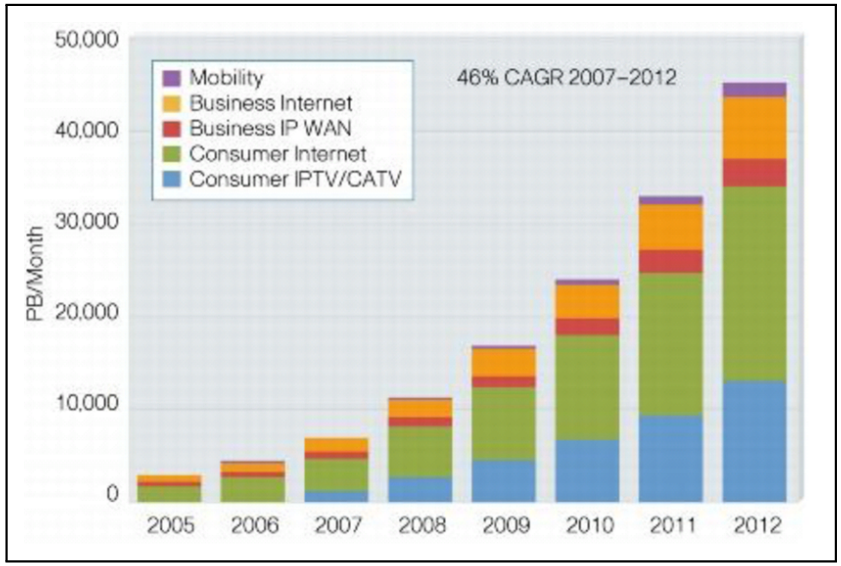
Authors: A. Banerjee and others

Internet traffic engineering using multi-protocol label switching (MPLS)

Authors : D. O. Awduche, B. Jabbari

Internet

- Streaming (Spotify, TV, VOIP)
- Games (MMORPG, FPS)
- File sharing (Torrent)



Internet

To satisfy these demands we need:

- Reliability
- Efficiency
- Service quality

Internet traffic engineering

"Most important aspect of Traffic Engineering is, to transfer IP traffic through a given network most efficient, economical, reliable, expeditious manner"
We need to:

- Scale and expand the network infrastructure
- Manage the installed capacity efficiently and effectively
- Enhanced survivability

Why MPLS was conceived

- The conventional shortest path routing protocols (IS-IS,OSPF)
  - These protocol don't take capacity characteristics into account, while making routing decisions
  - The outcome is, segment of the network can become congested, while others remain under-utilized
- Eliminating some redundancies by migrating network functions

MPLS Fundamentals

"MPLS was conceived to expedite packet forwarding in legacy routers, with software based forwarding engines"

- Separation of control plane and transport-plane
  - Which makes MPLS flexible to be combined with other protocols
- Supports explicit routed path
- Separation of forwarding header from content (IP) header
- Assist in both enhancement of routing control and estimation of traffic
- Doesn't provide Quality of Service, however if combined with Diff-Serv and Constraint-based routing, it can provide sophisticated Quality of Service (QoS)

What is Diff-Serv and Constraint-based routing

- Differentiated Services
  - "Differentiated Services (DiffServ) is a network architecture for classifying and managing network traffic and providing QoS on modern IP networks", Wikipedia
  - DiffServ is used to provide low-latency to critical network traffic (VOIP, Media)
- Constraint-based routing
  - What is Un-constraint routing?
    - The simple, distributed nature of link-state routing can be viewed as an advantage to IP networks.
    - Disadvantages of LSR however is that resource availability and traffic characterization aren't taken into account, which may cause congestion in the network.
    - Other similar protools are, OSPF and IS-IS
  - Constraint-based routing, is a routing technique where resource availability and traffic characterization are taken into account.

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- Doesn't provide Quality of Service, however if combined with Diff-Serv and Constraint-based routing, it can provide sophisticated Quality of Service (QoS)
- Can be viewed as a tunnelling technology that supports the implementation of VPN
- Supports a wide range of switched transport networks
  - Packet-switch
  - Time multiplexed
  - Wavelength multiplexed

MPLS fundamentals

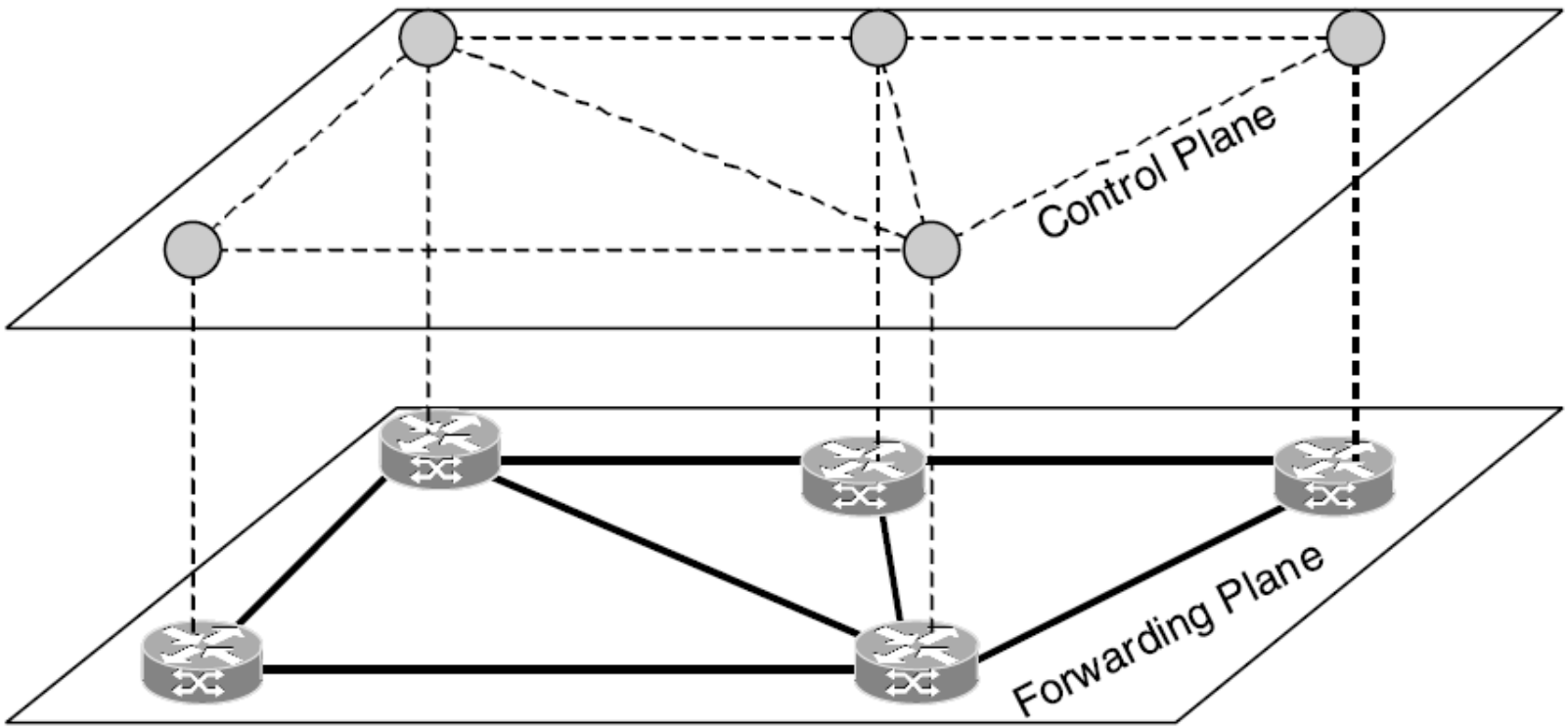


Fig. 2. Conceptual view of MPLS control plane and forwarding plane.

MPLS Fundamentals: Control Plane

Control plane is a collection of protocols that

- Collectively establish a network level functionality
- Facilitates the establishment of label switched path (LSP) by:
  - Distributing and managing network topology and information about available resources
  - Performing signal functions, establish and tear-down LSPs
- The control plane simply consists of IP routing and signalling protocols

MPLS Fundamentals: Control Plane 2

- Protocols in the control plane are implemented as software processes, which communicate with each other using message passing
- The control plane consists of two sub-systems
  - The signaling protocol (Resource reservation)
    - Handles Label distribution, binding, allocation
  - The routing protocol

MPLS fundamentals: forwarding plane

The forwarding plane's functions are:

- Label swapping operation using lookup tables
- Scheduling
- Queue management
- Rate shaping
- Policing

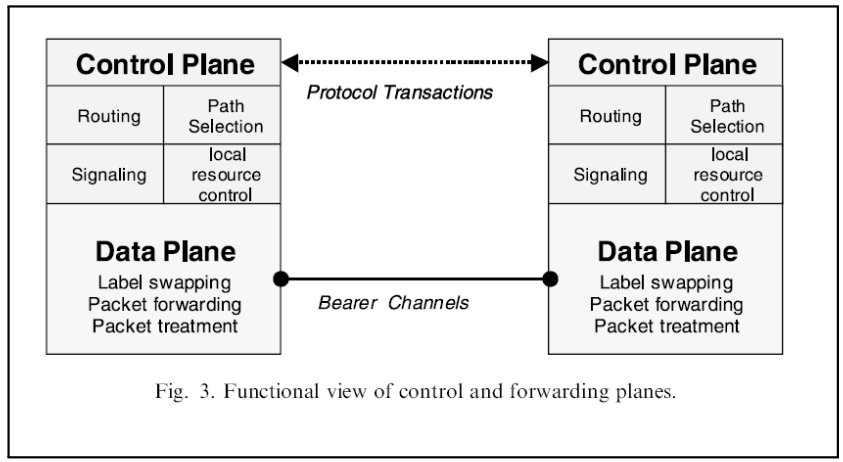
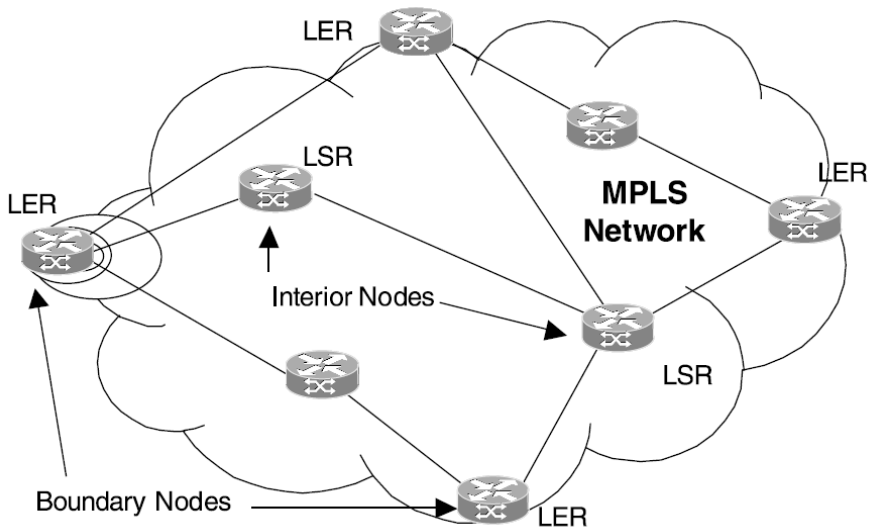


Fig. 3. Functional view of control and forwarding planes.

MPLS domain

In MPLS networks routers are divided into two categories

- Label Edge routers
- Label Switch routers



The difference is Label Edge routers can add/remove labels,

Forwarding equivalence class

A concept used in MPLS to assign packets belonging to the same *class of nodes.*

Advantages of FEC are:

- *Fast re-route*
- *Better than OSPF or IS-IS because of constraint-based routing*
- *Constrained based routing allows the exchange of information*
  - *Network topology*
  - *Resource availability*
  - *Administrative constraints*
- *Which is used to compute the best path to route*
- *Constraint routing (LSR, OSPF) takes into account congestion, That is why QoS is easier to ensure.*

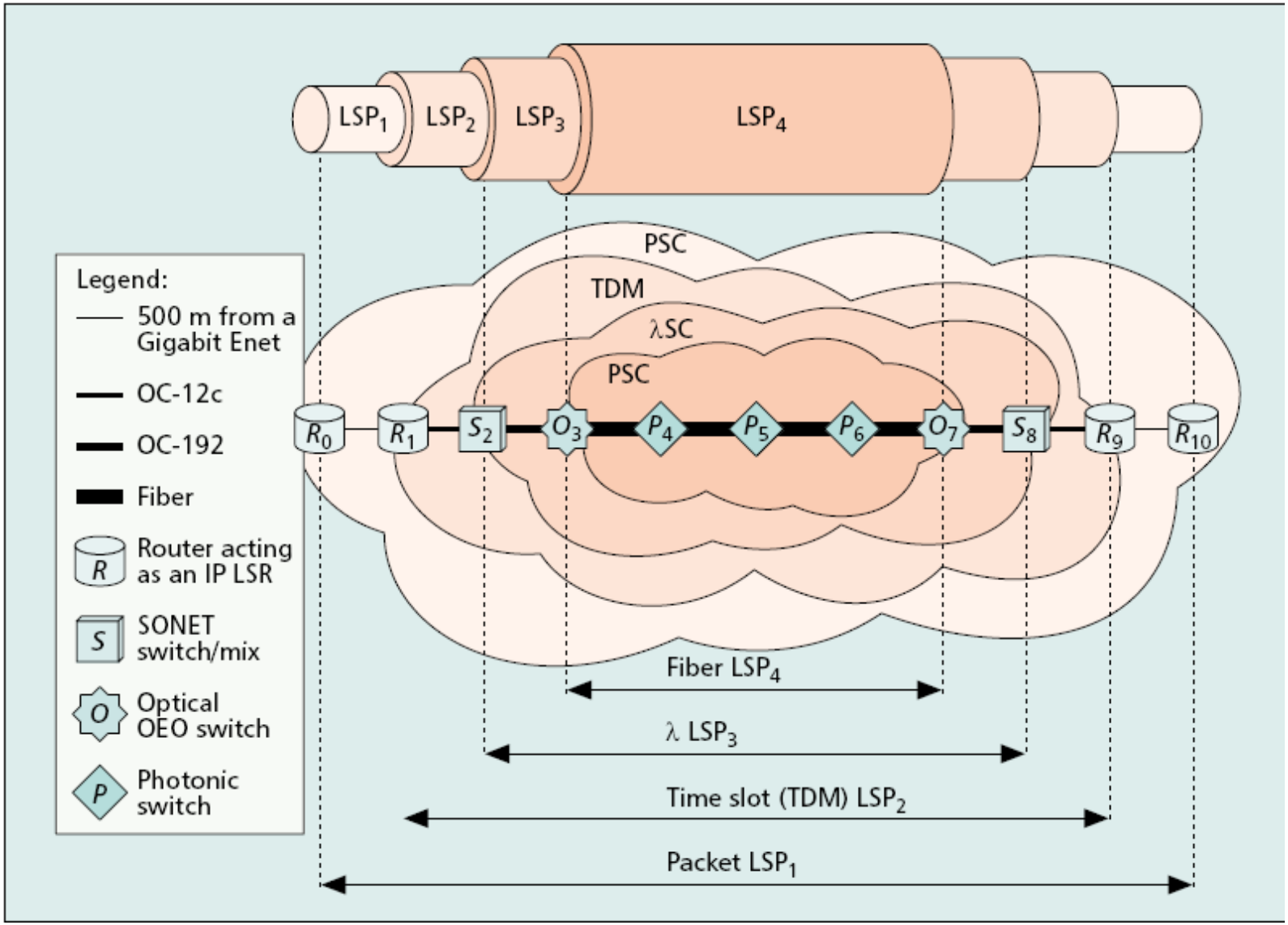
Quality of Service

- Routing has substantial influence in many of the key measures of the network.
  - Congestion
  - Throughput
  - Delay
  - Resource utilization
- Without taking these things into consideration QoS will be harder to optimize

Generalized MPLS

- Generalized MPLS is an extended and enhanced version of MPLS Some of these enhancement are:
  - Enhancements to RSVP-TE
  - Enhancements to OSPF and IS-IS
  - New Link-management protocol
  - Bi-directional LSP setup (MPLS supports uni-directional)
    - Reduced latency
    - Less Control overhead
    - Route selection is simpler
    - Cleaner interface
  - Failure detection and reporting to a pre-defined alarm center
- MPLS emphasizes the separation of control plane and network plane
- GMPLS extends this separation and allows the control plane to be physically diverse from the associated data plane

GMPLS: Hierarchial LSP



GMPLS : Suggested label

- GMPLS signaling allows, labels to be suggested by a upstream node. advantages are:
  - Reduced the LSP set up latency
  - Useful in optical networks, minimizes blocking
  - Permits nodes to configure their hardware with suggested label before the downstream node communicates a label to it
  - Early configuration
- Label suggestions can be overridden by a downstream node

GMPLS: Bi-directional LSP set up

- We have to assume that both direction have the same
  - Traffic requirement
  - Fate sharing
  - Protection and restoration
  - Resource requirement such as, latency, jitter
- The node that starts the establishment of an LSP is called, *the initiator*
- *The node used to refer to the destination node the terminator*
- *It is possible to create a two uni-directional LSPs in order to achieve bi-directional LSP*
- *Why is this not a wise thing to do?*

Disadvantages of two uni-directional LSP

- Latency
- The control overhead
- Route selection can become complicated
  - Because resources are allocated in separate segments
  - There may be a race for resource allocation
- Difficult to provide a clean interface

GMPLS Notify Message

- Added to notify the nodes responsible for restoring the connections when failure occurs, without intermediate nodes processing the notification and altering their connection
- In many cases, *Degraded link*[1] *are unacceptable to tear-down just because the control plane has failed*
[1]

[1] *Degraded link, are links where control plane has failed, but the data plane is still functional*

GMPLS Recovery techniques

Four primary steps for fault management are:

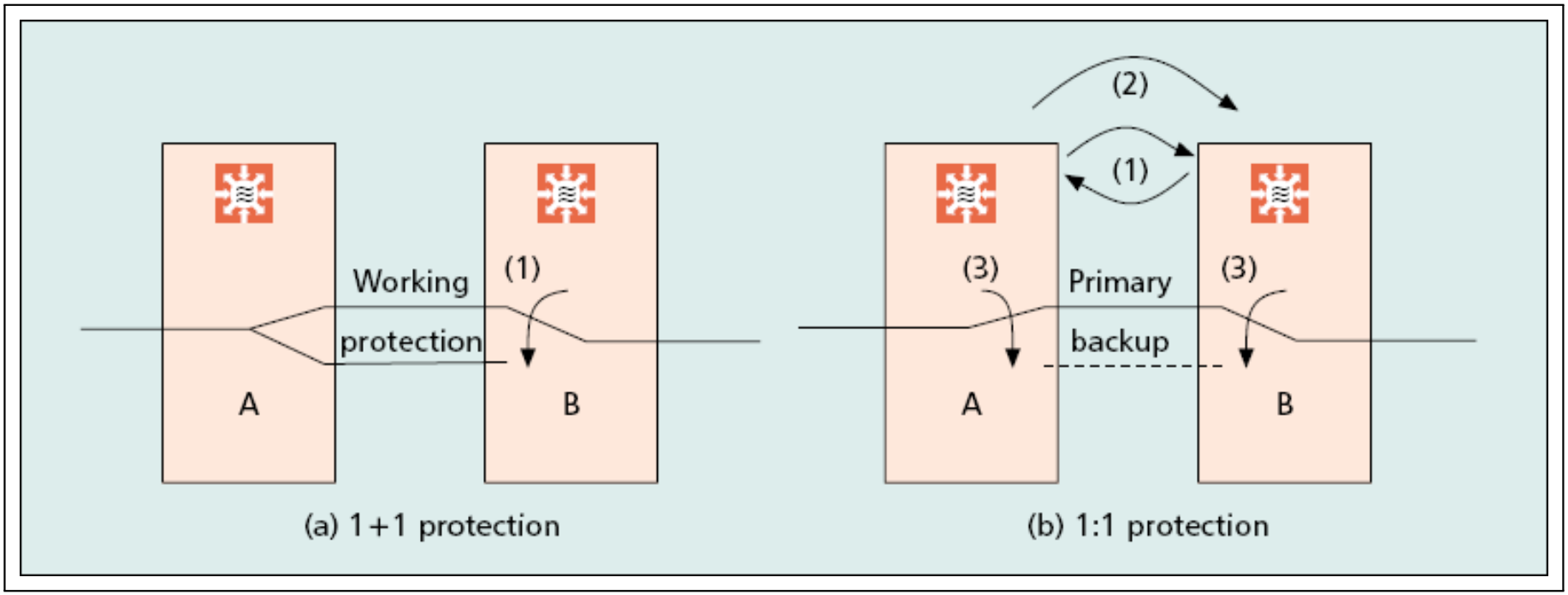
- Detection
  - Best handled in at the layer closest for failure
  - Loss of Light
  - Signal to noise ratio
  - Bit error rate
  - Dispersion
  - Crosstalk
- Localization
  - Link management protocol, sends ChannelFail messages through an separate channel than data-bearing channels
- Notification
  - Notify Messages in GMPLS
- Mitigation
  - Protection
  - Restoration

Protection mechanisms

Four types of protection mechanisms:

- 1+1 protection
  - Replicate the data into two separate channels
  - When failure is detected, the receiver switches from the working channel, to the protect channel
  - Although unnecessary, a signal is sent to notify the switch
- M:N protection,
  - M pre-allocated backup paths, N primary paths
  - Data is not replicated, backup paths are assigned and transmitted over, only in case of failure
- 1:N protection, 1 pre-allocated paths, N primary
- 1:1 protection, 1 backup path for 1 primary path

Span Protection



Protection techniques

- Path switching, failures are addressed at the path endpoints
  - Path protection, where secondary path are pre-allocated
  - Path restoration, connections are re-routed (dynamically or pre-calculated paths)
- Line switching, failure is addressed at the transit node where failure is detected
  - Span protection, where traffic is switched to an alternate parallel link that connects same two nodes
  - Line restoration, where traffic between two nodes are switched to an alternate route
- What is the differences between protection and restoration?

Difference between protection and restoration

- Difference between protection and restoration?
  - Protection requires pre-allocated resources
    - Usually 100 % resource redundancy
    - Simply said, we have to allocate resources for both channels (Primary and backup)
  - Restoration relies on dynamic resource allocation, and it may take up to "orders of magnitude" longer to restore

M:N protection

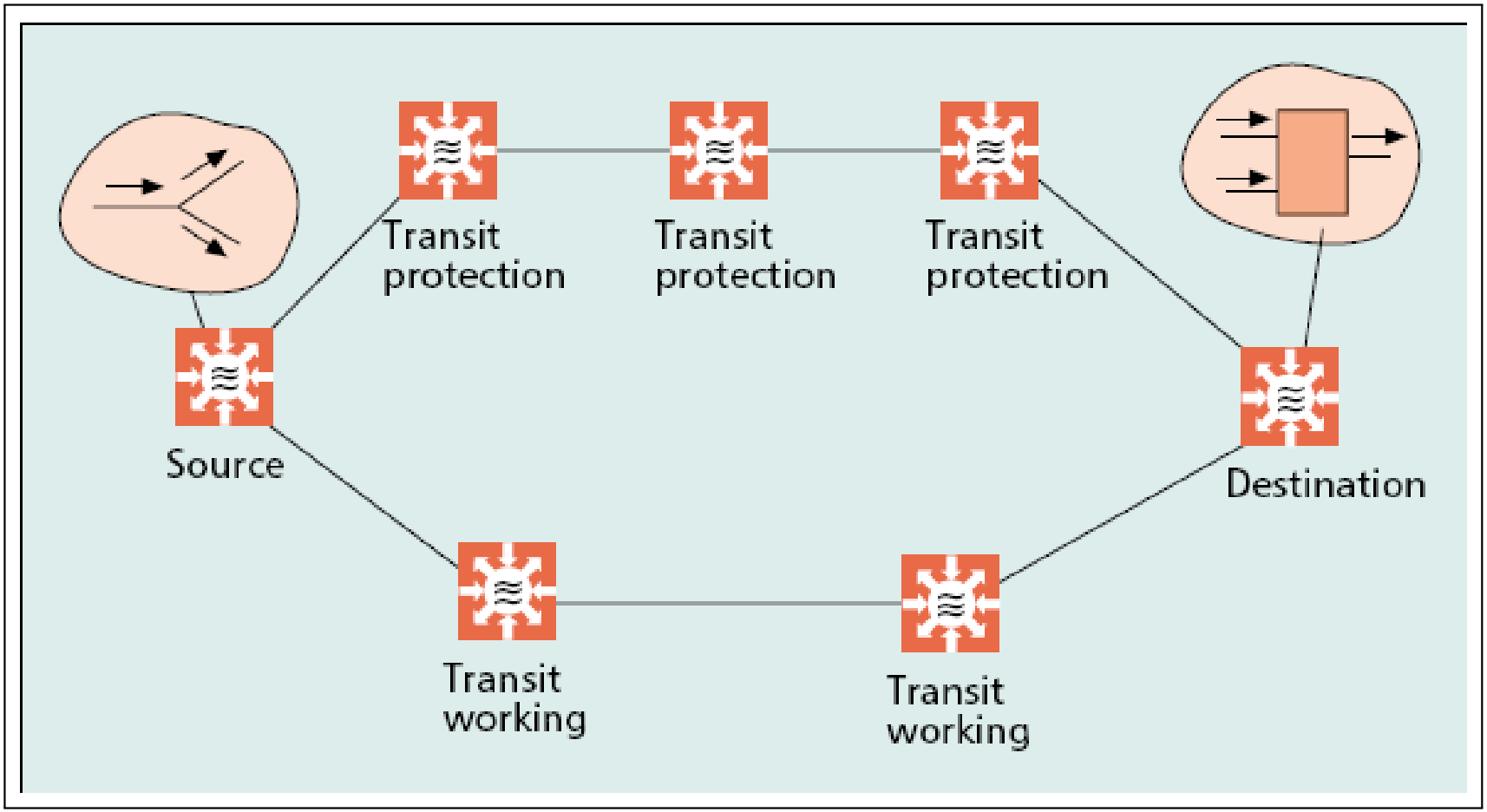
- When setting up the primary channels, a LPT (Link protection type) is advertised
- When failure is localized, a PATH message is sent, to allow intermediate nodes switch to the backup channel

Path protection

Requires switching to an alternate path when a failure occurs

- Path protection,
  - The connection is transmitted simultaneously over two (disjoint) paths
- Path restoration
  - Resources for the secondary paths are pre-allocated, but given a low-priority
  - Pre-computed path cut down on the restoration time

Path protection



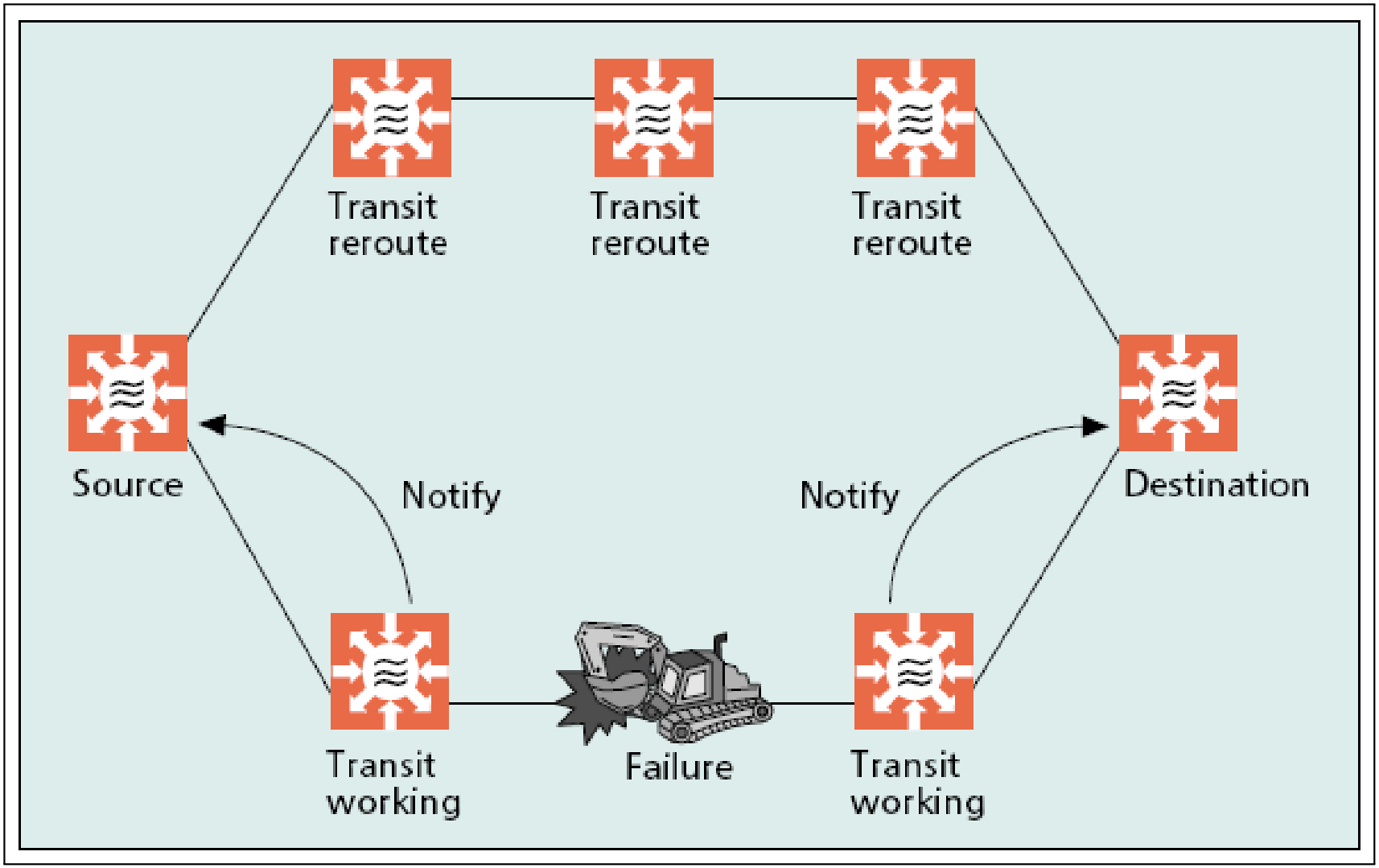
Restoration

- Designed to reacts to failures quickly and use bandwidth efficiently
  - Dynamic resource allocation
  - Route calculation
- Implemented at the source or intermediate nodes
- Pre-computed routes and resource pre-allocation enables faster re-routes
- Line Restoration
  - Traffic is switched via an alternate route
  - New path is selected by the intermediate nodes
  - May break TE requirement if a strict-hop explicit route is defined

Path Restoration

- Path Restoration
  - New path is calculated at the source
  - A restored path may reuse nodes in the original path

Path restoration



Summary MPLS

- Most important aspects of MPLS are:
  - Separation of control plane and data plane
  - Constraint-based routing
    - provides sophisticated QoS (if combined with Diff-serv)
  - Using a single forwarding paradigm
  - Supports heterogeneous underlying architecture (Optical, electrical, etc.)
  - Flexibility in the FEC
  - Forwarding Hierarchy by using label stacking.

Summary GMPLS

GMPLS extentions to the

- Enhancement to (RSVP and CR-LDP) signaling protocols
- Enhancement to (OSPF and IS-IS) routing protocols
- A new link management protocol (LMP)
- Bi-directional LSP set up (in a single request)
- Notification to a pre-defined alarm center (in case of failure)
- Protection and restoration techniques.
  - Network can detect a failures, report the failure, and quickly determine if whether spare capacity i available on other routers, and use signaling to restore the connection.

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[1] LMP will be used to maintain control channel connectivity, verify the physical connectivity of the data links, correlate the link property information, suppress downstream alarms, and localize link failures for protection/restoration purposes in multiple kinds of networks
RFC4204