광인터넷 제어 프로토콜
Optical Internet Control Protocol

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What is the Optical Internet?

- Optical Internet enables a very high capacity Internet.
  - IP provides universal connectivity
  - WDM switch acts as the main switching/routing device.
- Optical Internet changes the data network basic assumptions that the transport network consists of fixed pipes as the transport network viewed as a large Optical network with dynamically configurable back-plane with the introduction of MPLS and its extensions to MPλS/GMPLS.
  - Circuit-based Optical transport network
  - Packet-based Optical transport network

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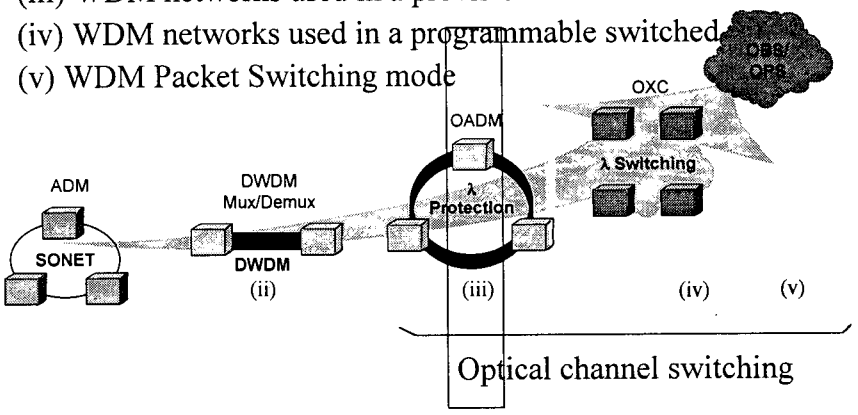
Optical Internet Evolution Steps

- Evolution toward the Optical Internet
  (ii) WDM used as a transmission technology
  (iii) WDM networks used in a provisioned mode
  (iv) WDM networks used in a programmable switched
  (v) WDM Packet Switching mode



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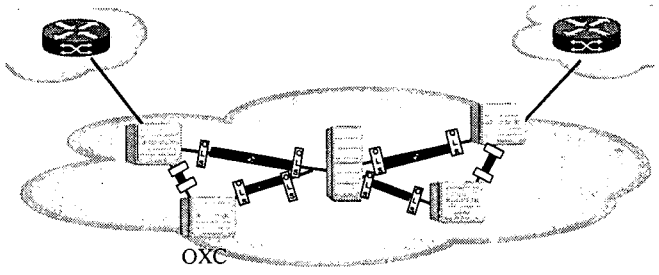
Possible Optical Internet Net Architecture



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The realization of the Optical Internet

- One realization issue will take place when the capabilities of optical technology spread toward the edges and extend the optical reach as close as possible to the final user.
  - Optical line system
  - Optical switching system
- Another issue is the design of the control plane of the next-generation optical inter-networks under the consideration to enable rich services such as *real-time optical channel provisioning, optical layer protection and restoration, optical layer traffic engineering, and optical bandwidth service management.*
  - IP-centric control plane is a strong candidate for next-generation optical networks based on GMPLS.

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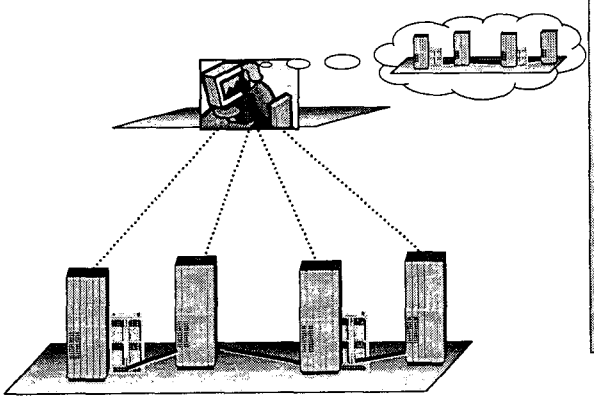
The Problems



- **Labor-intensive processes → Error-prone, slow and high operations costs**
- **Inflexible protection schemes, fixed-size pipes → Limited service levels and poor utilization**
- **Every action flows through the central Network Management system → Limited scalability, visibility and manageability**

One Cause of Limitations:
Lack of flexibility and intelligence in hardware and software

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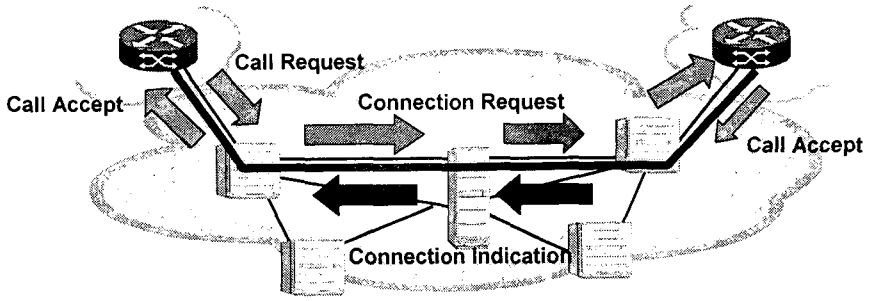
The Solution

- Automatic switched optical network is an optical network (e.g., SDH, OTN, WDM) in which connections can be created using switching control technology.



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Optical Internet Control Plane

- Optical Internet Network Architecture
  - Consists of IP routers or LSRs attached to an optical network, and lightpaths that connected to their peers over dynamically established
  - Interface with LSR and another carrier (service providers & carriers)
    - Optical User-Network Interface (O-UNI)
    - Optical Network-network Interface (O-NNI)
- Optical Interface in the data plane -on Data framing
  - Realized over an overlay network over optical lightpaths
- Optical Interface in the control plane- on routing/signaling
  - Client-Server
  - Peer relationship
  - Link management approach

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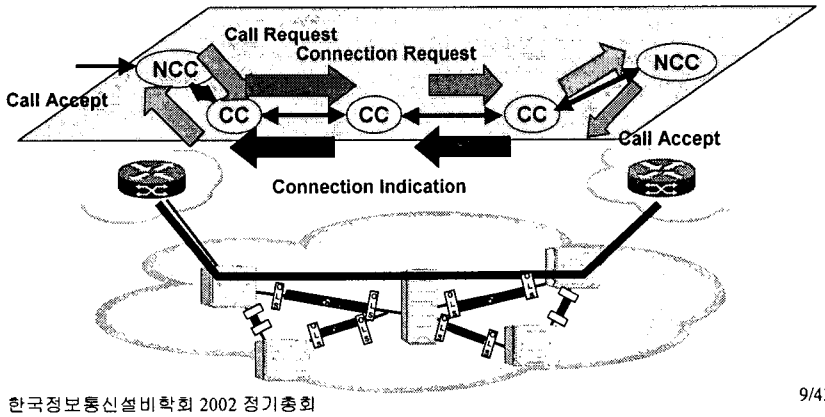
Possible Optical Internet Net Architecture

- The optical Internet as the Infrastructure for Next-Generation Internet Backbones
  - IP centric Optical Transport Networks Architecture
  - IP centric Control/management Plane



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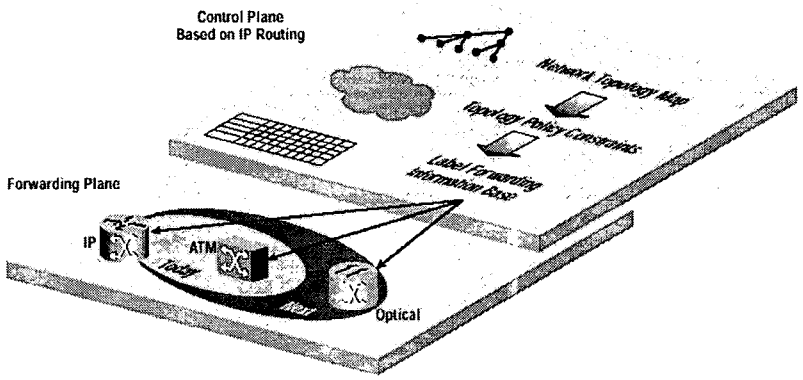
Optical Internet Protocol Architecture



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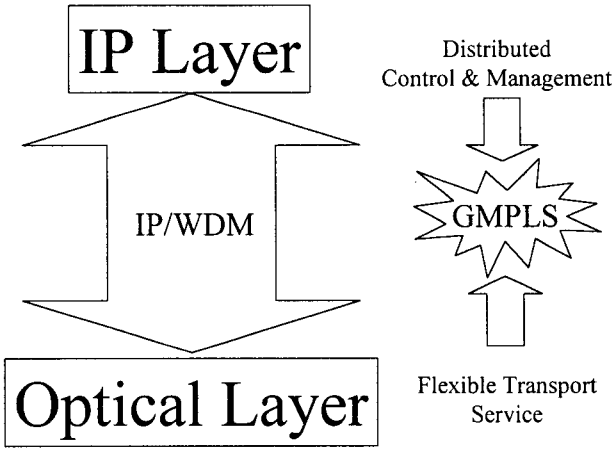
Convergence of IP and Optics : Control Plane



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Why GMPLS?

- GMPLS (MPLS TE control plane concepts are Generalized and applied to the Optical Network)
  - GMPLS distributes the previously centralized optical transport network connection management function into network elements (NEs). (e.g., SS7 [centralized] ->MPLS [distributed])
- The reasons are
  - A well-designed control plane should facilitates network interoperation and integration among networks with varying transport technologies such as circuit-switched and data networks.
  - A well-designed control plane should applicable to all types of networks such as OTNs, SDM, PDH, ...
  - A well-designed control plane should be flexible to accommodate different network scenarios (service provider business models).

GMPLS

- What is GMPLS?
- GMPLS-Routing
- GMPLS-Signaling
- GMPLS-Link Management
- Other GMPLS supporting Procedures

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What is GMPLS?

- Optical Internet deals primarily with DCM (distributed connection management). This is a subset of network control & management functions such as fault, configuration, accounting, performance, security, and policy managements.
- The distributed control plane can be divided into four functional modules
  - Element-level resource discovery - Link Management protocol
  - State information dissemination - topology/link state exchange
  - Path selection - route/path computation
  - And path control - signaling control
  - ❖ these components complement each other

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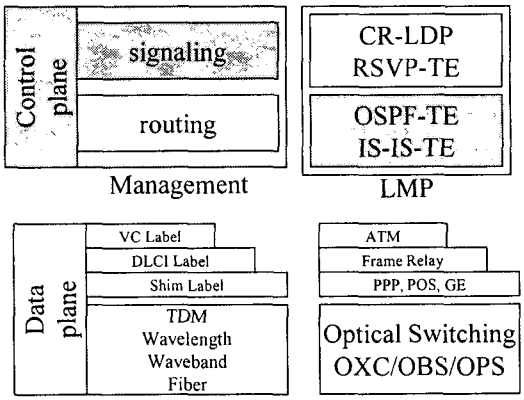
GMPLS Protocol Architecture



GMPLS:
Signaling and Routing extensions for the Optical layer

Generalized Label
IP/WDM

GMPLS

✓GMPLS-Routing
•GMPLS-Signaling
•GMPLS-Link Management
• Other GMPLS supporting Procedures

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GMPLS-Routing

- Re-using existing IP routing protocols allows for non-PSC layers to take advantages of years for IP routing
  - Extensions for intra-domain traffic engineering used of link-state routing protocol -> **OSPF-TE , IS-IS-TE extensions**
  - Extensions for inter-domain (BGP) traffic engineering
    -> BGP extensions **[Optical BGP]**
  - Constraint-based routing interacting with IP Layer Routing & WDM layer Routing

❖ Review of the availability of existing routing protocols to facilitate the value-added capabilities in Optical Internet (BGP, RIP)

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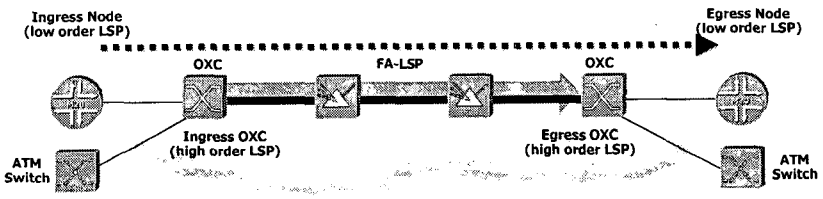
OSPF-TE , IS-IS-TE extensions



- An Ingress OXC can advertise an FA-LSP into IGP as a point-to-point TE link in the routing protocol
  - IGP floods **Forwarding Adjacency(FA)-LSP** among routers and OXCs
- Link state database and traffic engineering database maintains conventional links & FA-LSPs
  - Local and remote interface IP addresses
  - Traffic engineering metric ...

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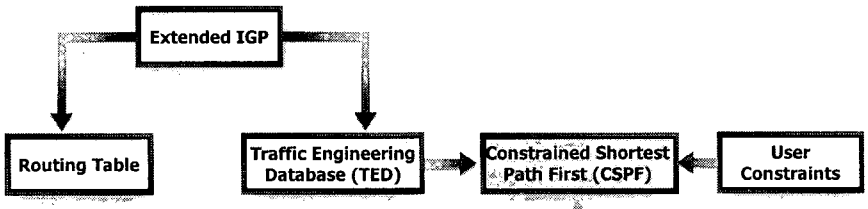
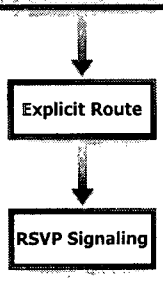
Constraint-Based Routing



- Reduce the level of manual configuration
- Input to CSPF:
  - Path performance constraints
  - Resource availability
  - Topology information (including FA-LSPs)
- Output: Explicit route for GMPLS signaling



GMPLS

- GMPLS-Routing
- ✓ GMPLS-Signaling
- GMPLS-Link Management
- Other GMPLS supporting Procedures

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GMPLS-Signaling

- What is needed: An IP signaling protocol!
  - Ability to establish and maintain Label Switched Path along an Explicit route
  - Ability to reserve resources when establishing a path
- Two proposed signaling mechanisms for GMPLS Traffic Engineering are being considered
  - ReSource reserVation Protocol (RSVP)
  - Constraint-based Routing Label Distribution Protocol (CR-LDP)

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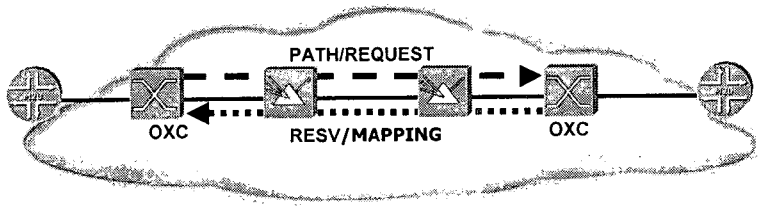
MPLS Signaling



- PATH / REQUEST Message
  - Generalized Label Request, Explicit Route
  - Upstream Label, Label Set, Suggested Label
- RESV / MAPPING Message
  - Notify message informs non-adjacent nodes of LSP events
  - Notify-ACK message supports reliable delivery

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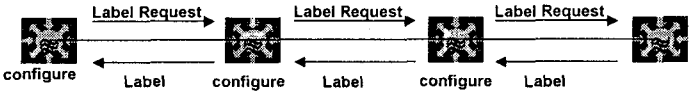
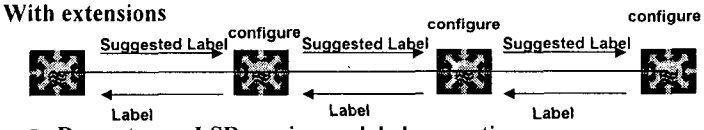
MPLS Signaling Extensions

- CR-LDP



- With extensions



- Downstream LSR can ignore label suggestion

- Suggested label LSP
  - Motivation
    - Is a generalized label that is given by an upstream node to a downstream node in a PATH/REQ message which can support of TDM and λ switching.
  - The downstream node should try to use this label if able and pass the same label back in the RESV/MAP
  - This feature can help speed up path establishment on LSRs that take time to configure the cross connect.

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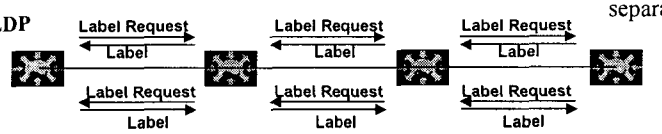
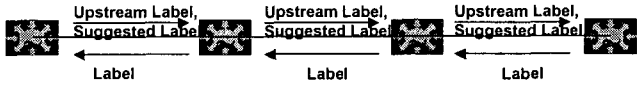
MPLS Signaling Extensions

separate signaling

- LDP



- With extensions



- Bi-directional LSPs
  - There is a possibility of contention for the same label when both sides can allocate for the same direction due to separate signaling.
  - This feature can help speed up path establishment on LSRs that take time to establish both way LSPs.
  - Simplifying failure restoration

GMPLS

- GMPLS-Routing
- GMPLS-Signaling
- ✓ GMPLS-Link Management Protocol
- Other GMPLS supporting Procedures

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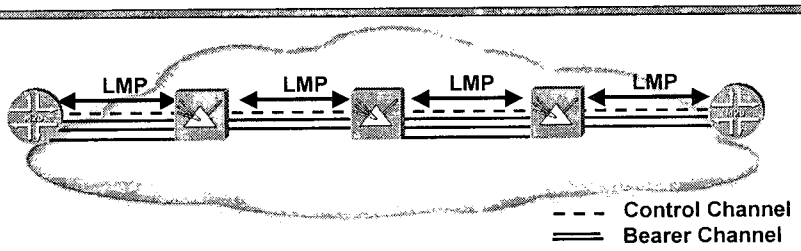
GMPLS -Link Management Protocol



- **Running between neighboring nodes to simplify link management**
  - **Establishes and maintains control channel connectivity**
    - **Control channel carries link provisioning, fault isolation, path management, label distribution, and topology information**
    - **Supports in-band and out-of-band mechanisms**
  - **Verifies physical connectivity of bearer channels**
    - **Identifies installer cabling errors at deployment time**
    - **Manages label associations for the link**
  - **Rapidly identifies link, fiber, or channel failures**

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Services Provided by GMPLS-LMP

- Control channel management
  - Lightweight keep-alive mechanism (Hello protocol)
  - Reacts to control channel failures
- Verify physical connectivity of bearer channels
  - Ping test messages sent across each bearer channel
  - Eliminates human cabling errors
- Link property correlation
  - Maintains a list of local label to remote label mappings
  - Maintains list of protection labels for each channel
- Fault isolation
  - "Loss of light" is detected at the physical (optical) layer
  - Operates across both opaque (DXC) and transparent (PXC) network nodes

GMPLS supplementary

- GMPLS-Routing
- GMPLS-Signaling
- GMPLS-Link Management Protocol
- ✓ Other GMPLS supporting Procedures

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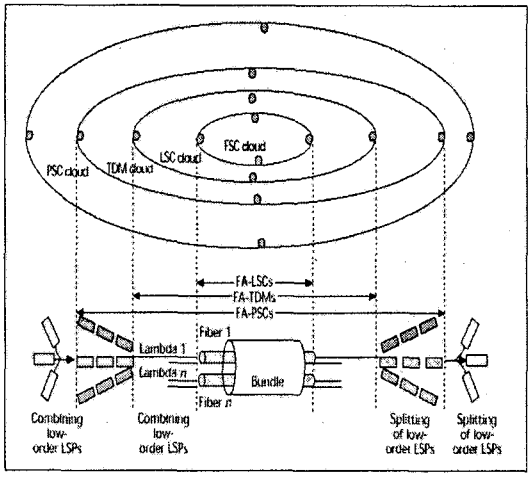
Multiple Interface Types

- Packet-Switch Capable(PSC) interfaces
  - ATM-LSRs (Label Switching Routers)
- Time-Division Multiplex Capable(TDM) interfaces
  - SDH/SONET Cross-Connect, ADM
- Lambda Switch Capable(LSC) interfaces
  - Wavelength
- Fiber-Switch Capable(FSC) interfaces
  - Photonic Cross-Connect



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GMPLS Label

- Label Structure
  - The label object which consists of a Link ID and a Label travels in RESV/Mapping upstream like the traditional label
  - The Link ID is used when a control channel controls multiple links (bundling).
  - Label format depends on the class of link on which the label is being used.
- Generalized Label supports each class of switching
  - Extends to include support of time-slot, wavelength, space division multiplexed position (SONET,SDH, ports, λ, generic labels)
  - Only carries a single level of label
  - Variable length label parameter

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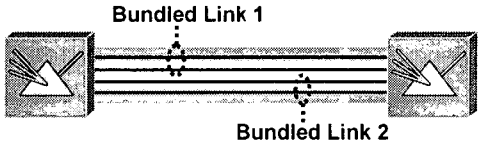
Link Bundling



- Multiple parallel links between nodes can be advertised as a single link into the IGP (OSPF and/or IS-IS)
  - Enhances IGP and traffic engineering scalability
- To improve routing scalability by reducing the amount of information that has to be handled by OSPF and/or IS-IS
- All component links in a bundle must begin and end on the same pair of LSRs, share common characteristics

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Resource table

Local port ID1	Neighbor NE address	Neighbor port ID	Physical attribute	Logical attribute	Operational state
Local port ID2	Neighbor NE address	Neighbor port ID	Physical attribute	Logical attribute	Operational state

- Physical attributes, which are technology and vender specific
  - Signal type, such as encoding, multiplexing structure, and wavelength grid
  - Optics type, such as short reach and long reach
  - Signal direction, such as unidirectional or bi-directional
- Logical attributes, which may describe characteristics of a pool of physical ports
  - A set of unidirectional wavelengths
  - A VPN ID
  - A shared risk link group
  - A protection type
- Local port ID, Neighbor node address & port ID

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Resource/Neighbor/Topology Discovery

- What discovery?
  - Resources
    - Node, Link, Wavelength, …
    - Addressing and reachability
    - What type of bandwidth, how much is available
  - Neighbor/Adjacency
    - Relationship with optical discovery
    - Separate topologies of a control plane and a transport plane
    - Link properties/capability
    - Subnetwork properties/capability: switching/protection/reliability
  - Topology
    - Connectivity
    - Interface types: p2p, NBMA, broadcast

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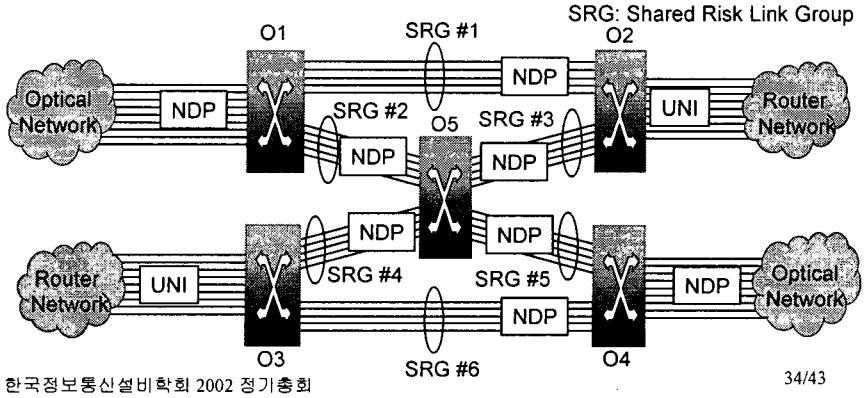
Neighbor/Topology Discovery

- Mechanism used to discover and verify the port connectivity
- IETF LMP (OIF) or IETF PPP (ODSI) messages carried in out-of-band.
  - NDP allows adjacent OXCs to determine IP addresses of each other and port-level local connectivity information (i.e., port X in OXC O1 connected to port Y in OXC O2)

NDP: Neighbor discovery protocol
SRG: Shared Risk Link Group



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Topology and resource status dissemination

- Link state routing protocols such as OSPF, IS-IS, and PNNI provide a standard way of exchanging topology and resource status information for connection route computation
- Reachability information is also disseminated to furnish mechanism that client NEs can use to find out which other client NEs they can reach over the optical network.

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Link State Information

- Link state Information
  - Static information such as neighbor connectivity, logical link attributes, and total BW. It is required for circuit operation.
  - Dynamic information such as BW availability and BW fragmentation information. It is required for circuit LSP operation.
  - ❖ The objective should be to distribute just enough link state information to support connection setup operations, which does not affect control plane scalability and stability.
- The areas of extension include
  - resource utilization
  - Switching capability
  - Support for multilayer switching
  - Protection and restoration at a number of layers (WDM, SONET, MPLS)
  - Diverse routing support (Shared Risk Link Group)

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Path Computation

- Constraint-based routing interacting with IP Layer Routing & WDM layer Routing
  - Consideration for extension of interaction or integrating with IP & WDM
- A diverse approach depending on computation complexity, implementation, and specific network context,
  - Offline - centralized
    - Facilitated by simulation and/or network planning tools
  - Online - distributed
    - Performed whenever a connection request is received
  - Offline and Online path selection
    - Operators could use online computation to handle a subset of path selection decisions and offline computation for complicated YE and policy-related issues such as demand planning, service scheduling, cost modeling, and global optimization.

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GMPLS Control Channel

- The link between two nodes consists of
  - An in-band or out-of-band Control Channel
  - One or more bearer channels
- Control channel is used to exchange
  - Link provisioning and fault isolation messages (LMP)
  - Path management and label distribution messages (RSVP or CR-LDP)
  - Topology information messages (OSPF or IS-IS)

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Signaling Requirements: Fault-Tolerance

- Lightpaths must not be deleted due to failures in the control plane
  - **Present RSVP/CR-LDP mechanisms associate the control path with data paths**
    - **Failure in the control path is assumed to affect the data path**
    - **Data path is therefore deleted or rerouted**
  - **In optical networks, the fabric cross-connects must remain if control path is affected**
    - **Enhancements to RSVP/CR-LDP needed for this.**

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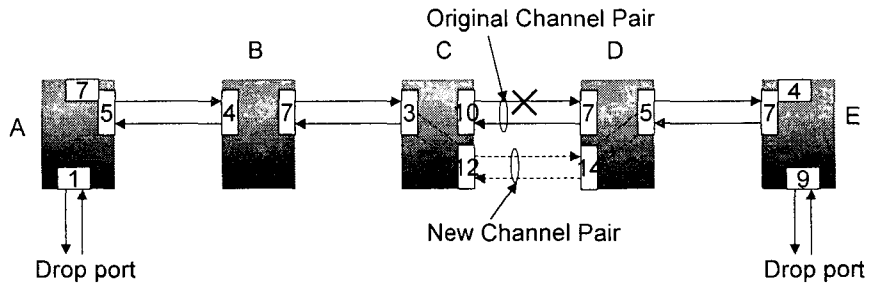
Link-Level Restoration Overview



- A lightpaths is locally restored by selecting an available pair of channels within the same link
- If no channel is available then the end-to-end restoration is invoked

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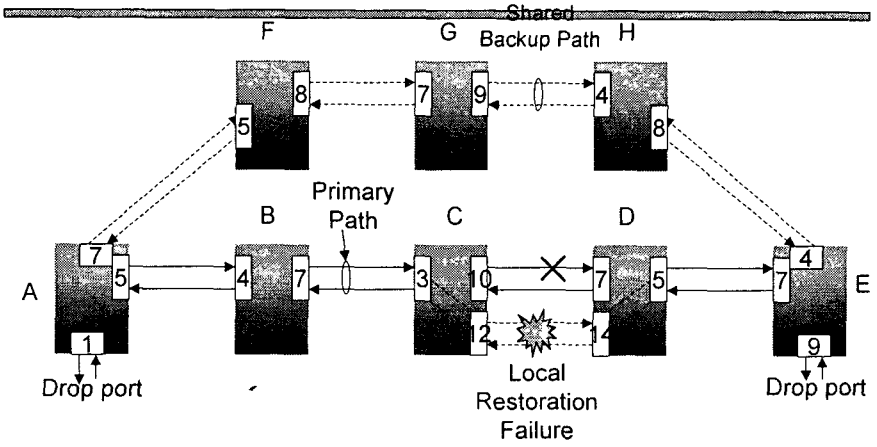
End-to-End Restoration Overview



- A shared backup path is "soft-setup" for each restorable primary path
- When local restoration fails, triggers are sent to the end-nodes
- End-to-end signaling over the backup path activates it and completes end-to-end restoration

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Conclusion

- Packet and Optical technology evolution enables the Two-Layer Provider Network (Optical Internet)
- IETF, ITU and OIF are defining the interface between the two layers (Standard Activities)
- Consideration of GMPLS as a distributed control plane architecture for Optical Internet
  - Routing
  - Signaling
  - Management

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