

# INF5050 - Protocols and routing in internet

Multiprotocol Label Switching (MPLS) /  
Generalized Multiprotocol Label Switching (GMPLS)

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# Outline

- ▶ Background
- ▶ MPLS: Fundamentals
- ▶ MPLS: Terminology
- ▶ GMPLS
- ▶ GMPLS: Recovery techniques
- ▶ Summary
- ▶ Resources

# What is MPLS?

- ▶ MPLS is a scalable data-carrying mechanism that directs data from one network node to the next based on short path labels rather than network addresses.
- ▶ Every network packet is assigned at least one label and packet-forwarding decisions are based on them exclusively, rather than the content of the packets.
- ▶ Operates somewhere between layer 2 (data link layer) and layer 3 (network layer). Considered a "layer 2.5" protocol.
- ▶ Standardized by the IETF in 1996. Based on work done by Ipsilon Networks and Cisco.

# Why MPLS?

- ▶ Avoids complex lookups in the routing table.
- ▶ Create end-to-end circuits using any protocol over any transport medium.
- ▶ Provide a highly scalable mechanism that was topology driven rather than flow driven.
- ▶ Load balance traffic to utilize network bandwidth efficiently.
- ▶ Allow core routers/networking devices to switch packets based on a simplified header.
- ▶ Remove the complexity and overhead of network managements (Assemble and reassemble IP packets).

# MPLS was conceived, why?

- ▶ The shortest path routing protocols like IS-IS and OSPF
  - ▶ Did not take capacity characteristics into account while making the routing decisions
  - ▶ The outcome is, segmentation over the network which leads to congestion, while others remain under-utilized.
- ▶ MPLS reduces the complexity and redundancies by adding new network functionalities.

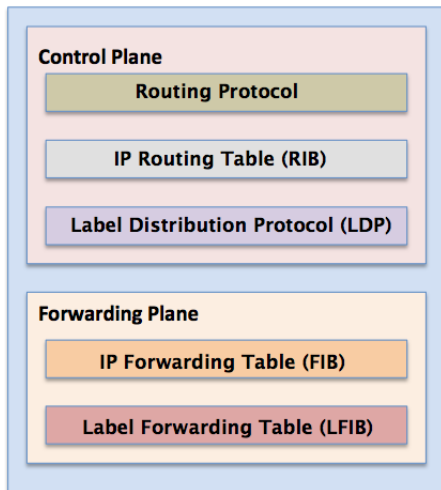
# MPLS Fundamentals

- ▶ Main idea:
  - ▶ attach a short fixed-length label to packets at the ingress to an MPLS domain
  - ▶ the labels are used to make the forwarding decisions.
- ▶ MPLS consists of a forwarding and a control plane.  
Though they are decoupled and independent from each other.
- ▶ Supports explicit routed path.
- ▶ Provides Quality of Service (QoS) if it is implemented with Diff-Serv and Constraint-based routing.

# Diff-Serv and Constraint-based routing

- ▶ Differentiated Services
  - ▶ A network architecture for classifying and managing network traffic and provide QoS on modern IP networks.
  - ▶ it is used to provide low-latency to critical network traffic. (Media, VOIP).
- ▶ Constraint-based routing
  - ▶ It is a routing technique where resource availability and traffic characterization are taken into account.

# MPLS architecture





# MPLS architecture

The planes are decoupled and independent of one another.

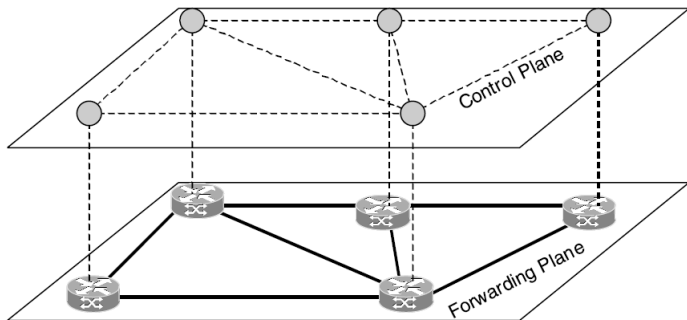


Fig. 2. Conceptual view of MPLS control plane and forwarding plane.

# MPLS Fundamentals: Control Plane

- ▶ Collection of protocols that establish network level functionality in the MPLS networks.
  - ▶ The protocols themselves are implemented as software processes to communicate with each other across node boundaries using message passing.
- ▶ They facilitate the establishment of label switched paths in the MPLS networks.
- ▶ The plane consist of the legacy IP routing and signaling protocols.

# MPLS Fundamentals: Forwarding Plane

- ▶ Consists of the datapath within a network element through which user traffic traverses.
- ▶ The forwarding plane performs label swapping operations using lookup tables and miscellaneous packet treatment functions such as scheduling, queue management, rate shaping, policing and others.
- ▶ It is generally implemented in hardware due to high speed operation support.

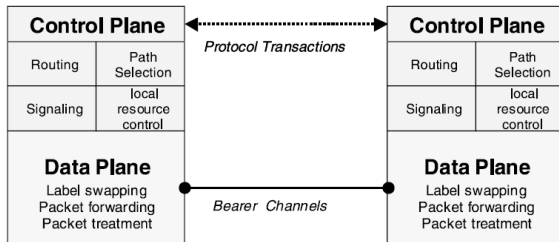


Fig. 3. Functional view of control and forwarding planes.

# MPLS: Terminology

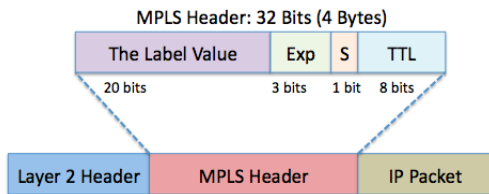
- ▶ FEC (Forwarding Equivalence Class)
  - ▶ Group of IP packets which are forwarded in the same manner (e.g. over the same path, with the same priority and the same label)
- ▶ Label
  - ▶ Short fixed length identifier which is used to identify a FEC
- ▶ Label Swapping
  - ▶ Looking up the oncoming label to determine the outgoing label, encapsulation and port
- ▶ Label switched path (LSP)
  - ▶ Path through one or more LSR for a particular FEC
- ▶ Label switching router (LSR)
  - ▶ an MPLS capable router

Advantages?



# What is a Label?

- ▶ an extra layer that "sits" between L2 and L3 layer known as header 2.5 (or "shim")
- ▶ don't need to lookup at the routing table, you use the label information to find the next hop
- ▶ creates a VPN rather than public networks
- ▶ isolates other traffics running on the network



# What is a Label?

## Header information

- ▶ **Label value:** the label itself for lookup in the MPLS forwarding table
- ▶ **EXP field:** gives Diffserv support on the MPLS network and carry the IP precedence value from the IP packet.
- ▶ **Stack bit:** Indicates the bottom of the MPLS header stack has been reached.
- ▶ **Time-To-Live:** prevents loop and path tracing in the MPLS network. This value decrements with each hop and packet discards occur at a zero value.

# Label distribution in MPLS and how LSP works

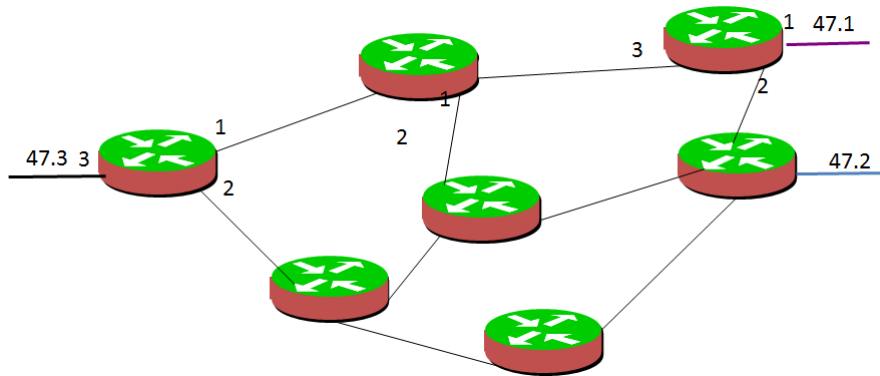
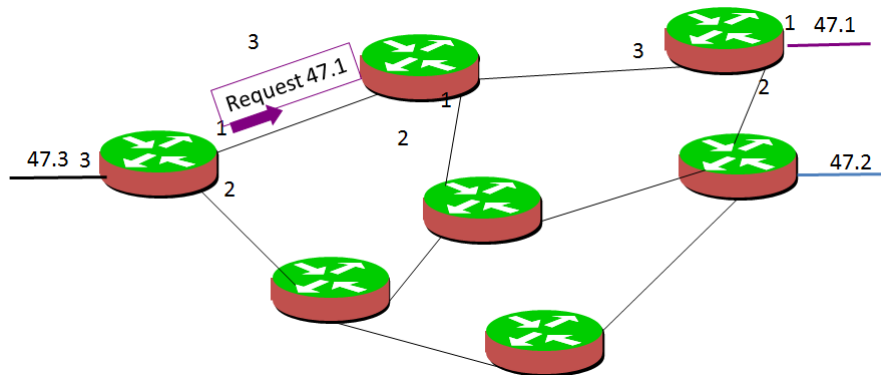


Figure: This is the initial phase



# Label distribution in MPLS and how LSP works



**Figure:** Ingress node makes a request to the nearest node for a given destination address

# Label distribution in MPLS and how LSP works

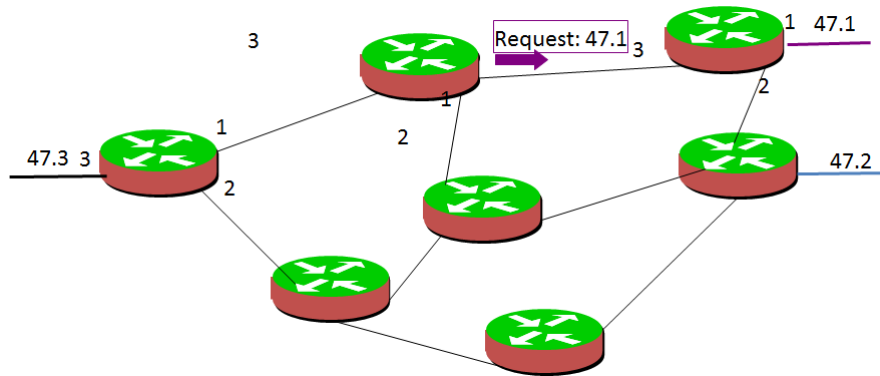
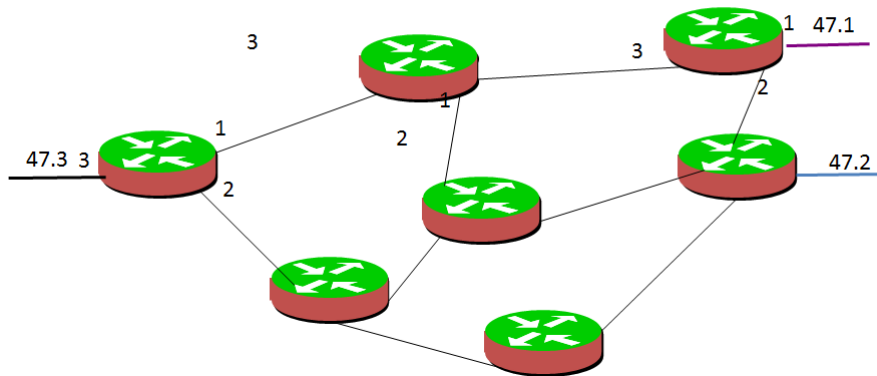


Figure: Route the message to the destination node

# Label distribution in MPLS and how LSP works

Intf In	Label In	Dest	Intf Out
3	0.40	47.1	1



**Figure:** A label table is initialized with information that when it receives the given label id, it is for this router 47.1

# Label distribution in MPLS and how LSP works

Intf In	Label In	Dest	Intf Out
3	0.40	47.1	1

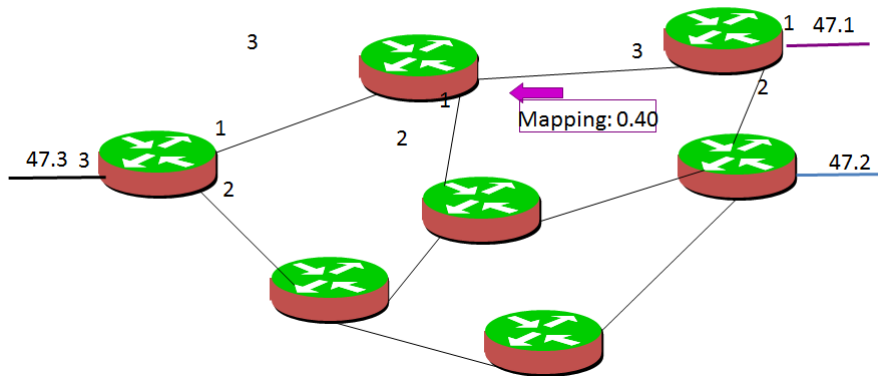
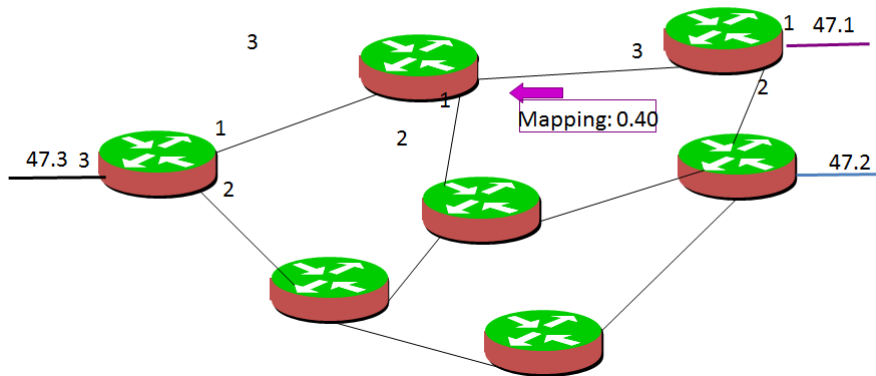


Figure: Map its label id to the router that sent request

# Label distribution in MPLS and how LSP works

Intf In	Label In	Dest	Intf Out	Label Out
3	0.50	47.1	1	0.40

Intf In	Label In	Dest	Intf Out
3	0.40	47.1	1

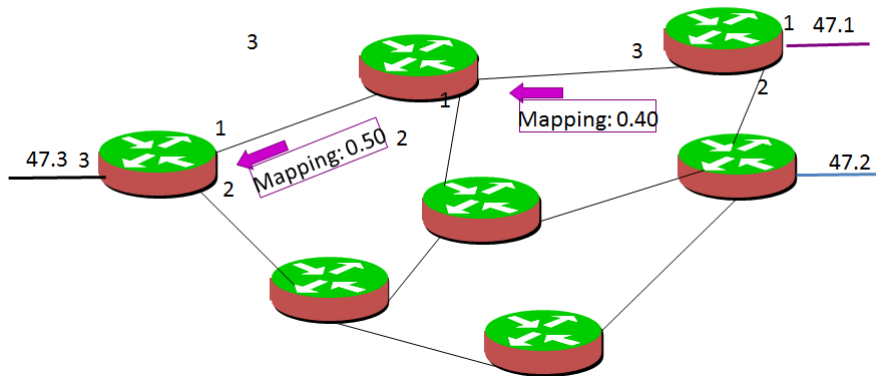


**Figure:** The router that receives the mapping data, adds it to its forwarding table and generates a "in" label

# Label distribution in MPLS and how LSP works

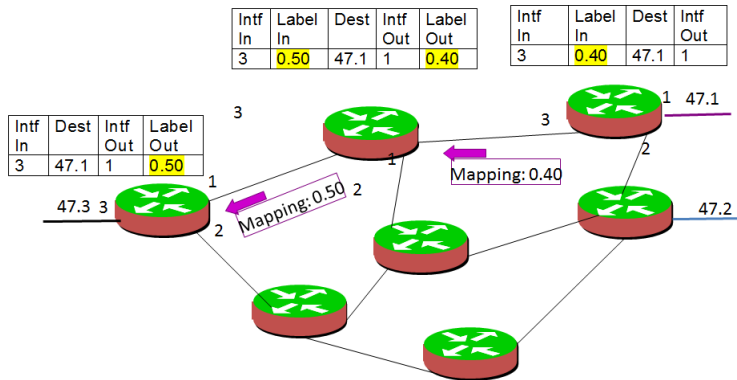
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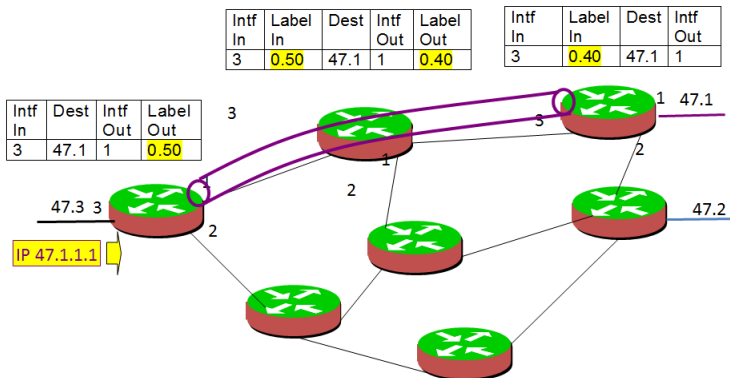
**Figure:** When finished, the egress node sends the mapping data of which label will be added

# Label distribution in MPLS and how LSP works



**Figure:** When it has reached the Ingress node, it will map the given label for the given destination IP

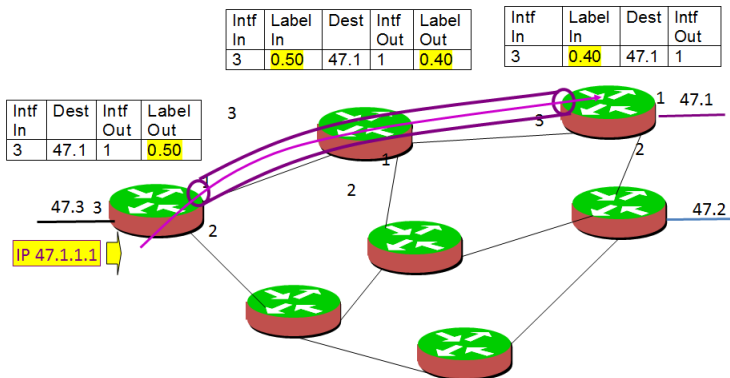
# Label distribution in MPLS and how LSP works



**Figure:** Send message/packet to 47.1, the Ingress node makes a routing lookup and assigns the given label for the destination

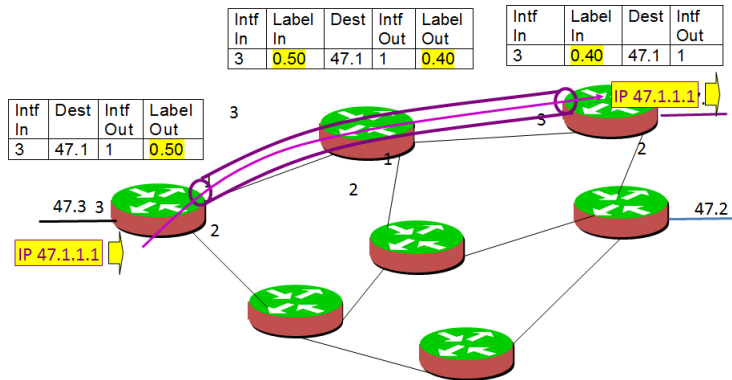


# Label distribution in MPLS and how LSP works



**Figure:** When forwarded, you add label onto the packet, when it arrives to a node, it checks the label and replaces it to another one and forwards it

# Label distribution in MPLS and how LSP works



**Figure:** When reached to the egress node, it will then strip out the label and deliver to the specific destination

# Disadvantages of MPLS

MPLS has performance issues in the network:

- ▶ constraint-based routing
  - ▶ Problem with computation of paths for LSPs subject to various types of constraints.
  - ▶ NP-complete problem
- ▶ traffic partitioning and assignment
  - ▶ This problem deals with the optimal partitioning and assignment of traffic to parallel LSPs between pairs of MPLS ingress and egress nodes.
- ▶ Low visibility and lack of access into the MPLS cloud.  
How to monitor that your carrier is delivering the correct performance?
  - ▶ Trace-route and ping no longer an option.
  - ▶ Probes are costly and difficult to maintain.
- ▶ restoration
  - ▶ many proposals for restoration in ATM might be applicable to MPLS.

- ▶ What is GMPLS?
  - ▶ a protocol suite extending MPLS to manage further classes of interfaces and switching technologies other than packet interfaces and switching, such as time division multiplex, layer-2 switch, wavelength switch and fiber-switch.

# GMPLS

- ▶ GMPLS is an extended form of MPLS and some of these improvements are:
  - ▶ RSVP-TE
  - ▶ OSPF and IS-IS
  - ▶ New link-management protocol
  - ▶ Bi-directional LSP setup
    - ▶ Reduce latency
    - ▶ Less control overhead
    - ▶ Route selection is simpler
    - ▶ Cleaner interface
- ▶ 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: Hierarchical LSP



# Summary

- ▶ MPLS
- ▶ GMPLS

# Resources

- ▶ Generalized Multiprotocol Label Switching: An Overview of Signaling Enhancements and Recovery Techniques  
IEEE Communication Magazine, July 2001. A. Banerjee et. al.
- ▶ Internet Traffic Engineering Using Multi-Protocol Label Switching (MPLS). Computer Networks 40, Elsevier, 2002 D.O. Awduche and B. Jabbari.