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 exclusivly, 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.

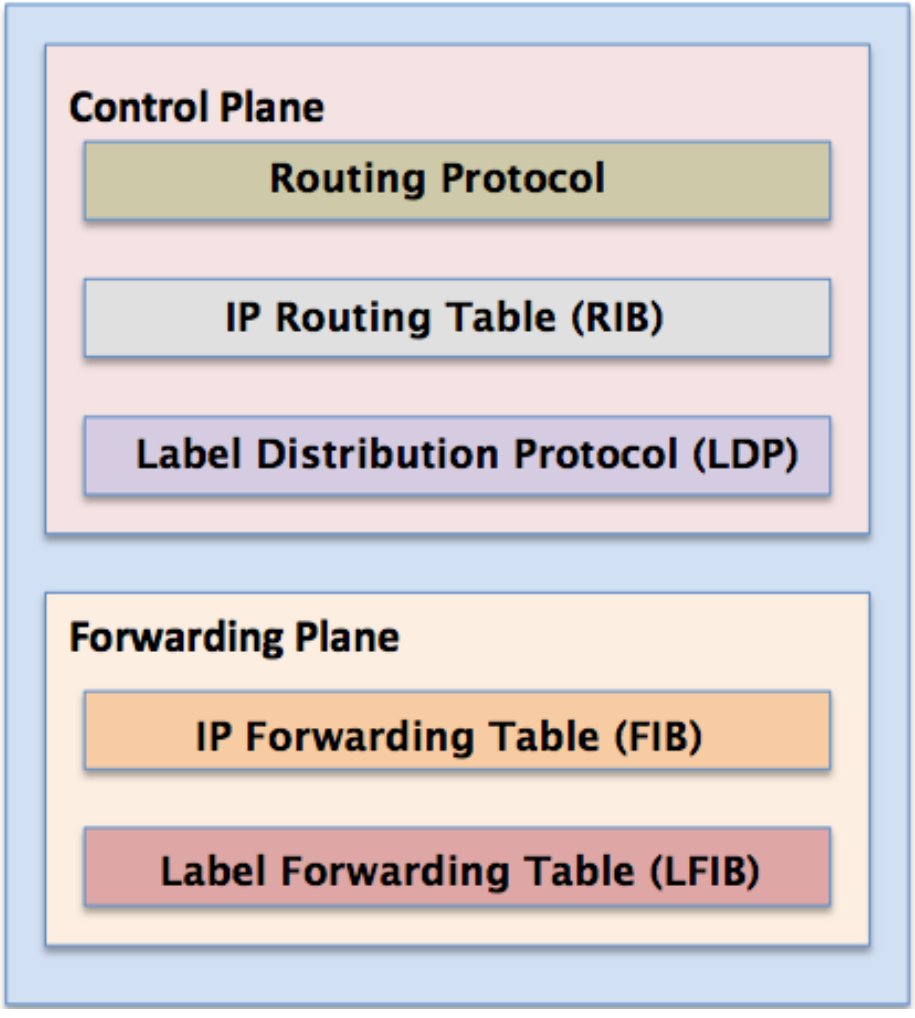
MPLS Fundamentals

- 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.

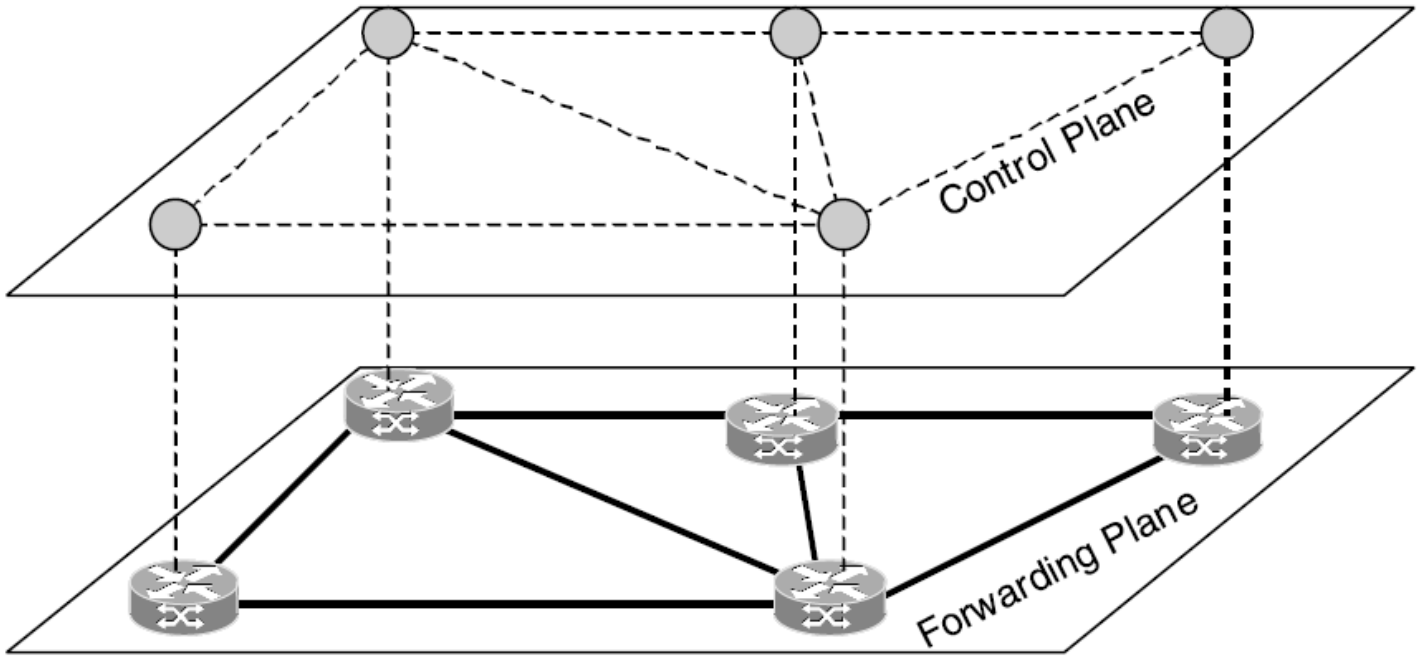


Fig. 2. Conceptual view of MPLS control plane and forwarding plane.

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 plne 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.

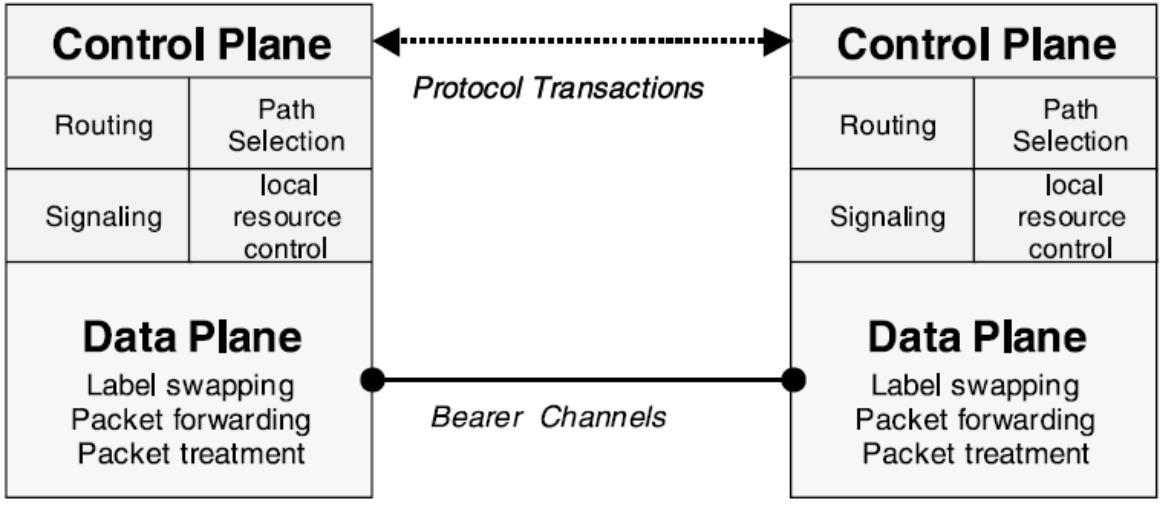


Fig. 3. Functional view of control and forwarding planes.

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

FEC

Advantages?

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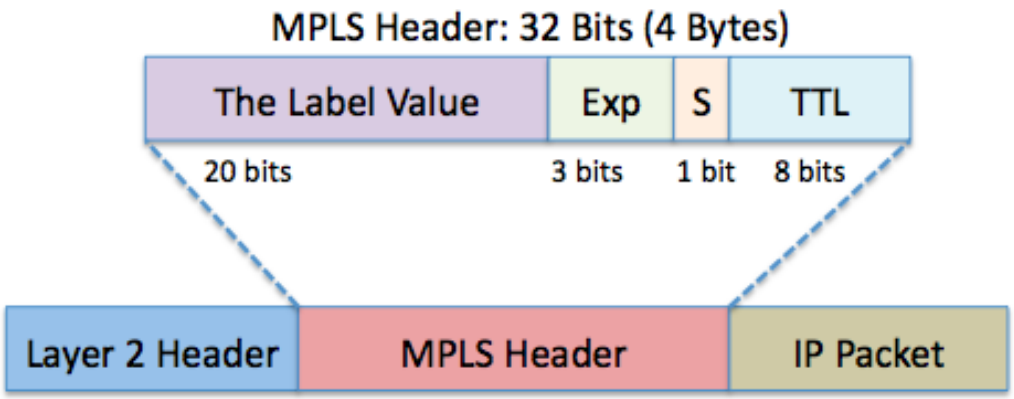
What is a Label?

- 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

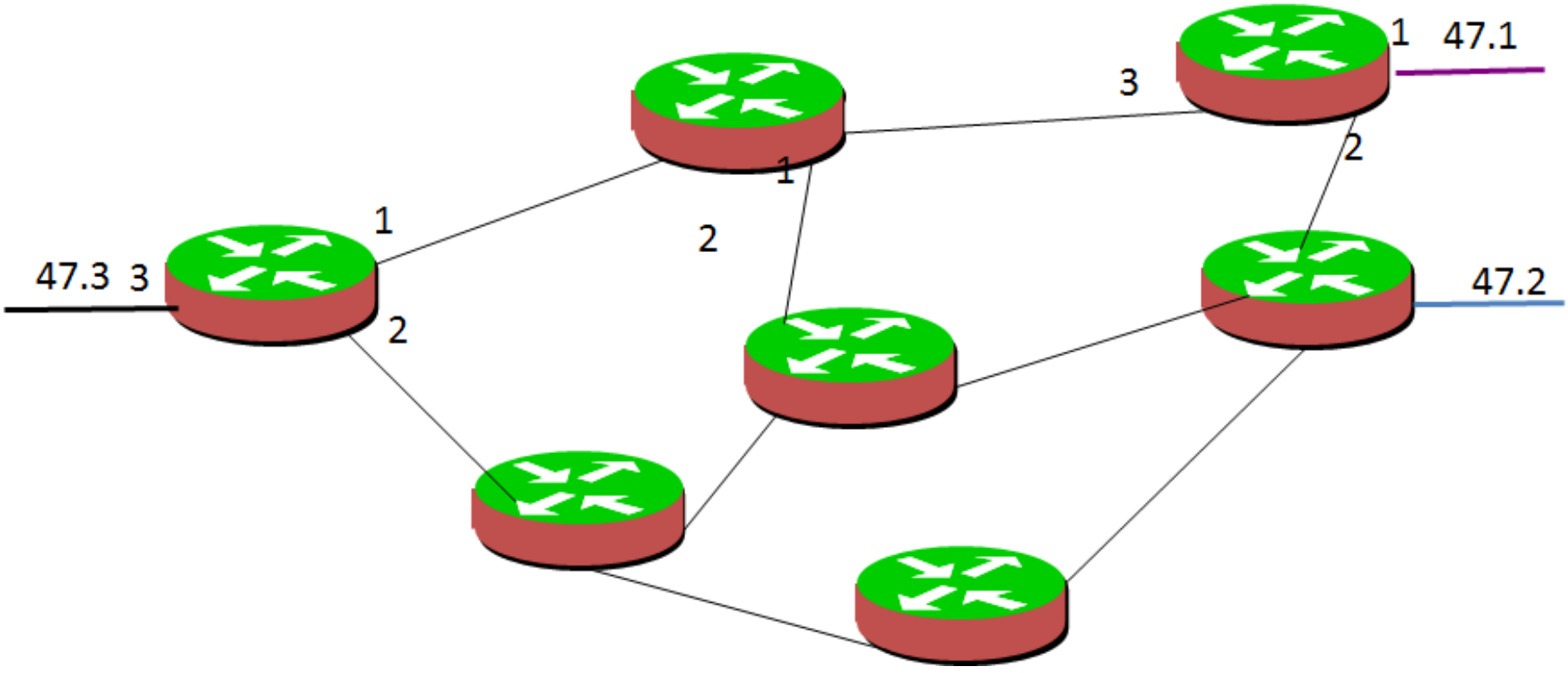


Figure : This is the initial phase

Label distribution in MPLS and how LSP works

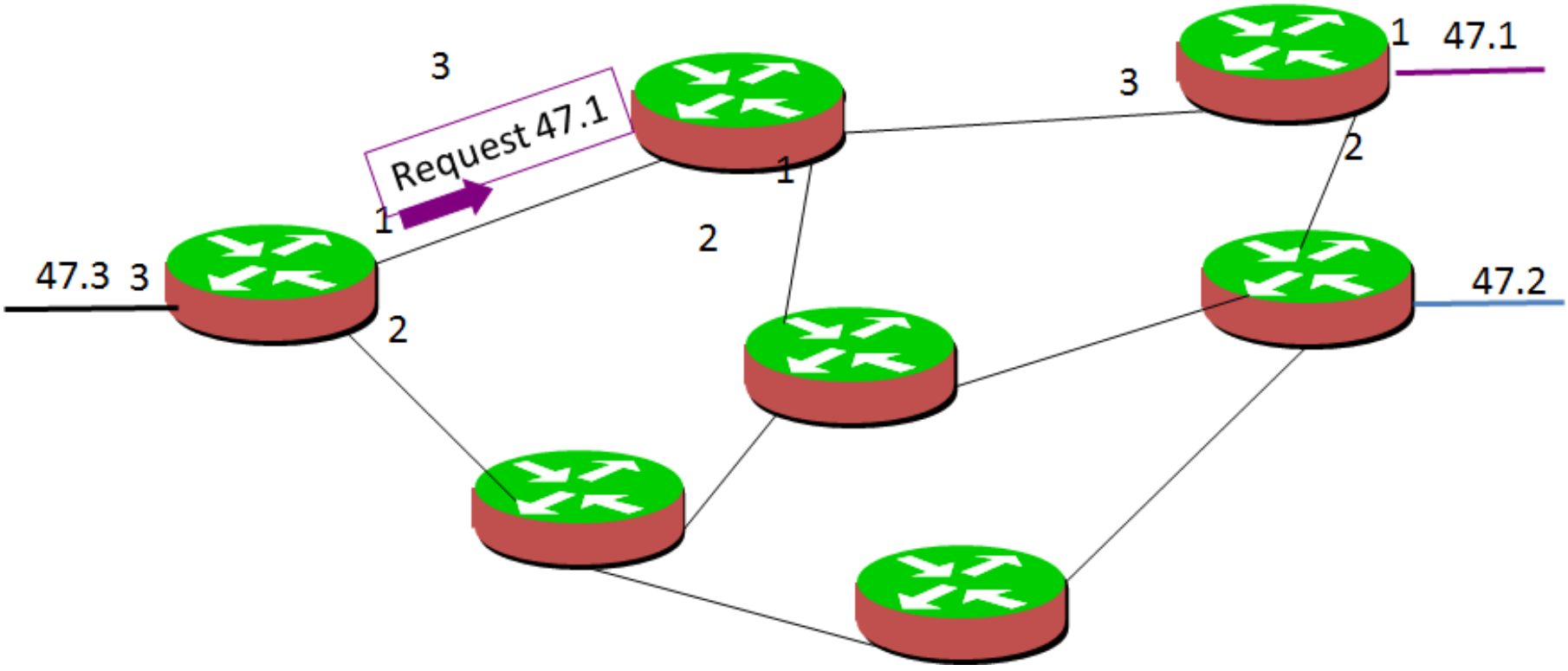


Figure : Ingress node makes a request to the nearest node for a given destination address

Label distribution in MPLS and how LSP works

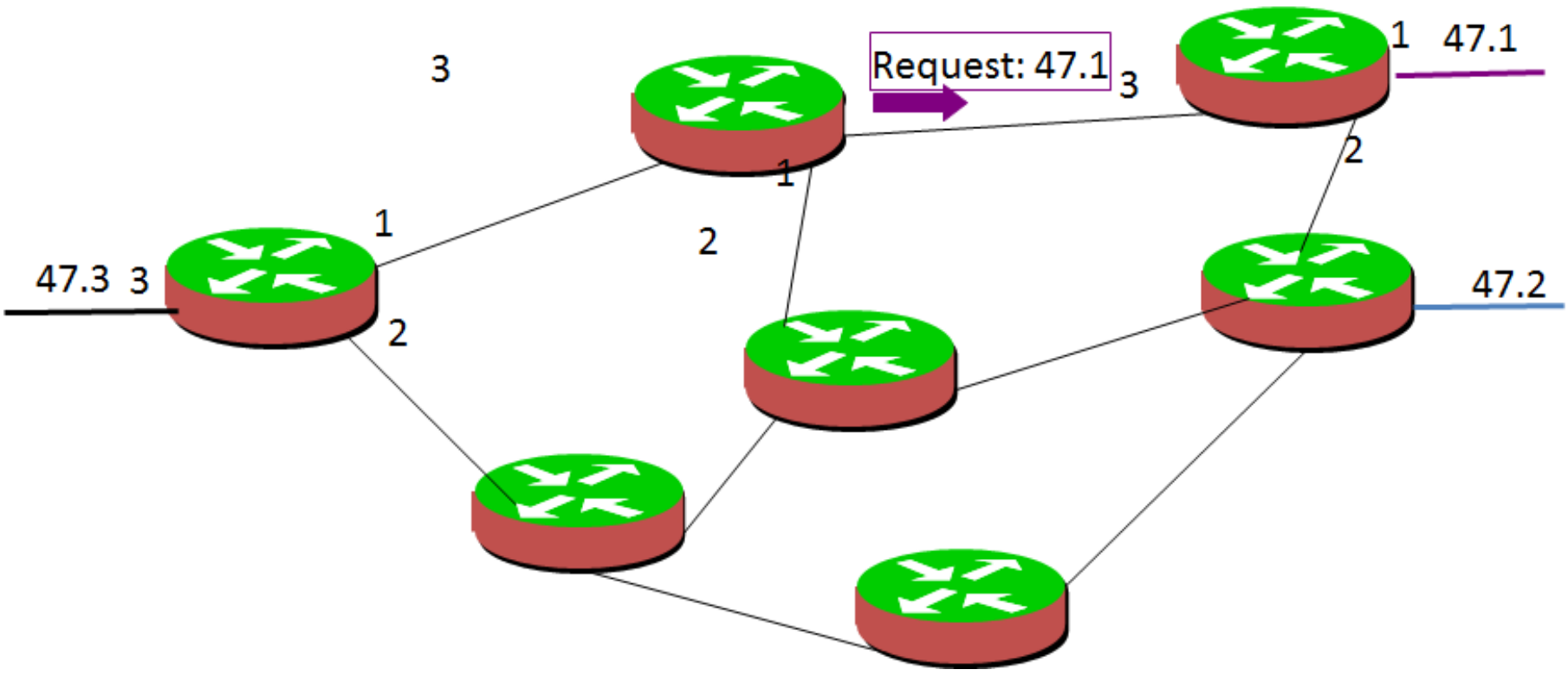


Figure : Route the message to the destination node

Label distribution in MPLS and how LSP works

Intf In	Label In	Dest	Intf Out
3	0.40	47.1	1

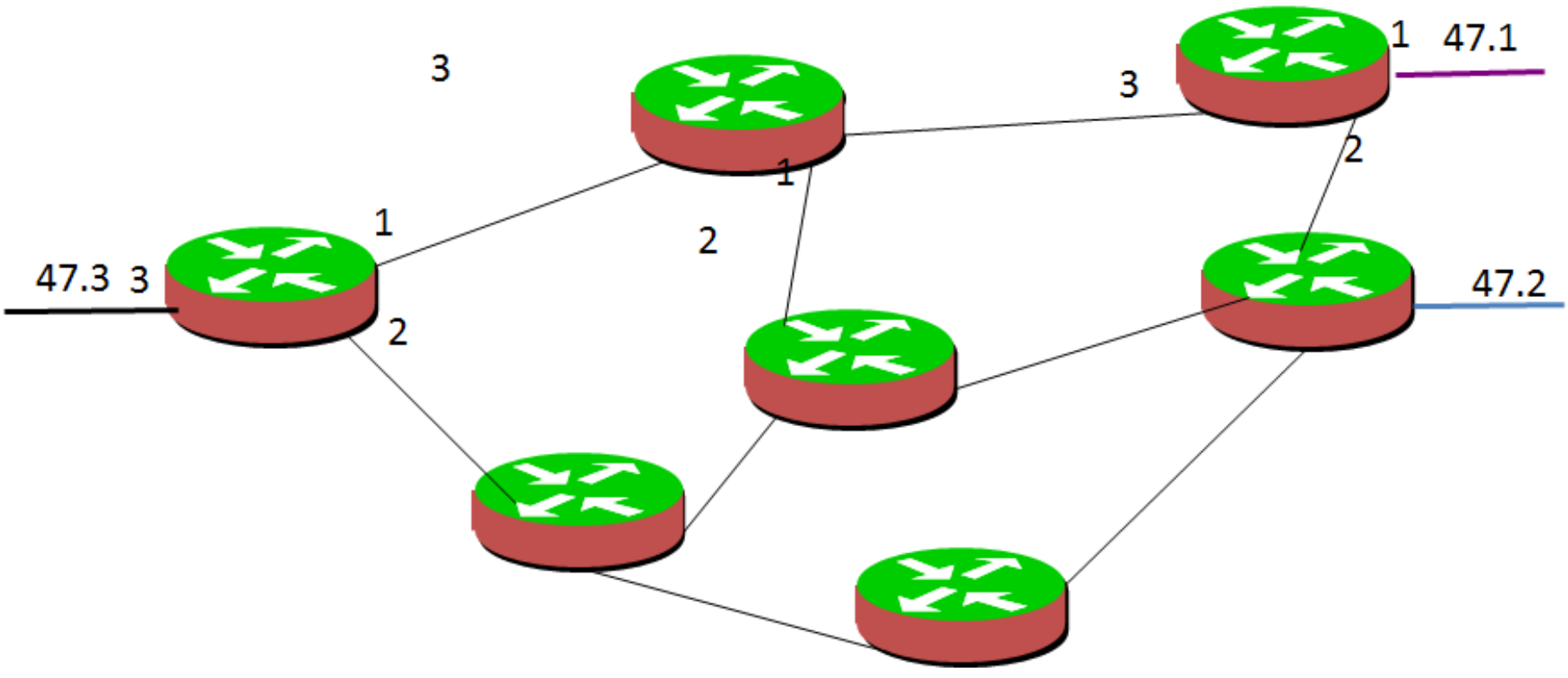


Figure : A label table is initialized with information that when it receives the given label id, it is for this router 47.1

Label distribution in MPLS and how LSP works

Intf In	Label In	Dest	Intf Out
3	0.40	47.1	1

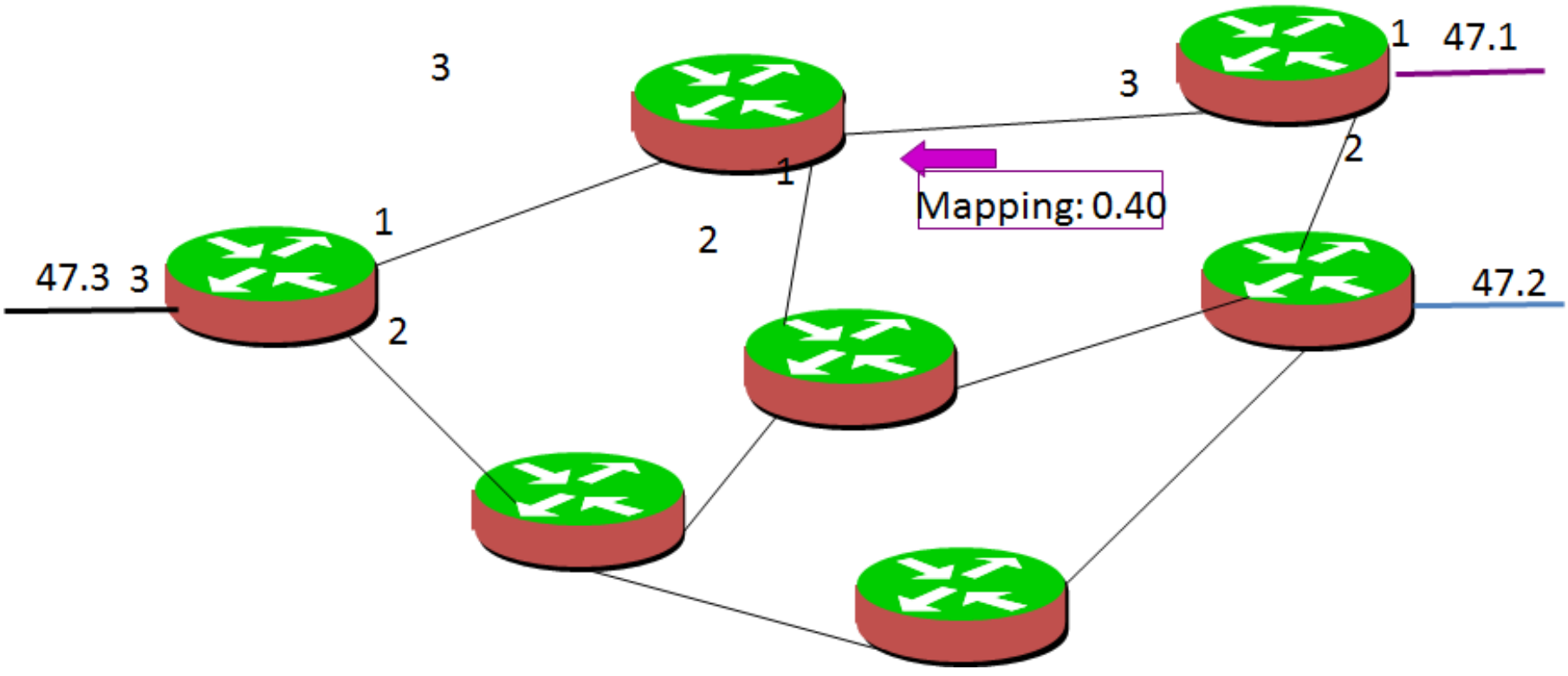


Figure : Map its label id to the router that sent request

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

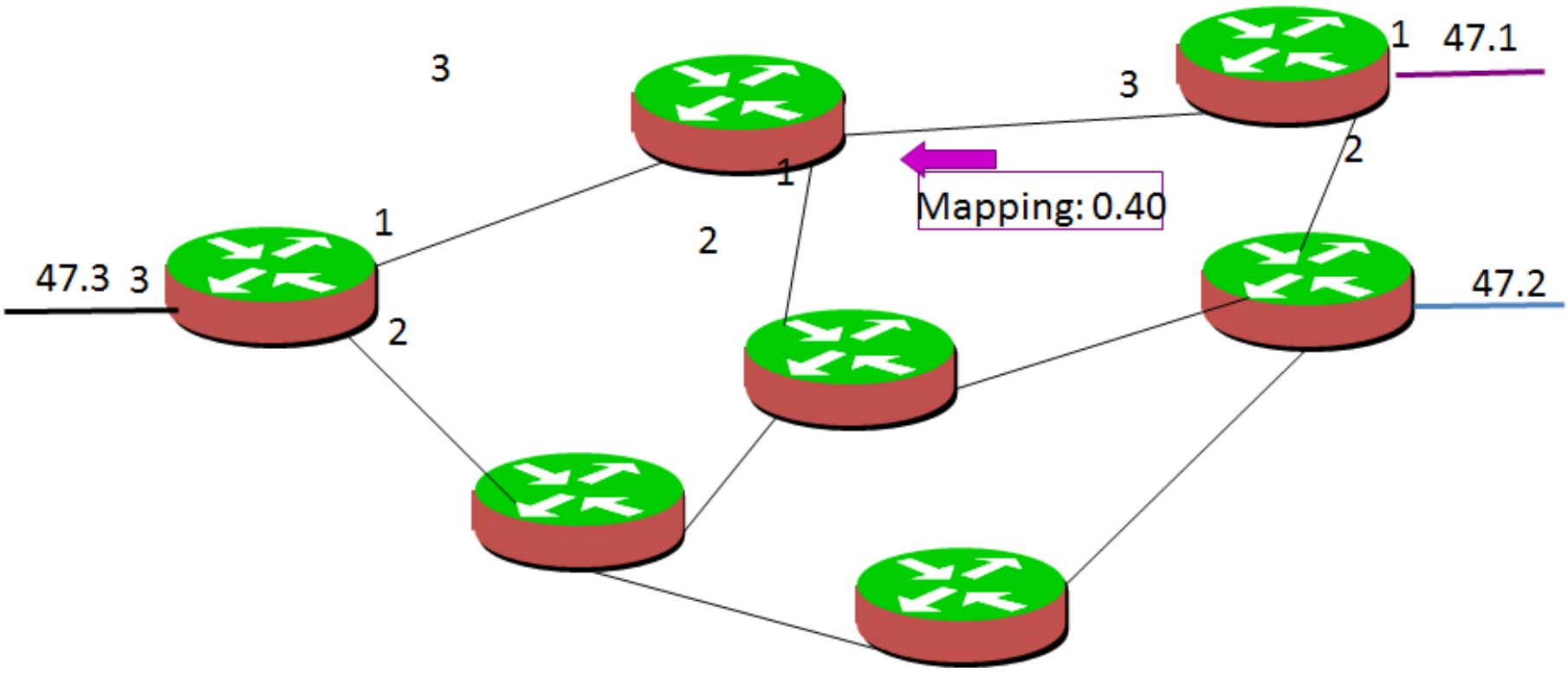


Figure : The router that receives the mapping data, adds it to its forwarding table and generates a "in" label

Label distribution in MPLS and how LSP works

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

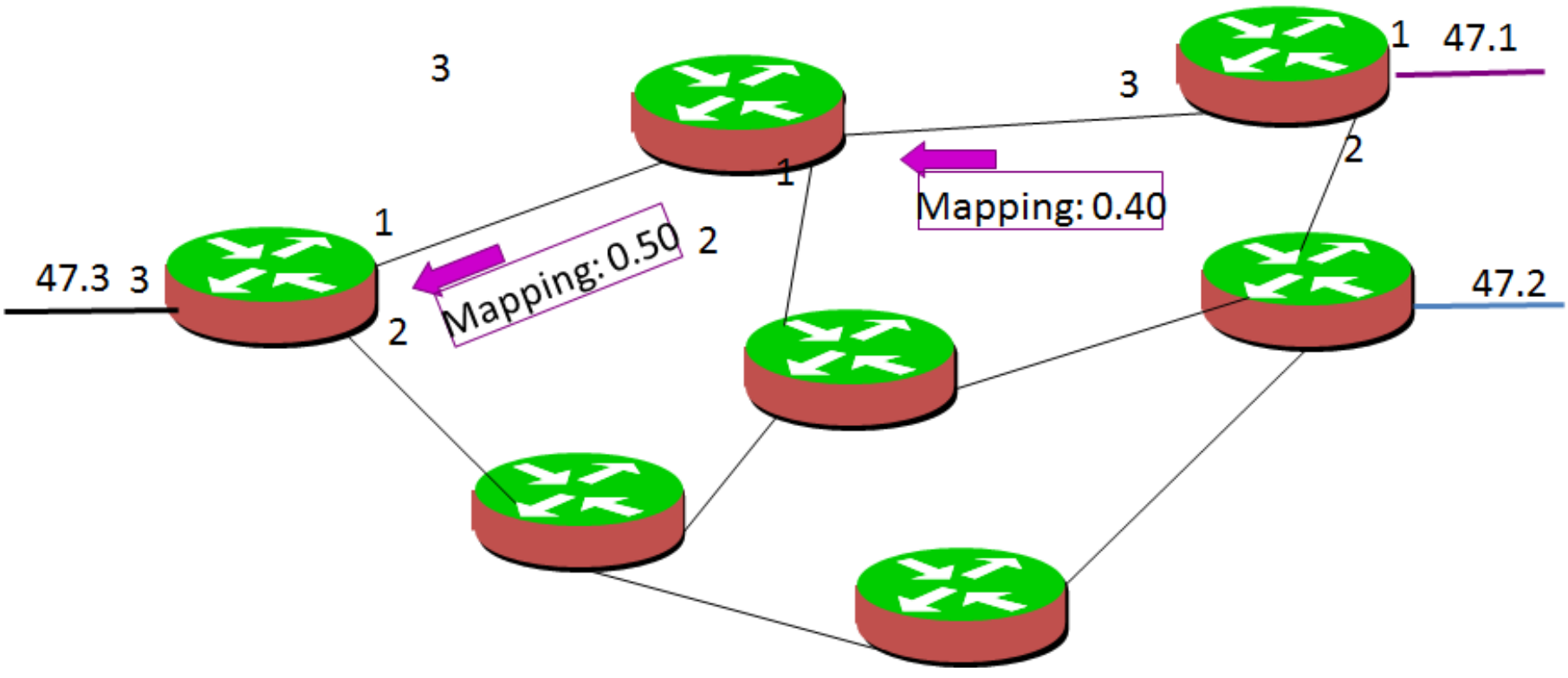


Figure : When finished, the egress node sends the mapping date of which label will be added

Label distribution in MPLS and how LSP works

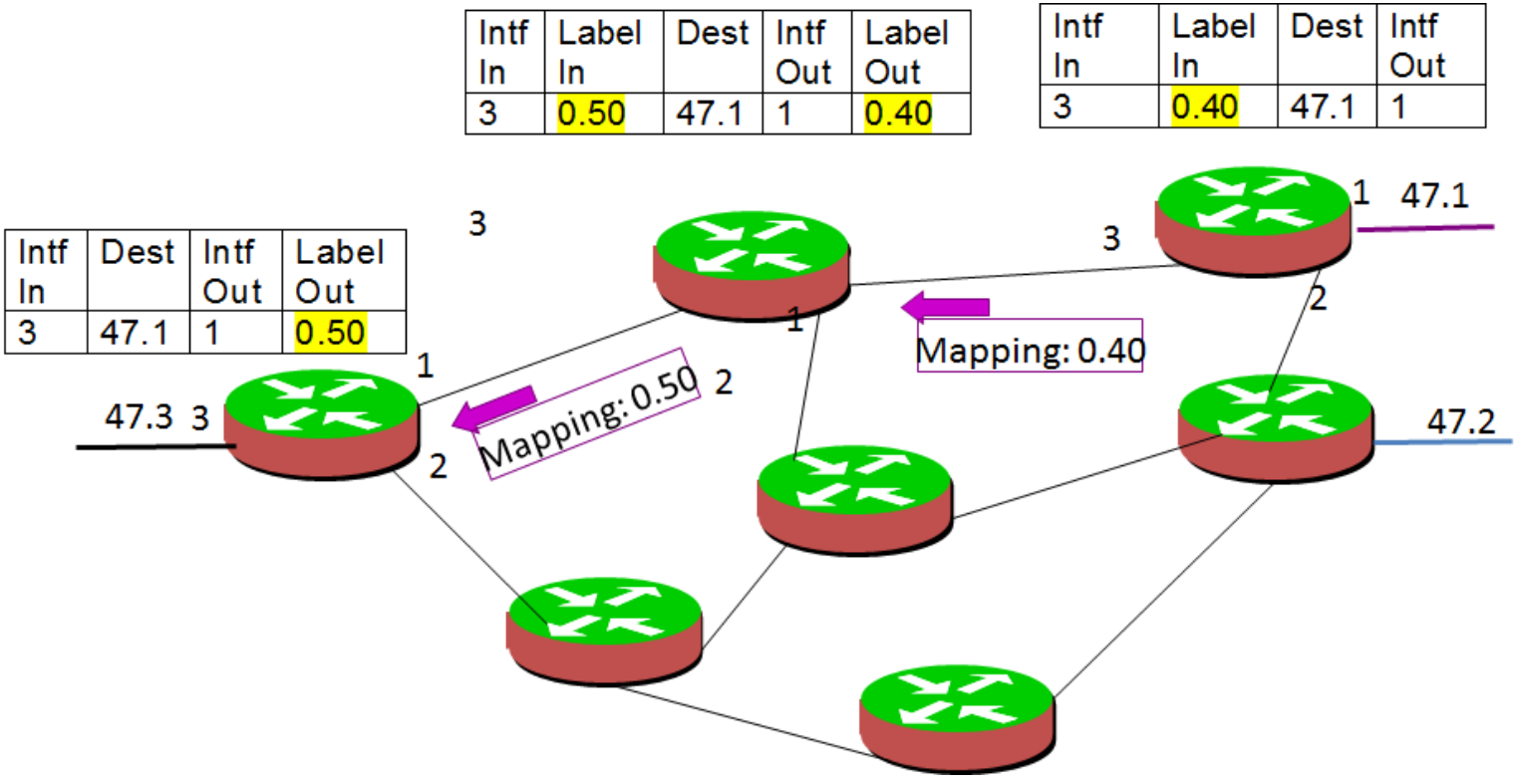


Figure : When it has reached the Ingress node, it will map the given label for the given destination IP

Label distribution in MPLS and how LSP works

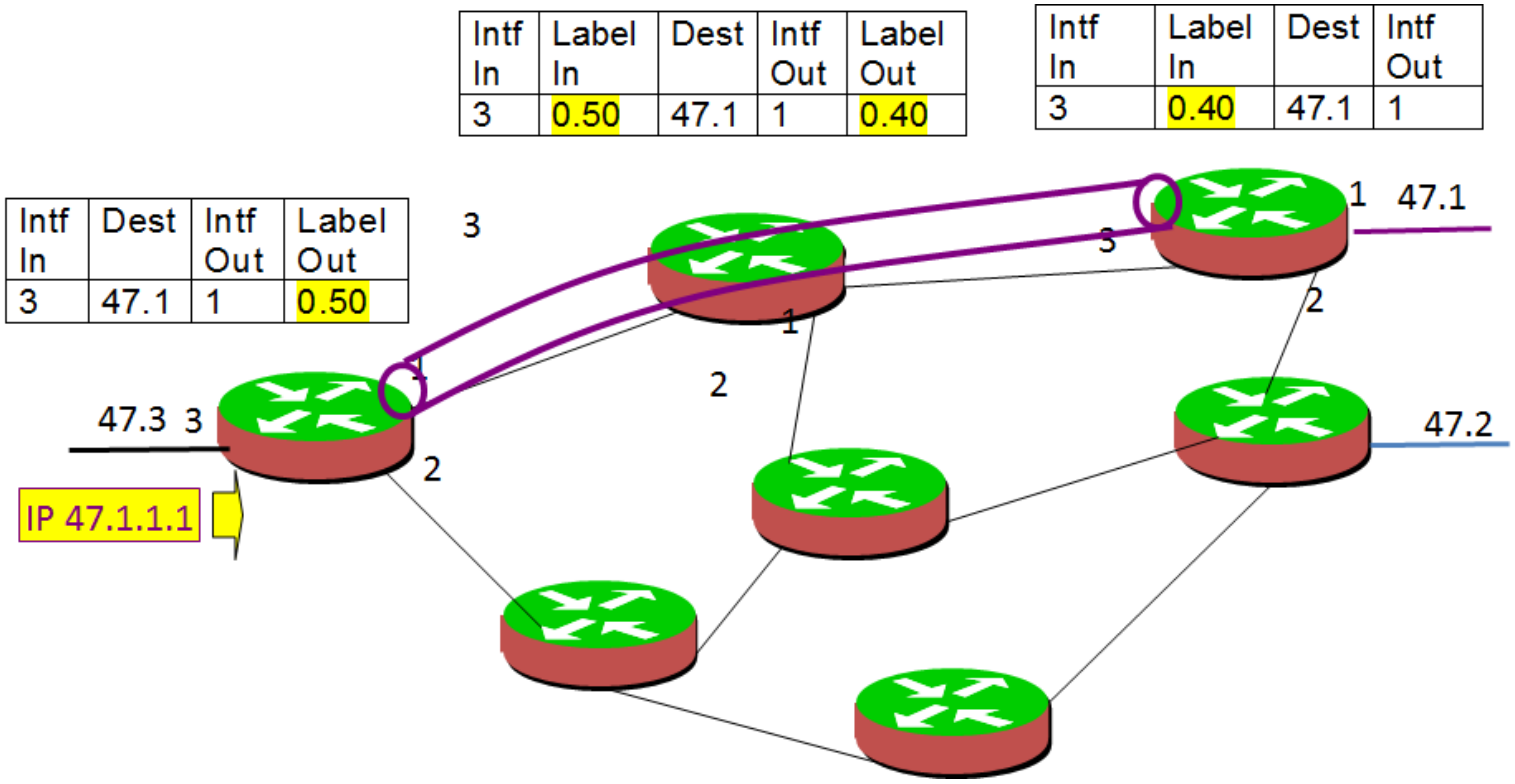


Figure : Send message/packet to 47.1, the Ingress node makes a routing lookup and assigns the given label for the destination

Label distribution in MPLS and how LSP works

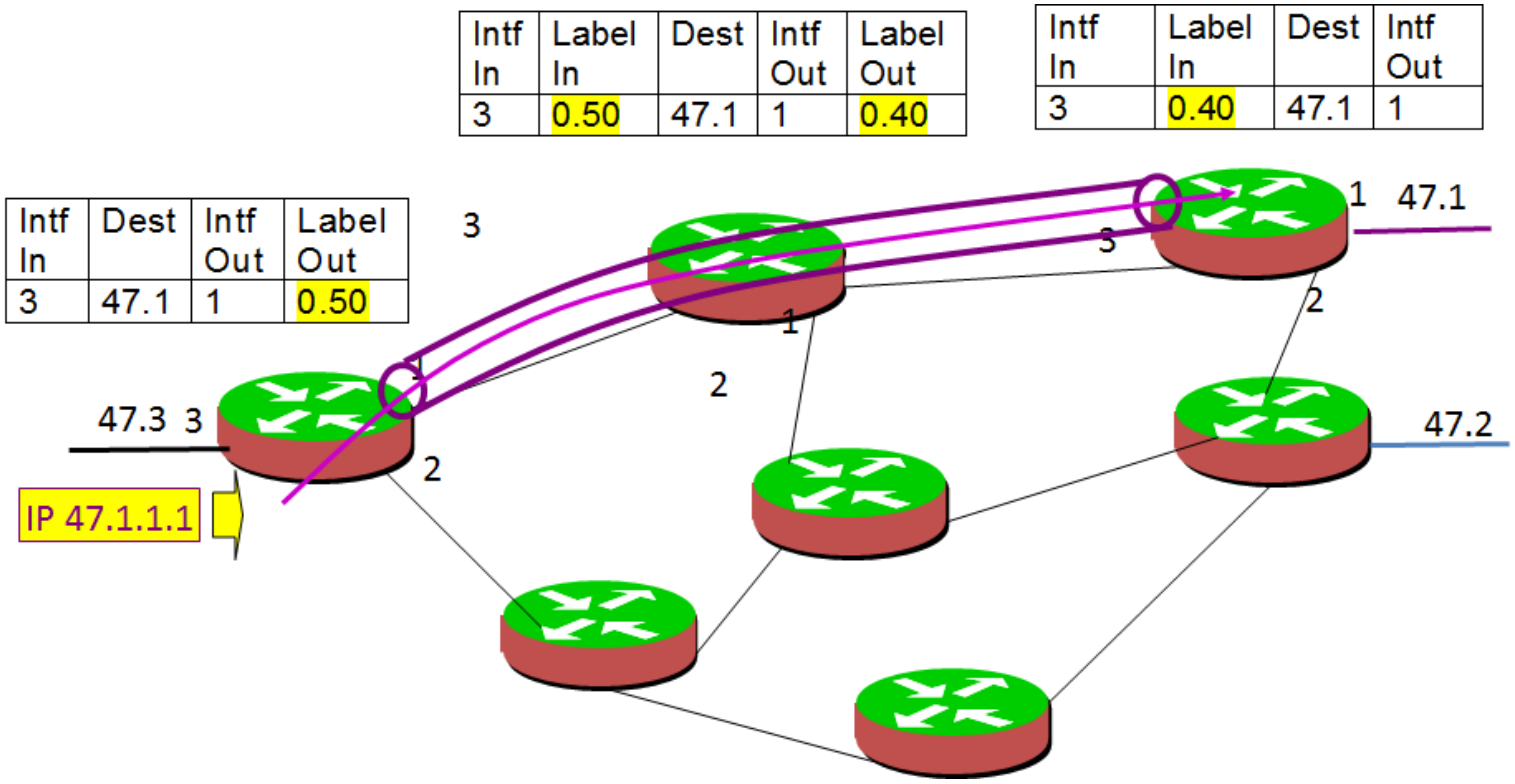


Figure : When forwarded, you add label onto the packet, when it arrives to a node, it checks the label and replaces it to another one and forwards it

Label distribution in MPLS and how LSP works

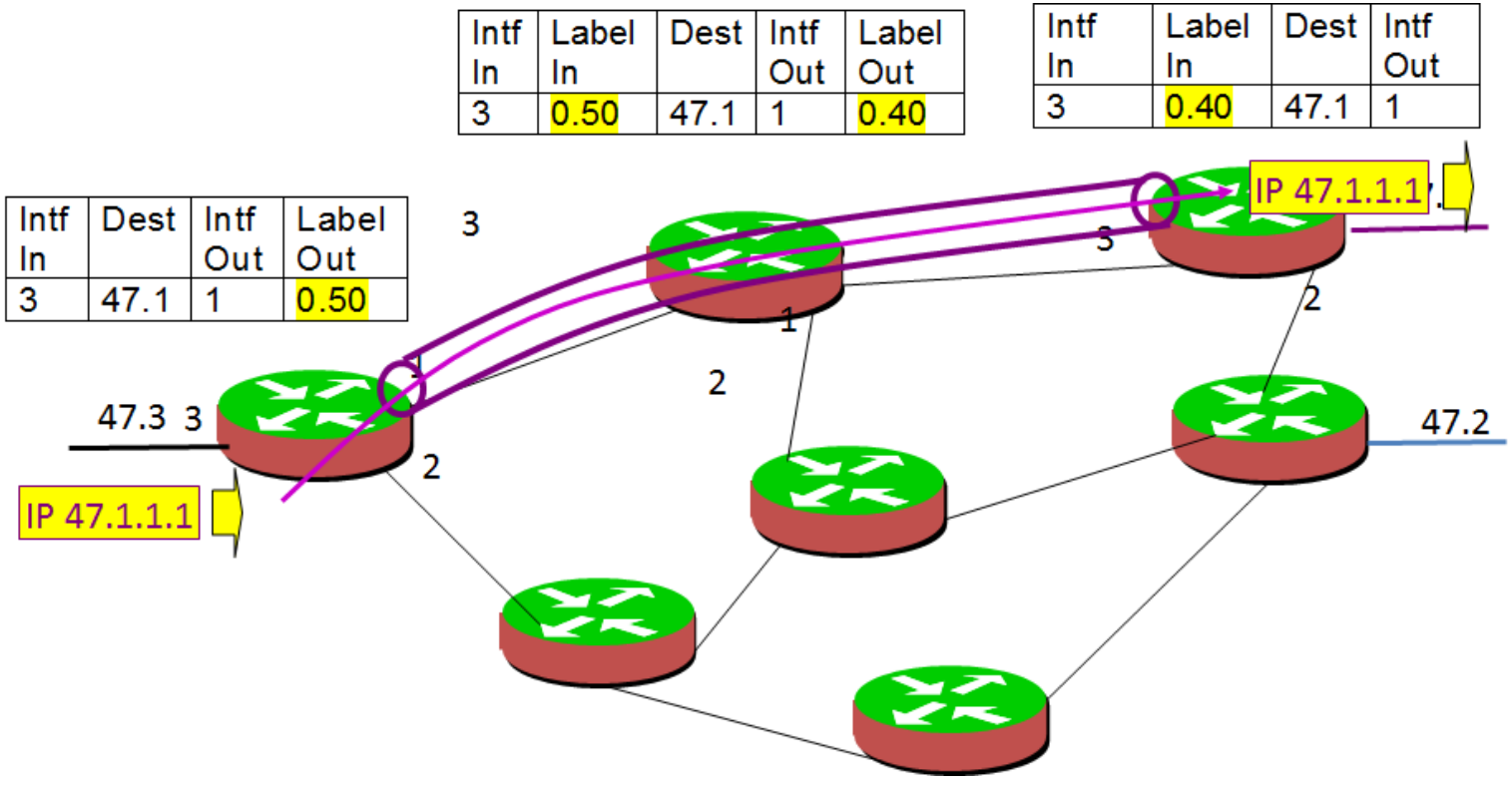


Figure : When reached to the egress node, it will then strip out the label and deliver to the specific destination

Traffic Engineering

Traffic engineering deals with performance optimization of operational ip networks. We want to transport ip packetsw in the most efficent reliable and expeditious manner possible through a given network. Avoid congestion and revocer from them when caused by poor resource allocation. Overutilized and congested resources with alternative viable paths that are under utilized. Generally: place traffic where the capacity exists to accommodate it.

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.

GMPLS

- 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 seperation of control plane and network plane
  - GMPLS extends this seperation and allows the control plane to be physically diverse from the associated data plane

GMPLS: Hierarchial LSP

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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.