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Multi-Protocol Label Switching

Complied by Madhura Sridhar
Under the guidance of Prof. Thomas Reddington

What is MPLS?

- MPLS is a specific type of protocol that enables transmission and shaping of network traffic.
- It was established and formulated in 1997.
- MPLS is directed towards improved traffic management and quality of service.

Introduction and basics

- MPLS is most commonly categorized as a layer 2.5 protocol.
- It resides between the data-link and the network layers in the TCP-IP model.
- MPLS directs data from one network element to another based on short path labels, different from the conventional network addresses.
- This thus helps in avoiding complex lookups in the routing table.

Label Switching

- The first device does the routing lookup just like before.
- But this is to determine the next router in the path, and not the next hop.
- The router applies a label based on this information.
- Future routers apply this label to route the traffic.
- They don’t need to perform any additional IP lookups.
- At the final destination router, the label is removed.
- And the packet is delivered via the normal IP routing.

Why label switching?

- The main intent was to reduce the overheads involved with router lookups.
- To achieve high performance.
- To support virtual circuits.
- Also for better network consolidation.
- To implement multi-service networks.

MPLS

- MPLS is a virtual circuit packet switching technology.
- Here, short labels are attached to network packets which describe how to forward them through the network.
- Independent of any routing protocol.

Packet Switching v/s Circuit Switching

- Circuit Switching:
- Source first establishes a connection to the destination.
- Source sends data over the connection.
- Source tears down the connection when done.
- Similar to how telephonic conversation works.

Packet Switching v/s Circuit Switching

- Packet Switching:
- Data is divided into packets.
- Each packet contains its own header.
- Destination reconstructs the message.

Virtual Circuits

- Combination of packet and circuit switching.
- It's a logical circuit between the source and destination.
- Every Virtual Circuit is identified by a VC ID.
- The source set-up will establish the path for the VC.
- Switch will then map the VC to an outgoing link.
- The packet will then have a fixed length label in the header.

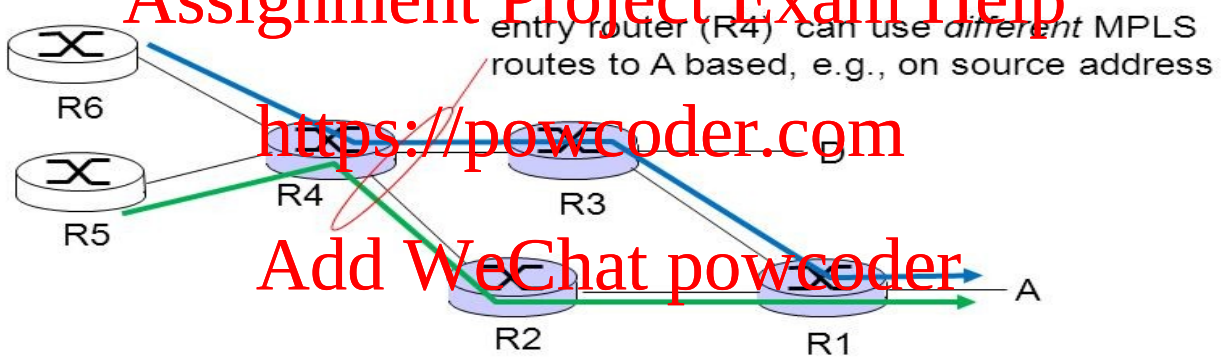
Virtual Circuits and IP datagrams

- Similarities:
- Data divided into packets.
- Packet has an address (IP address or VC ID).
- Store and forward transmission.

- Differences:
- VCs use VC ID.
- IP datagrams use destination IP address.
- VCs must signal along the path.
- Routers in VCs also know about the connections

MPLS versus IP routing

MPLS versus IP paths



- *IP routing:* path to destination determined by destination address alone
- *MPLS routing:* path to destination can be based on source *and* dest. address
  - *fast reroute:* precompute backup routes in case of link failure

IP-only router

MPLS and IP router

How does MPLS work?

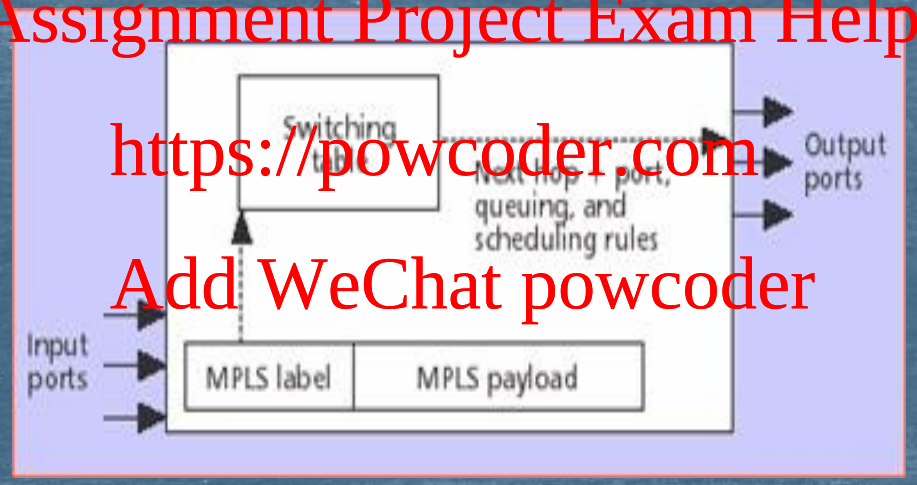
- MPLS Label Switched Path (LSP) is a unidirectional tunnel between a pair of routers, routed across an MPLS network.
- An LSP is required for any MPLS forwarding to occur.
- MPLS router roles/positions:

- Label Edge Router (LER) or ingress node: This is the router that first encapsulates a packet inside an MPLS LSP. It also makes the initial path selection.

- Label Switching Router ('LSR') or transit node: This router does the MPLS switching in the middle of an LSP.

- Egress node: The final router of an LSP, which removes the label.

How does MPLS work?



How does MPLS work?

- MPLS router roles may also be expressed as ‘P’ or ‘PE’.
- P stands for Provider Router.
- This router does label switching only.
- PE stands for Provider Edge Router.
- This router faces the customer and does label popping and imposition.
- MPLS labels are 32 bits long: label value (20 bits), EXP (3 bits), S (one bit), TTL field (8 bits)

MPLS Signalling Protocols

- To use an LSP, it must be signalled across your routers.
- An LSP is a network-wide tunnel, but a label is only a link-local value.
- An MPLS signalling protocol maps LSPs to specific label values.
- There are two main types of MPLS routing protocols in use today:

 - Label Distribution Protocol (LDP): a simple protocol that doesn't support traffic engineering.

 - Resource Reservation Protocol with traffic engineering (RSVP-TE).

- Most networks configure LDP to tunnel inside the RSVP.

MPLS Label Stacking

- MPLS labels can also be stacked multiple times.
- The top label is used to control the delivery of the packet.
- When destination is reached, the top label is removed and the second label takes over to direct the packet further.

Penultimate Hop Popping

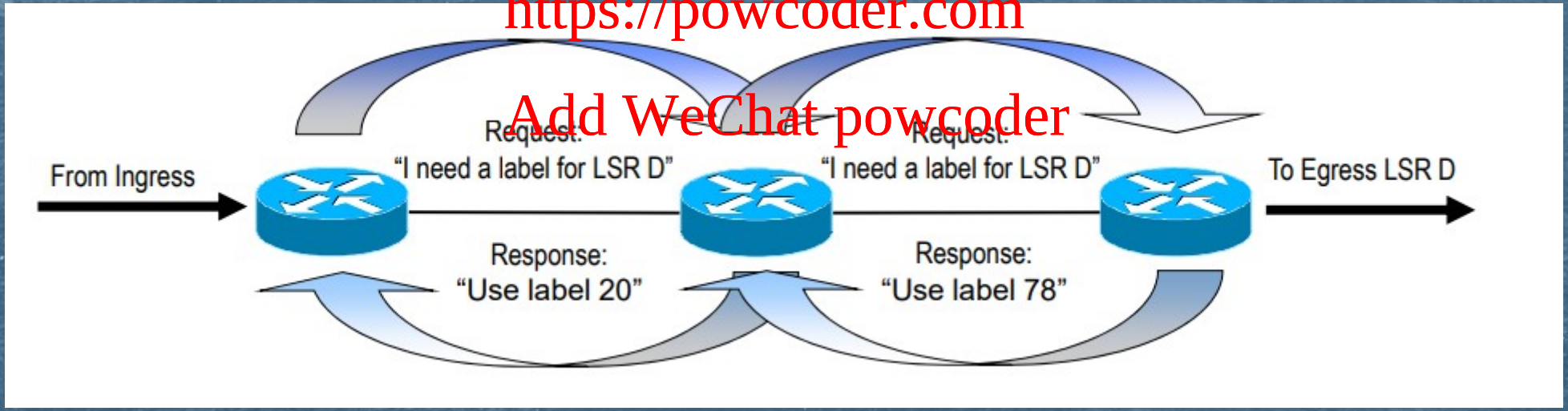
- There are two ways to terminate an LSP:
  - Implicit null: remove the label at the next-to-last hop.
  - Explicit null: preserve the label all the way to the very last router.

MPLS Capable Routers

- They are also called Label-switched Routers (LSR).
- Forward packets to the outgoing interface based only on the label value and not based on the IP address.
- MPLS forwarding decisions can differ from those of IP in a way that, the destination and source addresses are used to route flows to the same destination differently.
- This is called traffic engineering.

Label Distribution

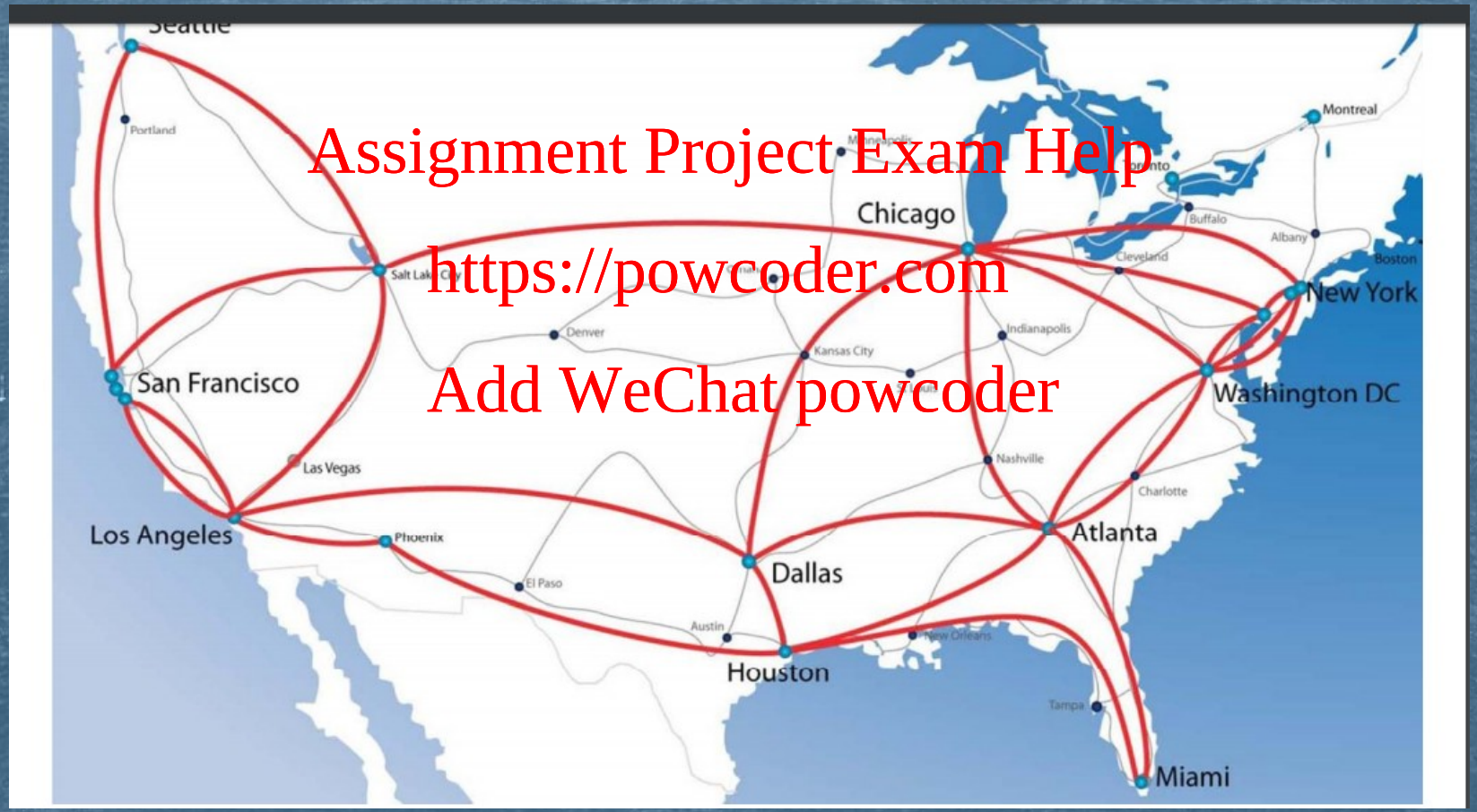
- Requests for labels flow downstream (ingress -> egress).
- Assignment of labels flow upstream (egress -> ingress).



MPLS Traffic Engineering

- Classic routing algorithms use non-TE routing.
- Routes are based on a metric like cost per link and a shortest path first (SPF) algorithm is used to find the shortest path.
- Traffic engineering takes this and adds additional constraints.
- For example, find the shortest path that also has the available bandwidth.
- Main principle is to take the uncongested path even though he latency maybe higher, than to congest the shortest path on one link while leaving available bandwidth unused on another link.

How to route from LA to Chicago?



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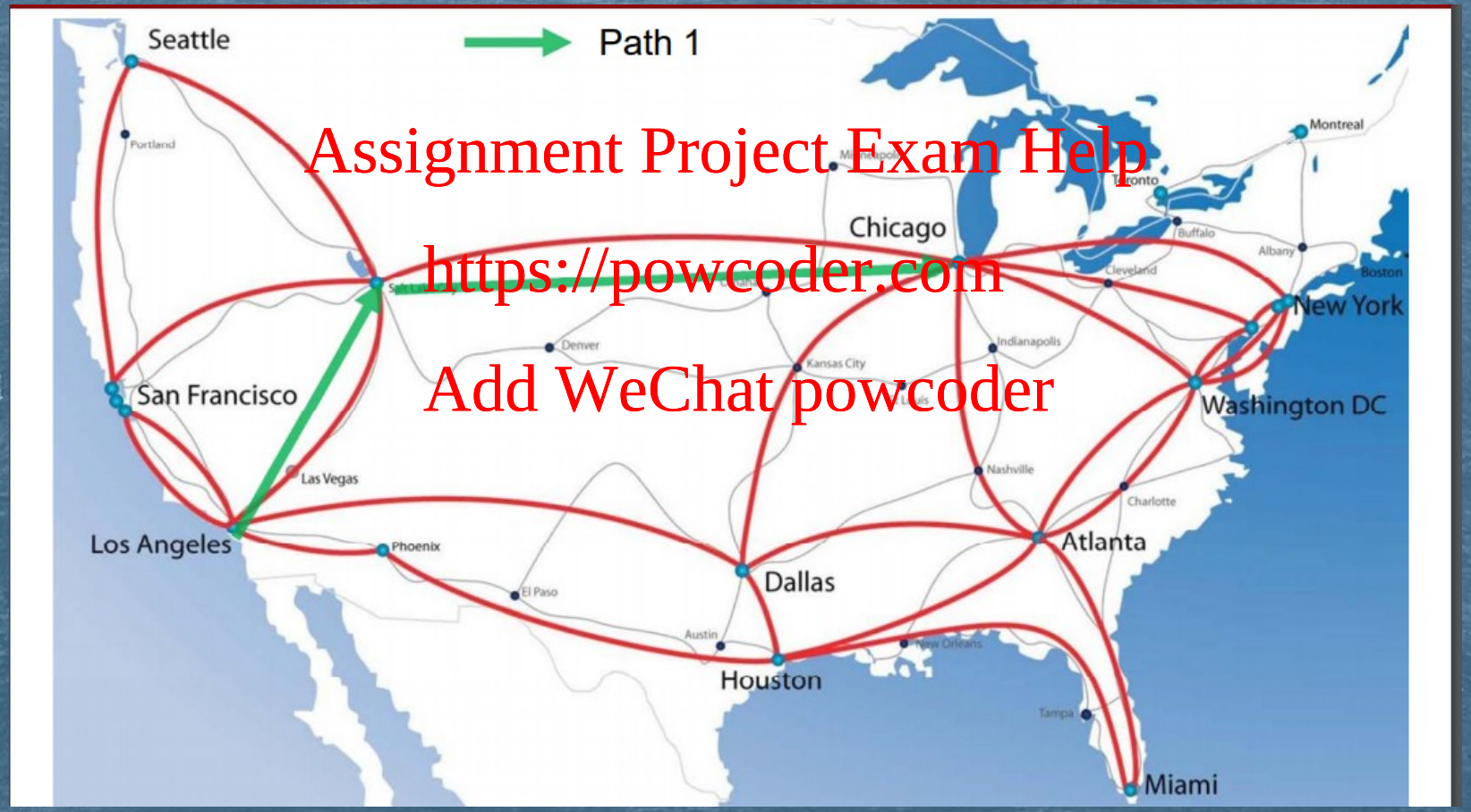

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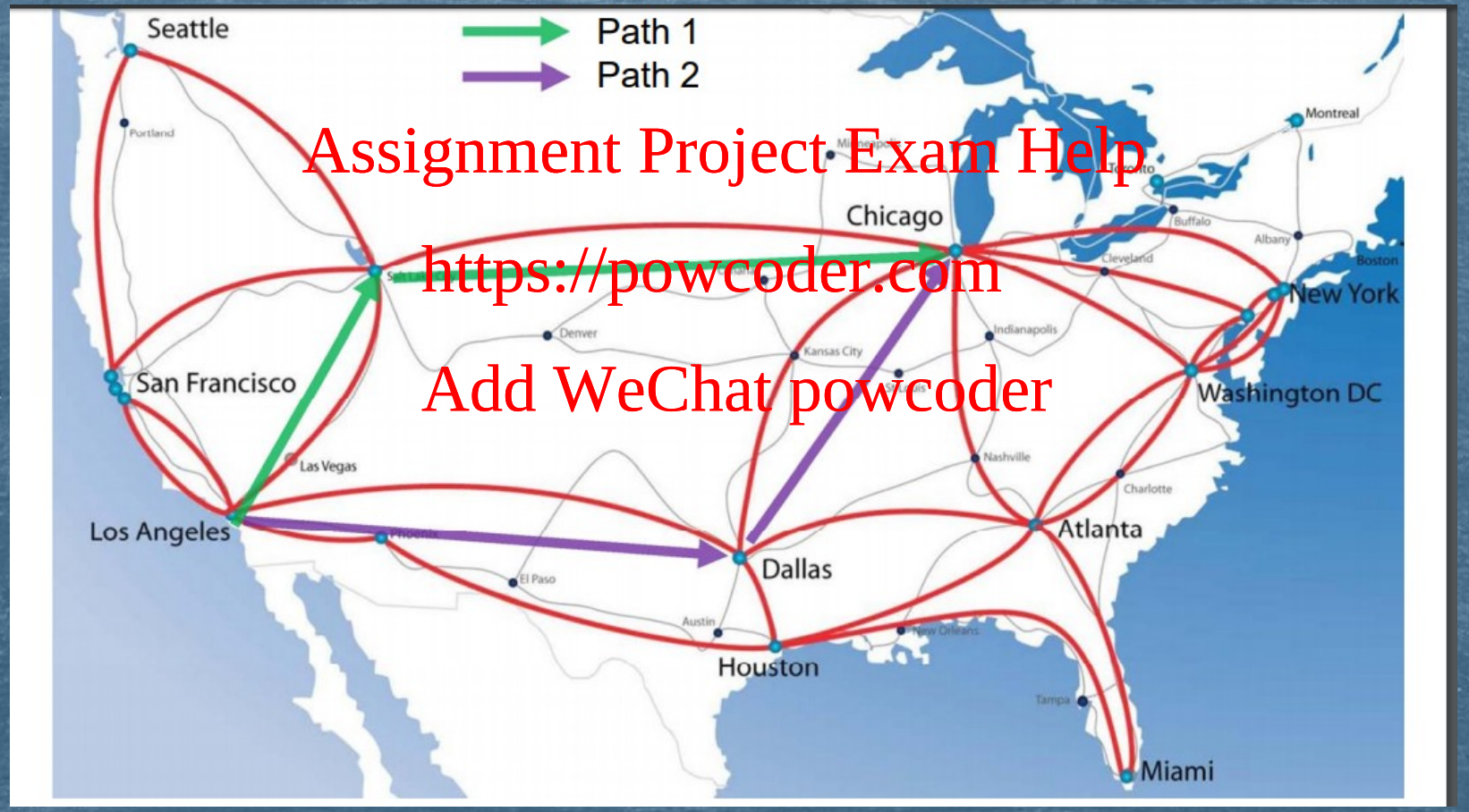

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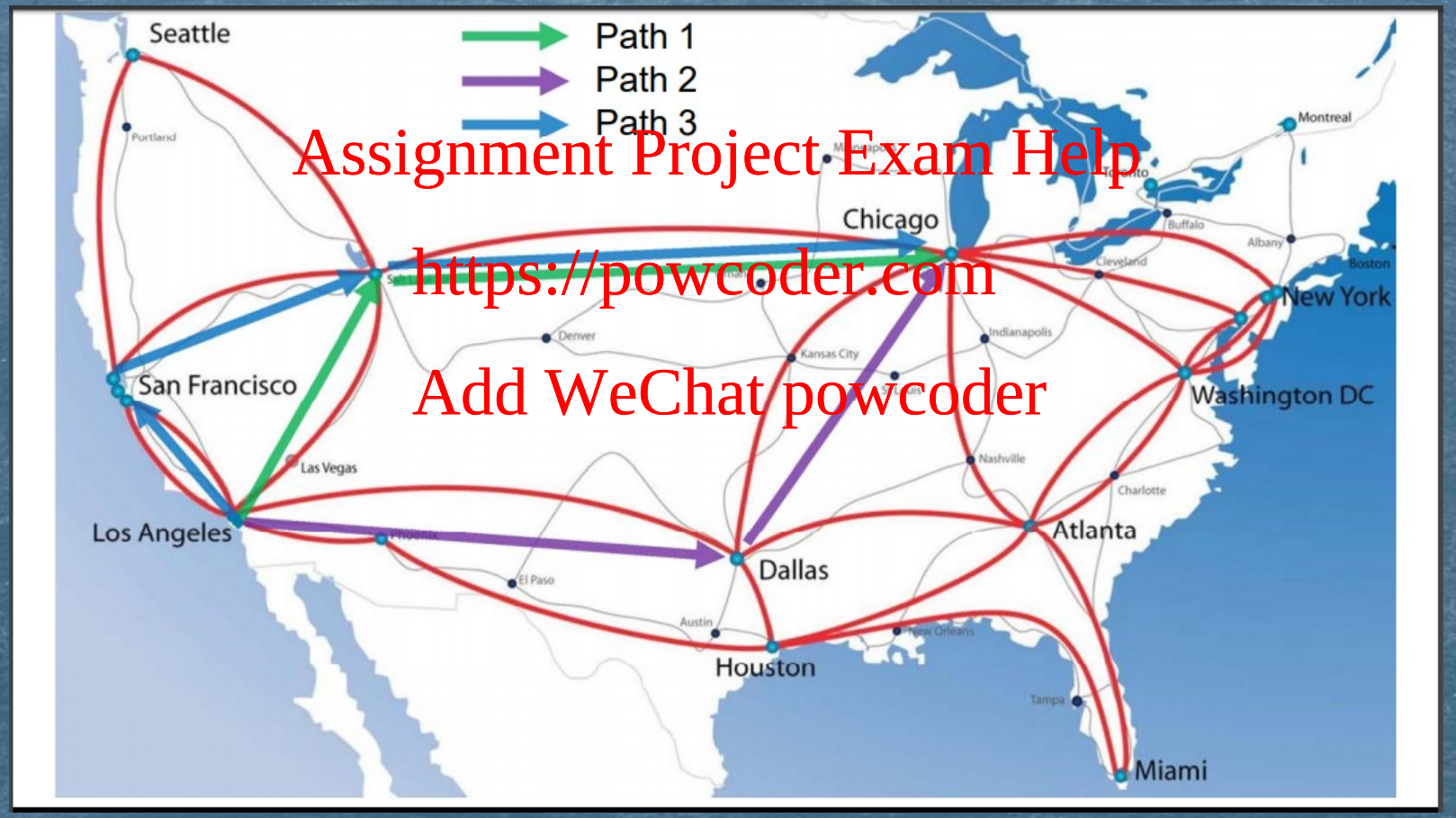

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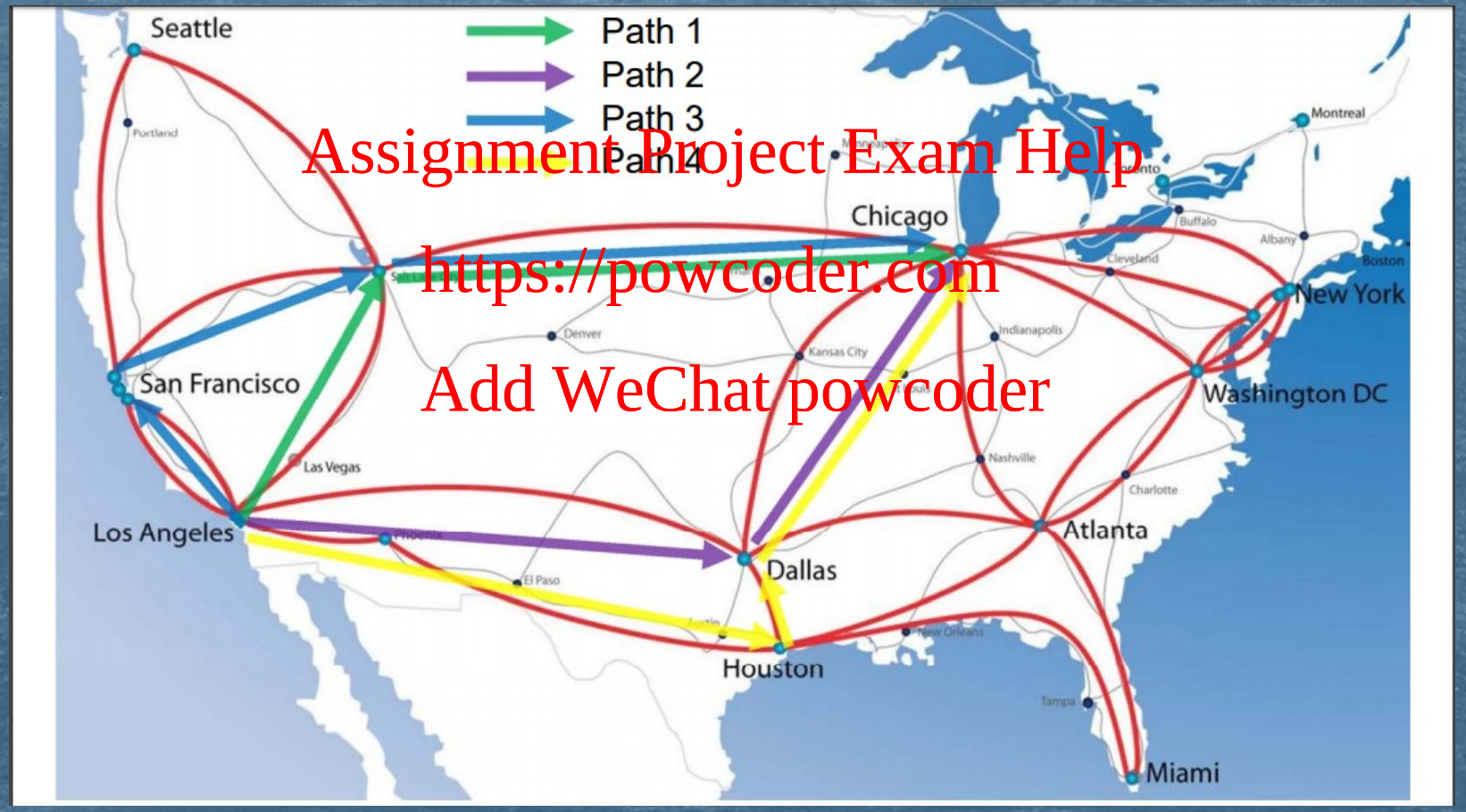


How does MPLS traffic engineering work?

- MPLS uses RSVP-TE to reserve bandwidth across the network.
- Since LSP is a 'tunnel' between two points in the network, with RSVP, each LSP has a bandwidth value associated with it.
- Using constrained routing, RSVP-TE looks for the shortest path with enough available bandwidth to carry a particular LSP.
- If the bandwidth is available, the LSP is signalled across a set of links.
- The LSP bandwidth is removed from the 'available bandwidth pool'.
- Future LSPs may be denied if there is insufficient bandwidth.
- They will be routed via some other path, even if the latency is higher.

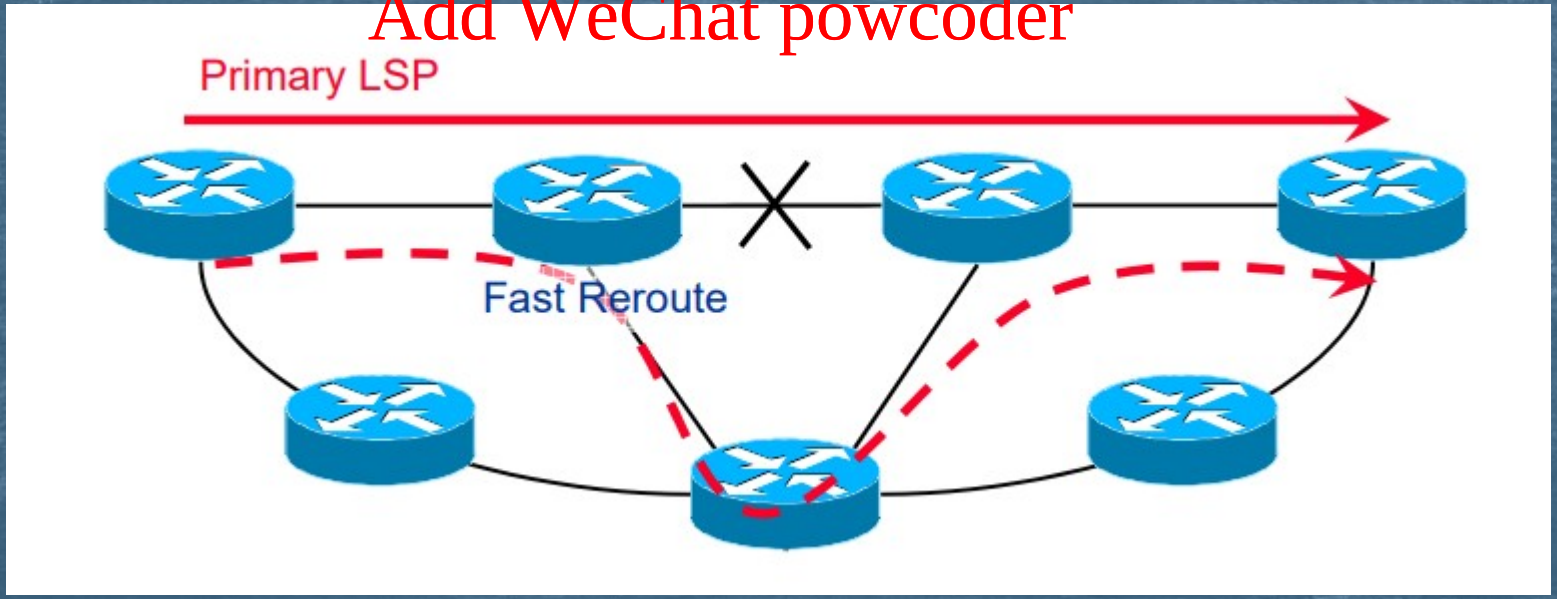
How RSVP reserves bandwidth?

How to determine LSP bandwidth?

- Offline calculation: calculation occurs outside the router.
- Auto-bandwidth: bandwidth value is calculated inside the router.
- In offline calculation, you can implement any algorithm that you like.
- But auto-bandwidth is more robust to traffic changes in the network.
- It is also easy to implement.

MPLS Fast Reroute

- Improves convergence during a failure.
- Pre-calculates backup paths for potential link or node failures.
- The next best path calculation happens before the failure actually occurs.
- The backup paths are pre-programmed into the router FIB awaiting activation.

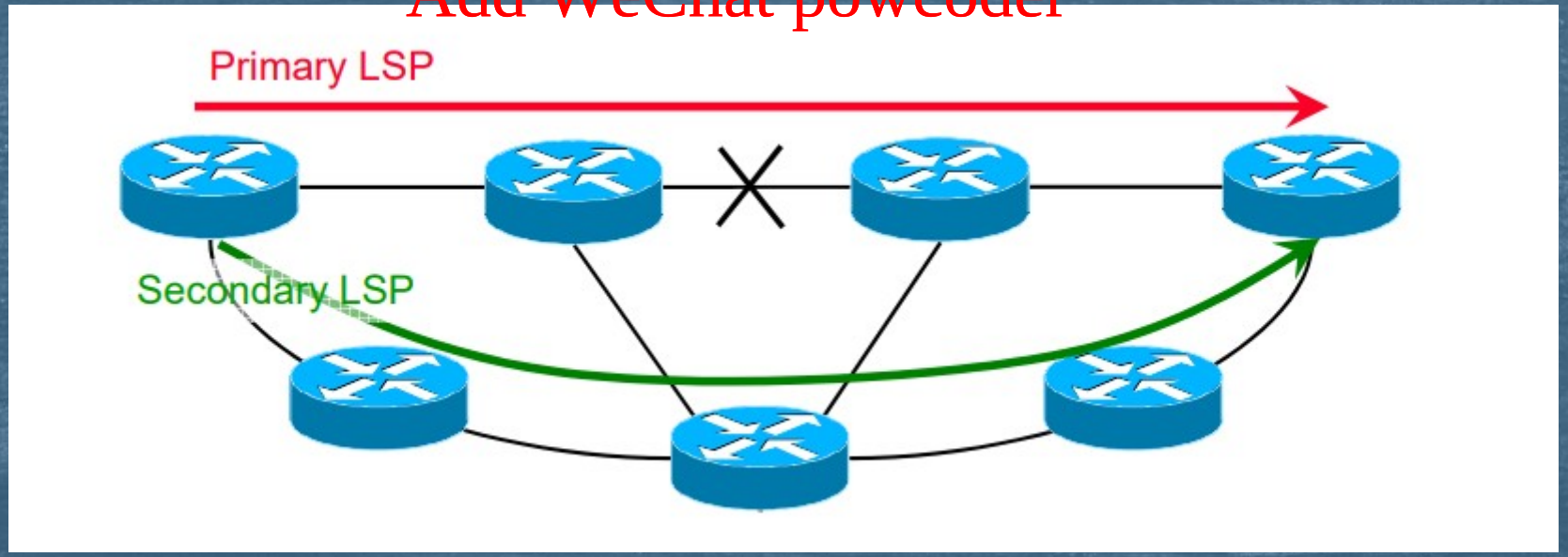


MPLS Protection Schemes

- There are two different ways to provide LSP protection:

- One to one protection/detour: an individual backup path is fully signalled through RSVP for every LSP, at every point where protection is provided (i.e every node).

- Many-to-one protection: a single bypass LSP is created between two nodes to be protected. During a failure, multiple LSPs are rerouted over the bypass LSP.



LSP Optimization

- Over time, network topologies can change.
- The optimization program recomputes the LSP paths.
- Many routers optimize in a smart way.

MPLS applications

- Link and node failure protection
- Traffic engineering
- Virtual point-to-point connections.
- Virtual point-to-multipoint connections.
- Virtual Private Networks.

MPLS Shortcomings

- It reduces the overall flexibility of the IP protocol.
- Increased overhead of carrying labels in the network.
- Current MPLS architecture and framework have left multicast as a future area of study.

References

- https://www.nanog.org/meetings/nanog49/presentations/Sunday/mpls-nanog49.pdf
- https://en.wikipedia.org/wiki/Multiprotocol_Label_Switching

THANK YOU