Networking Technologies and Applications

MPLS

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MPLS

- MultiProtocol Label Switching
  - RFC 3031 (and a lot of others)
- Motivation
  - Ethernet and other L2 tech (Frame Relay, ATM etc.) do not scale up
  - IP routing is slow
- Independent of other layers
- Frequently called layer 2.5
- Label Switching: connection-oriented, next hop defined by the label
  - Labels are assigned per-link
  - Scales with number of flows, not number of nodes

MPLS

- MPLS header goes between L2 and L3 headers
- Forwarding decision uses the Label value
- Exp: reserved for experimental features (in original spec)
  - Used for Class of Service, Explicit Congestion Notification
- S: bottom of label stack (see next slide)
- TTL: time to live, limit routing loops

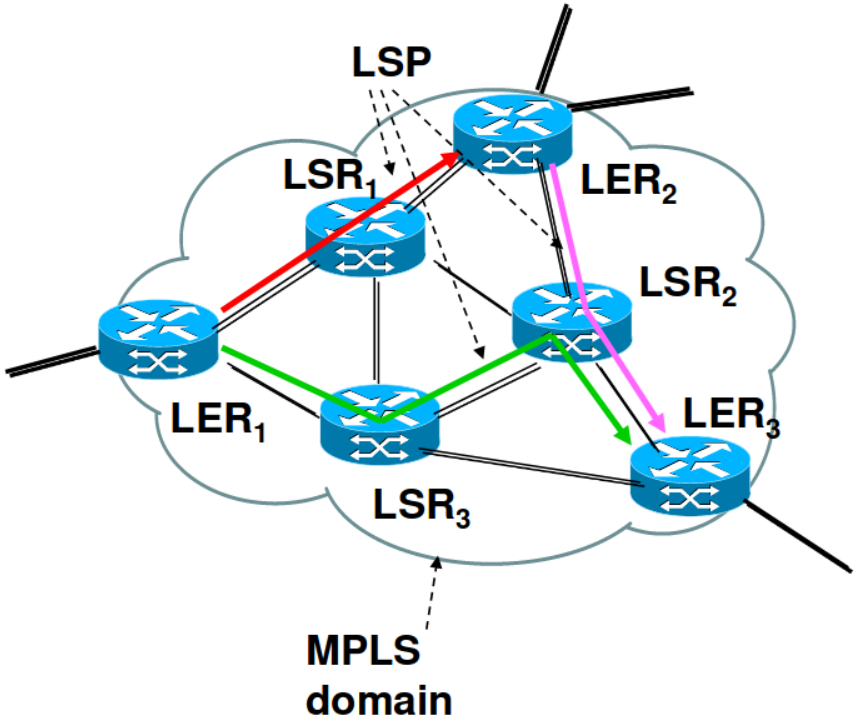
MPLS

- Label stack: apply multiple MPLS headers to the packet
  - Forwarding: based on the label on top of the stack
  - Specifies an outgoing interface
  - Specifies a label operation: swap/push/pop
- Label values are local to a link
  - More scalable than Ethernet VLAN, where tags are global to the domain
- Exact label match is faster than longest IP prefix match

MPLS

- Label Edge Router (LER)
- Label Switch Router (LSR)
  - Label Switched Path (LSP)
    - one direction
  - Forwarding Equivalence Class (FEC)
    - group of flows with same QoS and same path
    - classify packets into FEC when they enter the MPLS network (at LER)
    - one LSP per FEC

MPLS



MPLS

- How to build LSP for a FEC?
  - Each LSR negotiates a label for each FEC with their neighbors
  - Label Information Base (LIB) similar to Routing Information Base for IP
- Label Distribution Protocol (LDP)

–RFC 3036, obsoleted by RFC 5036 (and expanded by a lot more)

  - Discover peers, establish sessions, distribute labels
- Resource Reservation Protocol – Traffic Engineering (RSVP-TE)
  - RSVP RFC 2205, RSVP-TE RFC 3209 (and expanded by a lot more)
  - PATH, RESV
- These are NOT routing protocols, we need to run an IGP first (OSPF, IS-IS)

MPLS

- Quality of Service (QoS) – reserve resources for important traffic
- Integrated Services (IntServ)
  - per-flow allocation (after call admission control says okay)
- Differentiated Services (DiffServ)
  - per-class allocation
  - mark packets for class at the network edge
- MPLS can support both
  - Class of Service field (3 bit) for DiffServ
  - RSVP-TE for IntServ

MPLS

- Traffic Engineering
  - Not shortest path routing, not a single spanning tree
  - Consider traffic density
  - Backup routes for fast switch-over on node/link failure
  - Reserve path with bandwidth guarantee (IntServ)
- Better resource usage across the network
- Explicit Routing (Source Routing)
  - Source specifies the whole path the packet should take
  - IP: high per-packet overhead, source needs topology discovery
  - MPLS: no overhead, just build LSP accordingly

MPLS

- Traffic Engineering: how to build explicit routes?
- Path Computation Element (PCE)
  - Central node (or process on some designated nodes)
  - Offline computation, based on topology discovery via OSPF/IS-IS
  - Build the computed paths as LSP via LDP/RSVP-TE
- Input
  - Physical topology
  - Traffic matrix (existing connections or statistics)
  - Other constraints (e.g. reserve BW for other uses)

MPLS

- Protection and Restore
- 1+1 use two paths simultaneously, send the same traffic both ways
  - Decrease packet loss probability
- 1:1 have a backup path, switch over on error, few packets lost
- After node/link failure is detected
  - Switch over to backup LSP in 50 ms
  - Report to PCE
  - Recalculation can take several seconds
  - New LSP set distributed

GMPLS

- Generalized MPLS
- Operation over circuit-switched L2 networks
- Especially SDH/SONET optical networks
- Label can identify
  - An optical fiber in a bundle
  - A wavelength in WDM
  - A time-slot in TDM
- Link Management Protocol (LMP) RFC 4204

MPLS

- MPLS-based VPN
  - Connect local L2 networks over an L3 network via tunnel
  - MPLS Pseudowire
- Competition: Carrier Ethernet
  - IEEE 802.1aq Shortest Path Bridging
  - IEEE 802.1ah Provider Backbone Bridging
- See the Ethernet Services slide deck for details