MPLS [RFC 3031]

- IP Switching
  - Use labels; works with other protocols [not just with IP]
  - Use labels to determine forwarding action instead of 32/128 bit addresses
- 20 bit label

Ingres Label Switched Router adds a label (header)
LSRs switch based on label values
Egres router removes the MPLS header
Examine LSR 2:
How does LSR2 process each packet with MPLS header?

Loot at interface it came on (why?), label L2
Consult switching table associated with incoming interface
Action: Replace L2 by L3, forward on output interface O2
Other actions: Push new MPLS header; Pop MPLS header
Processing done in hardware (very fast)

Layer 3 routing vs. MLPS

- Lookup Time
  - Longest prefix matching
  - 20 bits vs. 32 or 128 bits
- Label has local significance only
  - IP addresses have global significance
Two important questions

- How does an Ingres router select a label?
- How do the intermediate routers make up their switching/forwarding tables?

Forwarding Equivalence Class

- **FEC:**
  - Group of packets that receive same treatment by routers
  - FEC controls packet’s path through network and packet’s forwarding treatment on that path
  - Examine an Ingres router.
  - For each destination one FEC? (all packets to that destination will get same treatment)
  - What if some need to be treated differently?
    - Examine source, destination IDs, application protocol, incoming link, QoS, current network condition, VPN requirements, ... and find FEC

- FEC and quick forwarding are two greatest advantages of MPLS
- Force packets to go through a certain path
MPLS message format

<table>
<thead>
<tr>
<th>Label (20 bits)</th>
<th>Res(3)</th>
<th>B</th>
<th>TTL(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP Header</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B=1: Stack bottom (no more MPLS headers below)

Reserved Labels

- Some labels have special significance
  - 0 to 15
    - 0: IPv4 null label (pop stack, treat rest as IPv4 packet)
    - 1: router alert: pkt needs special handling, route based on next label
    - 2: IPv6 null label
    - 3: Multicast null label
    - 4-15 reserved
TTL handling

- Copy TTL from IP header to TTL of first MPLS header at first ingress
- Decrement TTL for each hop
- When popping, copy TTL of MPLS header into TTL of IP header
- Same when pushing a stack of MPLS headers

Packet handling at Ingres

- Determine FEC
- Map FEC to LSP
- Assign a label (or encode FEC in a label)

- Label binding: FEC -> Label
Label assignments

- Always downstream assigned
  - Why?

- Downstream unsolicited or
- Downstream on demand

Downstream Unsolicited

Upstream

Downstream

Here is label

OK

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Downstream on demand

Hierarchical MPLS networks
- One MPLS network completely inside another
- Example
**Example**

LSP i

---

A

\[ \text{Autonomous system} \]

B

---

C

\[ m \]

\[ n \]

\[ o \]

\[ p \]

D

---

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Action at C?

Action at D?
Multiple MPLS headers

- Multiple MPLS headers for an IP packet
- Fragmentation because of this:
  - Ingres node must take care of this
- Why not single MPLS header?
  - Don’t mix LSP i and LSP j
  - AS does not need to know complete routing strategy

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LDP

- Label Distribution Protocol
- Similar to combination of OSPF and BGP
- LSR does a neighbor discovery
  - Send hello messages containing LDP id on all interfaces; Use UDP to send messages to far away routers
- LDP id identifies label space appropriate for this message
  - IP address of LSP + 2 bytes to identify label space within same route
- Loop detection/FEC merging

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LDP Messages

- Discovery
  - Hello messages; find other LSRs
- Session
  - Establish, maintain and terminate sessions
- Advertisement
  - Create, change and delete mapping for FEC
- Notification
  - Advisory info

Misc

- Loop detection
- FEC merging/aggregation