4.3 MPLS (Multi-Protocol Label Switching)

- Combining some properties of virtual circuits (VC) with the flexibility and robustness of datagrams.
- What are the strengths and weaknesses of the two packet switching technologies:
  - VC
  - Datagram
4.3 MPLS (Multi-Protocol Label Switching)

- What are the strengths and weaknesses of the two packet switching technologies?
  - VC
    - Short, fixed-length labels (Fast)
    - Labels have local scope (only known by up- and down-stream neighbors)
  - Datagram
    - Globally known (IP)
    - Matured technology
    - Flexible, extensible

4.3 MPLS

Three major uses

- Enable non-IP devices:
  - To enable IP capabilities on devices that do not have the capability to forward IP datagrams
- Explicit Routes
  - To forward IP datagrams along “explicit routes” – routes pre-calculated, with some preferences, constraints, etc.
- VPN support
4.3.1 Destination-Based Forwarding

- MPLS-enabled router allocates a label for each prefix in its routing table
- Advertise both label and prefix to its neighboring routers (Label Distribution Protocols)

(a) R2 allocates labels and advertises bindings to R1.
(b) R1 stores the received labels in a table
4.5.1 Destination-Based Forwarding

(c) R3 advertises another binding, and R2 stores the received label in a table.

- R1 is the label edge router (LER)
- LER performs a complete IP lookup on arriving IP datagrams, then applies labels to them as a result of the lookup

### 4.3.1 What’s been accomplished?

- R2 never needs to examine IP address; only the label.
  - IP prefix is variable length
  - Use longest prefix match
  - Now use exact match algorithm: much simpler
- Enable non-IP devices to forward IP datagrams.
  - Such as ATM (note: no hardware changes)
  - These are called LSR (label switching routers)
  - Also has been applied to optical switches
4.3.1 Where are the labels?

- Two common methods:
  - ATM VPI/VCI
  - “Shim”, inserted between layer 2 header and the IP header (or other layer-3 header)

4.3.1 Result: Overlay network: A mixed network of IP, LSR, ATM

- In an overlay network, each router potentially connects with all other routers via VC. (Shown only R1’s connection.)
- (a) R1 has five routing adjacencies (R2, …, R6)
- (b) Now R1 has only one adjacency; LSR1.
- MPLS leads to significant reduction in routing adjacencies.
- ATM: only software change
- GMPLS: optical switches
### 4.3.2 Explicit Routing

- Explicit routing allows explicit routes to be established (not easy in native IP).
- Allows policy implementation
- Use RSVP to establish path/connection
- Allows traffic engineering
- Fat re-route (pre-calculation of “backup path” to avoid some links)
- CSPF (Constrained shortest path first)

![Explicit Routing Diagram]

### 4.3.3 VPN and Tunnels

- Layer-2 VPN:
  - MPLS is used to tunnel layer-2 data
  - Such as ATM cells or Ethernet frames
  - MPLS-enabled IP routers can emulate ATM VC (pseudowire emulation)
  - What does an MPLS tunnel look like?

![VPN and Tunnels Diagram]
What does an MPLS tunnel look like?

- The header router needs to be configured with the incoming port, incoming VCI, “demultiplexing label” for this emulated circuit, and the address of the tunnel end router.
- The tail end router needs to be configured with the outgoing port, outgoing VCI, and “demultiplexing label.”

Fig. 4.46 - Forward ATM cells along a tunnel

Note that labels may be “stacked”

Main advantage of MPLS: shorter tunnel header
4.3.3 VPN and Tunnels

- Layer 3 VPN also uses stack of MPLS to tunnel packets across an IP network
- ISP creates an illusion for each customer that there are no other customers on the network.
- Which layer is MPLS?

4.4 Routing Among Mobile Devices

- See Fig. 4.26
- Mobile IP
  - home agent
    - Router located on the home network of the mobile hosts
  - home address
    - The permanent IP address of the mobile host.
    - Has a network number equal to that of the home network and thus of the home agent
  - foreign agent
    - Router located on a network to which the mobile node attaches itself when it is away from its home network

Diagram:

- Sending host
- Home network (network 18)
- Foreign agent (12.0.0.6)
- Mobile host (18.5.0.9)
Routing for Mobile Hosts

- Problem of delivering a packet to the mobile node
  - How does the home agent intercept a packet that is destined for the mobile node?
    - Proxy ARP
  - How does the home agent then deliver the packet to the foreign agent?
    - IP tunnel
    - Care-of-address
  - How does the foreign agent deliver the packet to the mobile node?

Routing for Mobile Hosts

- Route optimization in Mobile IP
  - The route from the sending node to mobile node can be significantly sub-optimal
  - One extreme example
    - The mobile node and the sending node are on the same network, but the home network for the mobile node is on the far side of the Internet
      - Triangle Routing Problem
  - Solution
    - Let the sending node know the care-of-address of the mobile node. The sending node can create its own tunnel to the foreign agent
    - Home agent sends binding update message
    - The sending node creates an entry in the binding cache
    - The binding cache may become out-of-date
      - The mobile node moved to a different network
      - Foreign agent sends a binding warning message
Summary

- We have looked at the issues of scalability in routing in the Internet
- We have discussed IPV6
- We have discussed Multicasting
- We have discussed Mobile IP