CSC 402 – Internet Technology

Recap

- Evolution of P2P
- WWW in a nutshell
- Napster
- BitTorrent

Multiprotocol Support

- By 1996, a number of vendors were promoting proprietary multilayer-switching solutions:
  - IP Switching (Ipsilon Networks)
  - Tag Switching (Cisco Systems)
  - Aggregate Route-Based IP Switching (IBM Corporation)
  - IP Navigator (Cascade/Ascend/Lucent Technologies)
  - Cell Switching Router (Toshiba)
- Basic standards:
  - RFC 3031 (January 2001): Multiprotocol Label Switching Architecture
  - RFC 3032 (January 2001): MPLS Label Stack Encoding
  - ...
  - RFC 6178 (March 2011): Label Edge Router Forwarding of IPv4
  - Option Packets
  - RFC 6215 (April 2011): MPLS Transport Profile User-to-Network and
  - Network-to-Network Interfaces
  - IETF drafts

Multiprotocol Support

- Traditional IP routing
  - IP packets are routed individually by every router Aka ”hop-by-hop routing”.
  - Decision regarding the next hop is made locally and on every host.
    - The IP routing work is repeated many times.
- Longest prefix matching.
- E.g., 192.168.20.19 vs. entries 192.168.0.0/16 and 192.168.20.16/28.
- The longest prefix here is 192.168.20.
  - Address in packet is compared to stored IP entries in the router table, starting at left.
  - Prefix that matches largest number of address bits is desired match.
- COMPLICATED!
  - Larger router may have many (eg. 100,000) prefixes.

Multiprotocol Support

- Traditional IP routing – Disadvantages
  - Header analysis performed at each hop
  - Increased demand on routers
  - Utilizes the best available path
  - Some congested links and some underutilized links!
  - Degradation of throughput
  - Long delays
  - No QoS
  - Not possible with connectionless protocols

Multiprotocol Support

- Why MPLS?
  - For a long time it was impossible to forward IP packets entirely in hardware.
  - To speed up packet forwarding, MPLS has been developed.
  - New latency dependent applications.
  - Quality of Service (QoS): Less time at the routers.
  - Traffic Engineering: Flexibility in routing packets.
  - Connection-oriented forwarding techniques with connectionless IP.
    - Utilizes the IP header information to maintain interoperability with IP based networks.
    - Decides on the path of a packet before sending.
- MPLS is:
  - Fast packet switching technology
  - **Operates between Layer 2 and Layer 3** (aka Layer 2.5)
  - Very similar to ATM (Asynchronous Transfer Mode)
  - Much faster than software-based IP forwarding
- MPLS emulates some properties of a circuit-switched network over a packet-switched network

Multiprotocol Support

- MPLS allows most packets to be forwarded at Layer 2 (the switching level) rather than having to be passed up to Layer 3 (the routing level).
- Each packet gets labeled on entry into the service provider's network by the ingress router.
- All the subsequent routing switches perform packet forwarding based only on those labels—they never look as far as the IP header.
- Finally, the egress router removes the label(s) and forwards the original IP packet toward its final destination.

TCP/IP	OSI Model	Protocols
Application Layer	Application Layer	DNS, DHCP, FTP, HTTPS, IMAP, LDAP, NTP, POP3, RTP, RTSP, SSH, SIP, SMTP, SNMP, Telnet, TFTP
	Presentation Layer	JPEG, MIDI, MPEG, PICT, TIFF
	Session Layer	NetBIOS, NFS, PAP, SCP, SQL, ZIP
Transport Layer	Transport Layer	TCP, UDP
Internet Layer	Network Layer	ICMP, IGMP, IPsec, IPv4, IPv6, IPX, RIP
Link Layer	Data Link Layer	ARP, ATM, CDP, FDDI, Frame Relay, HDLC, MPLS, PPP, STP, Token Ring
	Physical Layer	Bluetooth, Ethernet, DSL, ISDN, 802.11 Wi-Fi

MPLS

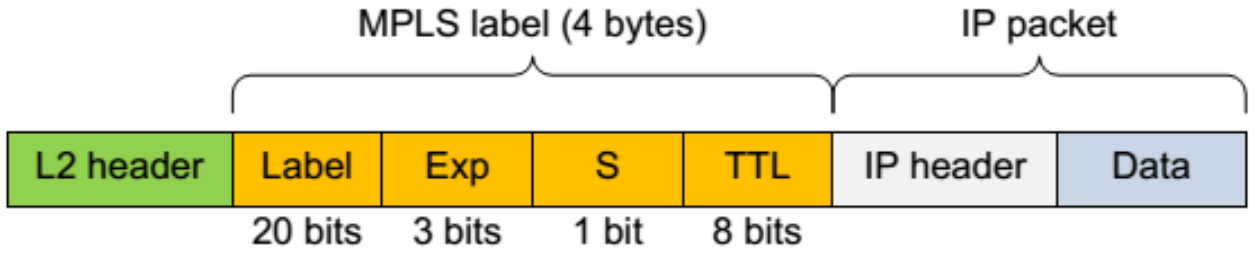
- **MultiProtocol Label Switching (MPLS)** – a switching mechanism that puts labels on packets and then uses those labels to forward packets.
- **Multiprotocol** – works with any type of link-layer protocols such as IPv4, IPv6, at the network layer and Ethernet, Token Ring, FDDI, ATM, Frame Relay, and PPP at the link layer.
- **Label** – unlike IP, which bases its forwarding on a packet's destination IP address, MPLS forwards packets based on other information in the header (labels).
  - Labels are added to the top of the IP packet.
  - Labels are assigned when the packet enters the MPLS domain.
- **Switching** – labeled packets are forwarded after a label lookup instead of a lookup into the IP routing table - done in hardware - considerably faster.

MPLS Approach

- The header is analyzed only once at the entrance to a MPLS domain aka ”source routing”.
- Packets going from A to B are associated with a certain flow.
- The flow is identified with a label.
- Label is then analyzed in the core of a MPLS domain.
- With labels, you either find 1 exact match, or you no not find a match at all.

Label

- An MPLS label (32 bits) is attached to a packet.
- Label value, 20 bits
  - Is meaningful to a given router only (i.e., it is local, not global)
  - Specifies a Forwarding Equivalence Class (FEC)
- Exp (Experimental), 3 bits
  - Aka Class of Service (CoS)
- S (Stack), 1 bit
  - Used to indicate a hierarchy of labels
- TTL (Time-To-Live), 8 bits
  - Similar to TTL in IP



Label

- Ranges of values (0 through 2^20 – 1):
  - 0 - 15: special labels
  - 15 - 1,023: can be used
  - 1,024 - 9,999: reserved
  - 10,000 - 99,999: used by vendors
  - 100,000 - 1,048,575: can be used
- Special labels:
  - 0 (IPv4 Explicit Null Label) – the label must be removed
  - 1 (Router Alert Label) – the packet should be delivered to router software
  - 2 (IPv6 Explicit Null Label) – the label must be removed
  - 3 (Implicit Null Label) – the label must be removed (for LDPs)
  - 4 - 15 (Not defined) – reserved for future use

Label

- Labels are set by each node and are of local significance only
- Once a labeled packet is received, the label is swapped and the packet is sent according to the forwarding table
- If the label value is incorrect/not set/etc., then:
  - The packet is dropped
  - The IP header is not analyzed
  - An ICMP message is not generated
- A packet can have a number of labels (aka the label stack)
  - Labels are analyzed in a **Last-In, First-Out (LIFO)** fashion
  - Switching decision is made according to the last label

IP vs MPLS

- Routing decisions
  - IP routing – based on destination IP address
  - Label switching – based on labels
- Entire IP header analysis
  - IP routing – performed at each hop of the packets path in the network
  - Label switching – performed only at the ingress router
- Support for unicast and multicast data
  - IP routing – requires special multicast routing and forwarding algorithms
  - Label switching – requires only one forwarding algorithm

Acronyms

- **MPLS** – MultiProtocol Label Switching
- **FEC** – Forward Equivalence Class
- **LER** – Label Edge Router
- **LSR** – Label Switching Router
- **LIB** – Label Information Base
- **LSP** – Label Switched Path
- **LDP** – Label Distribution Protocol

FEC

- A group of packets that require the same forwarding treatment across the same path.
- Packets are grouped based on any of the following:
  - Address prefix.
  - Host address.
  - Quality of Service (QoS).
- FEC is encoded as the label .
- Assume packets have the destination address as: 124.48.45.20, 143.67.25.77, 143.67.84.22, and 124.48.66.90
- Labelling can be done by “Address Prefix”
  - FEC –1 label x: 143.67.25.77 and 143.67.84.22
  - FEC – 2 label y: 124.48.45.20 and 124.48.66.90

FEC

- Assume packets have the destination address and QoS requirements as
  - 124.48.45.20, qos = 2
  - 143.67.25.77, qos = 1
  - 143.67.84.22, qos = 3
  - 124.48.66.90, qos = 4
  - 143.67.12.01, qos = 3
- FEC –1 label a: 143.67.25.77
- FEC – 2 label b: 124.48.45.20
- FEC – 3 label c: 143.67.84.22 and 143.67.12.01
- FEC – 4 label d: 124.48.66.90