Review


_Reference: Computer Networks: A Systems Approach._ Larry Peterson, Bruce Davie, Morgan Kaufmann  
A Brief Review

✓ A Day in the Life of a Web Request

• Layers and Protocols

• Example Analysis
  • MPLS
  • Proxy
  • CDN
  • Data Center Networking

• Wireshark Review
  • HTTP
  • DNS
  • TCP

• What is next?
Synthesis: A Day in the Life of a Web Request

• Journey down protocol stack complete!
  • Application
  • Transport
  • Network
  • Link

• Putting-it-all-together: synthesis
  • **Goal**: Identify, review, understand protocols (at all layers) involved in a seemingly simple scenario: Requesting a www page
  • **Scenario**: Student attaches laptop to campus network
    Requests and receives www.google.com
Scenario
Connecting to the Internet

• Connecting laptop needs to get
  • Its own IP address
  • Address of first-hop router
  • Address of DNS server

Use DHCP

• DHCP request
  • Encapsulated in UDP
  • Encapsulated in IP
  • Encapsulated in 802.3 Ethernet

• Ethernet frame broadcast
  • Destination: FFFFFFFF on LAN
  • Received at router running DHCP server

• Ethernet demultiplexed to IP, demultiplexed UDP, demultiplexed to DHCP
Connecting to the Internet

• DHCP server formulates **DHCP ACK** containing
  • Client IP address
  • IP address of first-hop router for client
  • Name & IP address of DNS server

• Encapsulation at DHCP server
  • Frame forwarded (**switch learning**) through LAN
  • Demultiplexing at client

• DHCP client receives DHCP ACK reply

Client now has IP address, knows name & address of DNS server, IP address of its first-hop router
Connecting to the Internet

• Before sending **HTTP** request, need IP address of www.google.com: **DNS**

• DNS query created
  • Encapsulated in **UDP**
  • Encapsulated in **IP**
  • Encapsulated in Ethernet

To send frame to router, need MAC address of router interface: **ARP**
Connecting to the Internet

- **ARP query** broadcast
  - Received by router, which replies with **ARP reply**
    giving MAC address of router interface
  - Client now knows MAC address of first hop router,
    so can now send frame containing DNS query
Using DNS

- IP datagram containing DNS query forwarded via LAN switch from client to 1st hop router
- IP datagram forwarded from campus network into Comcast network, routed (tables created by RIP, OSPF, IS-IS and/or BGP routing protocols) to DNS server
- Demultiplexed to DNS server
- DNS server replies to client with IP address of www.google.com
To send HTTP request, client first opens **TCP socket** to web server

**TCP SYN segment** (step 1 in 3-way handshake) inter-domain routed to web server

Web server responds with **TCPSYNACK** (step 2 in 3-way handshake)

**TCP connection established!**
HTTP Request/Reply

- **HTTP request** sent into TCP socket
- IP datagram containing HTTP request routed to www.google.com
- Web server responds with **HTTP reply** (containing web page)
- IP datagram containing HTTP reply routed back to client
- Web page **finally** displayed
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Internet Protocol Stack

• **Application**: supporting network applications
  - FTP, SMTP, HTTP

• **Transport**: process-process data transfer
  - TCP, UDP

• **Network**: routing of datagrams from source to destination
  - IP, routing protocols

• **Link**: data transfer between neighboring network elements
  - Ethernet, 802.11 (WiFi), PPP

• **Physical**: bits on the wire
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MPLS

• MPLS-Capable Device: **Label Switched Device**

• Labeled Switched devices can reach the MPLS Network without touching the IP header of the packet

• Traffic Engineering Capabilities

• Implement Virtual Private Networks (VPNs)

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R1-R4: Label Switched Device, R5-R6: standard IP Routers
Proxy

- Satisfy client request without involving origin server
  - User sets browser: Web accesses via cache
  - Browser sends all HTTP requests to cache
    - Object in cache: Cache returns object
    - Otherwise cache requests object from origin server, then returns object to client
Content Distribution Network

- Enter Deep (Access ISPs): Close to users (Akamai)
- Bring Home (IXPs): Smaller number of larger Clusters (Limelight)
Data Center Networking

- Top Of Rack (TOR) Switches

- Requests
  - Internal
  - External (first to load balancers)

- Hierarchical design for scaling purposes
  - Limiting host to host communication
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What is Next?

• Journey down protocol stack **complete** (except PHY)

• Solid understanding of networking principles

• Next Steps
  • Wireless Networks
  • Multimedia
  • Network Security
  • Network Measurements
  • Internet of Things
  • ...

Acknowledgements

• The following materials have been used in preparation of this slide set:

  7th Edition
  James Kurose, Keith Ross
  Pearson
  2016

  5th Edition
  Larry Peterson, Bruce Davie
  Morgan Kaufmann
  2011