Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Computer Networks

Gnkgo, Informatik B. Sc. 4. Semester

Contents

1 Internet

- Internet connects End Systems/ Hosts by a system of communications links and package switches

- Packets: data segment and header

- IP (Internet Protocol): Specifies the format for packets sent among routers and end systems

  - unreliable service
  - best-effort delivery
  - modify before forwarding the packet to the next hop
    * destination MAC address
    * Time-to-live
    * IP checksum

- DSL (digital subscriber line): broadband residential access

  - downstream data channel: tens to few hundred Mbps
  - upstream data channel: few Mbps to few tens Mbps

- FDM (Frequency-division multiplexing): link dedicates a frequency band on the band to a communication for the duration of connection. The width of this band is called bandwidth.

- TDM (time-division multiplexing): time is divided into frames of fixes size, and each frame is split into a fixed amount of slots. These slots are dedicated to one connection

2 Packet, Circuit Switching

- Packet switching relies on buffers to account for unexpected bursts

- Circuit switching is better applicable when the peak-to-average utilization ratio is low.

- large Peak / Average → On-demand

- small peak /average → circuit

3 Delays

- **nodal processing delay:**

  - Time used to decode the header, determine which output needs to be used, bit-level checking, etc.
  - Negligible in comparison to other delays, little room for improvement here

- **queuing delay:**

  - Time that the packet has to wait in the queue until the desired output will be free
  - Better load balancing (i.e., via routing), reduce queue size

- **transmission delay:**

  - Time after the packet gets out of the queue until it's on the output line; let L be the length of the packet, R the transmission rate from router A to B, then the transmission delay is L/R.
  - Increase the link capacity

- **propagation delay:**

  - Time the package takes to propagate through the physical medium (e.g., at light speed with radio waves), i.e., it takes on the way from router A to B
  - If possible, use data replication to shorten the client-server distance. Improving routing or physical transmission media also helps

4 Layers

Layers
Application
Transport
Network
Link
Physical

- **Application Layer:** Application protocols and layers reside here. The internet includes many protocols here, as HTTP (provides Web document requests and responses), SMTP (for e-mail transfer), and FTP (file transfer from host to host). The DNS is also an application layer protocol. Packet of information at this layer is called a message.

- **Transport Layer:** Transports application layer messages between application endpoints. In the internet, there's TCP and UDP. E.g. longer messages are split into shorter segments. Packets in this layer are called segments (TCP & UDP) or Datagram (UDP).

- **Network Layer:** The layer is responsible for moving datagrams from host to host. It receives a segment and an address. This layer includes the IP, which defines the fields in a datagram and how to work on those fields. Packets in this layer are called datagrams / packet.

  - ARP: broadcast domain receives everyone until a router.
  - Goes through MAC.

- **Link Layer:** The network layer brings a datagram from one node to another, but to move a packet from one specific node to another, it relies on the link layer.

  - It delivers the packet to the next node. E.g. Ethernet or WiFi. Link layer protocols are called frames.
  - Error detection

- An Ethernet switch can interconnect a 10 Mbps Ethernet network and a 1 Gbps Ethernet network.

- The 802.11b wireless protocol incorporates a link-layer ACK not present in regular Ethernet.

- **Physical layer:** The job of the link layer is to move whole frames from one node to another; however, the job of the physical layer is to move individual bits. Many protocols exist, depending on the physical medium; e.g. Ethernet has different protocols for different cable types.

5 Address Resolution Protocol (ARP)

- It allows a host to get the MAC address associated with an IP address.

6 Ethernet

1. Frame starts with destination address.

   - If not destined to this device, it can be simply dropped.

2. Source address.

3. Type / length field.

   - Tells receiver what payload this frame carries.

4. Data and pad.

   - Minimum length of an Ethernet frame is 64 bytes in total.

5. Frame check sequence.

   - Cyclic Redundancy Check (CRC) for error checking.

7 Wireless Local Area Networks (WLANs)

- Multiple access points can operate on different channels.

- Nodes are often mobile, requiring dynamic routing.

8 TCP/IP Model

TCP/IP Model
Application Layer
Transport Layer
Internet Layer
Network Interface Layer

- The network interface layer encompasses both the link and physical layers.
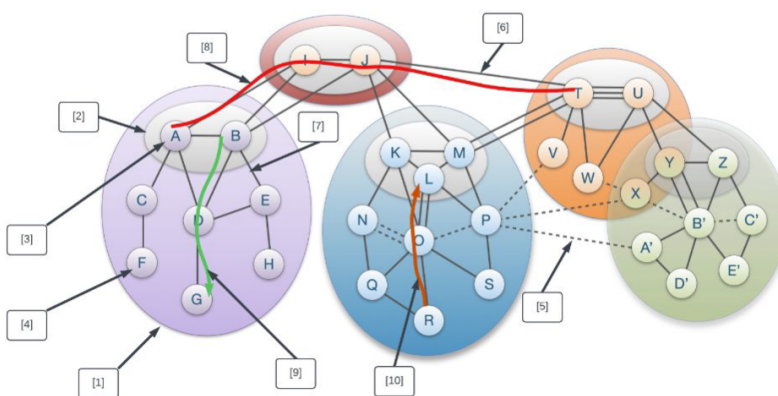
9 Congestion Control

- A state in which one link in a subnet is so overwhelmed that it cannot effectively handle the amount of traffic that could use it.

- A link can become congested even if it has sufficient bandwidth.

- Network layer congestion can occur even if no link is congested.

9.1 Receive Procedure

1. Divide and check for zero remainder

9.2 Path Lookup

Figure 1: Path Lookup

9.3 Recipe to get IP addressing:

10 Quiz

- **The Maximum Segment Size (MSS) of TCP is equal to:** MSS = MTU - header(IP) - header(TCP)

| Column Name	Explanation
Prefix	The prefix notation (CIDR) representing the subnet's network size. IP address followed by a slash and the number of significant bits in the subnet mask.
# of hosts	Maximum number of usable hosts in the subnet. Calculated as $2^{(32-\text{prefixlength})} - 2$, accounting for network and broadcast addresses.
Prefix mask	Subnet mask in dotted-decimal notation, each segment represents 8 bits.
Network Address	Obtained by bitwise AND operation between IP address and subnet mask.
Broadcast Address	Highest address in the subnet, obtained by flipping all host bits to 1s in the network address.
Last Host Address	Highest usable IP address, obtained by setting all host bits to 1s in the network address, except for the last bit.

Table 1: IP Addressing Recipe
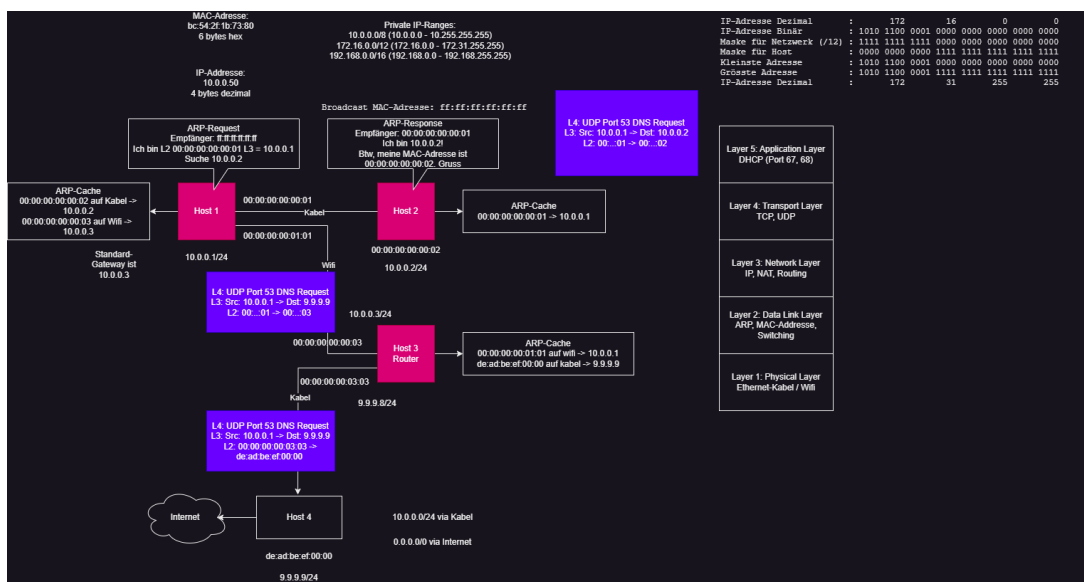
Figure 2: Mac vs IP-Address

- UDP sockets type is SOCK_DGRAM while TCP sockets type is SOCK_STREAM.

- For a SOCK_STREAM, an operating system stores both local and remote port.

- Given a directed graph G(V, E), with $|V|$ and $|E|$ being the numbers of vertices and edges, how many variables do you need for the max-flow LP formulation discussed in class?

- There is no connection establishment in UDP.

- The objective of flow control is not to overwhelm the hosts.

- The objective of congestion control is to not overwhelm the network.

- During congestion avoidance in TCP, the successful acknowledgment of a segment results in the sender congestion window growing by one segment per RTT.

- TCP (SOCK_STREAM) is a connection-based protocol. The connection is established, and the two parties have a conversation until the connection is terminated by one of the parties or by a network error.

- UDP (SOCK_DGRAM) is a datagram-based protocol. You send one datagram and get one reply, and then the connection terminates.

- Given a directed graph G(V, E), with $|V|$ and $|E|$ being the numbers of vertices and edges, how many variables do you need for the max-flow LP formulation discussed in class?: $O(|E|)$

- QUIC can handle switching from WiFi to a cellular network without having to reestablish the connection:
  - Uses connection IDs independent of the IP address instead of a 4-tuple like TCP to identify connections.
  - This way packets using the connection ID are still valid, even if the source IP address changes.

- If we create our simple query (`dig @a.root-servers.net www.ethz.ch`) and send it to the first root-server, we don't get a `www.ethz.ch` IP in return. Why is this?
  - Root server does not support recursive resolution.

- The minimum information one needs to resolve any DNS hostname is the IP address of a DNS root server.

11 Quic

- Operate in Application and Transport layer.

- Combines connection and TLS handshake $\rightarrow$ reducing the connection setup time by one RTT.

- Enables Zero-RTT communication if the hosts have communicated before (improved handshake).

- Connection hand-over is possible by identifying connection with a connection ID instead of the 5(/4)-tuple (even with changing IP addresses e.g. when changing networks with a mobile device).

- Resolves head-of-line blocking by the logical abstraction of streams (contrary to TCP, which required you to open multiple parallel TCP connections).

- Middleboxes and NAT routers are known to drop unfamiliar transport layer protocols. Quic uses UDP to give inseparability with existing hardware.