Computer Systems V: Networking

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Overview

Section 1: Basics

Motivations

- Single computers are limited (memory, computational power, etc.)
- Networks allow computers to specialize and to increase total capacities
- Additional advantages of distributed computing
  - Redundancy

History

- The **Internet** connects computers across the world, while the **World Wide Web** is a specific system for organizing documents and information on the Internet
- **ARPANET** was the first network to the **TCP/IP protocol**, which underlies the modern Internet, in 1974
  - TCP/IP was invented by Robert Kahn and Vint Cerf
  - Funded by DARPA and the NSF
- Tim Berners-Lee invented the World Wide Web in 1989
  - Organized by **uniform resource locators (URLs)**

Basics

- In the most basic arrangement, a **client** communicates with a **server**
- Client **requests** a **remote service**, server **provides** the service
- Client sends requests, server returns **responses**
- Networks pass units of data called **packets** from source to destination at certain **addresses** on certain **ports**
  - **Header** provides routing information and other important metadata
  - **Payload** is actual data being transmitted
- **Protocols** define how information is transmitted and how interactions take place

Network topologies

- The computers on a network are laid out locally according to some topology, such as:
  - **Star**: one central hub
  - **Tree**: hierarchical structure
  - **Ring**: connected circularly
  - **Mesh**: as many connected together as possible
  - **Bus**: all connected along a single link

OSI model

- The **Open Systems Interconnection (OSI) model** is a standard conceptual design for a computer network
- Seven **layers** building from the lowest to highest level
- Each layer is associated with a **protocol data unit (PDU)** which describes the "quantum" of data that the layer transmits, stripping headers from lower layers

#	Type	Layer	PDU
7	Host	Application	Data
6	Host	Presentation	Data
5	Host	Session	Data
4	Host	Transport	Segment/Datagram
3	Media	Network	Packet
2	Media	Link	Frame
1	Media	Physical	Bit

Physical layer

- Actual binary signals are transmitted
  - Electrical signals in a wire
  - Fiber optic cables
  - Wireless (radio, WiFi, etc.) signals
- Communication channel can either be:
  - **Simplex**: one way only
  - **Half-duplex**: one way at a time
  - **Full duplex**: both ways at a time
- Also includes network topology

Network layer

- The **Internet protocol (IP)** controls routing of data
  - Data is fragmented into **datagrams** to be transmitted in the physical network
  - Each datagram is routed from the source IP to the destination IP
  - The network is divided into many **subnets**

Transport layer

- Arbitrary-size data sequences are transmitted
- Centered around the **Internel protocol suite**
- The **transport control protocol (TCP)** is coupled with IP in **TCP/IP** to send data over the Internet
  - Data is split into **segments**
  - Segments are received in order
  - Network is reliable and error-checking is implemented
  - Packets can be resent when delivery fails
- The **user datagram protocol (UDP)** does not guarantee delivery and is connectionless

Section 2: Application Layer Protocols

DNS

- The **Domain Name System (DNS)** maps domain names to IP addresses
- The entire space of domain names is partitioned into a hierarchical structure of **DNS zones**, which **delegate** name resolution to subzones
- Every name server holds several **resource records** which, for example, define subdomains and map domains to IPs

HTTP

- The **Hypertext Transfer Protocol (HTTP)** transmits specially annotated text, called **hypertext**, in the World Wide Web
- A **user agent** (like a **web browser**) requests a specific resource using HTTP, and the server responds with the requested data, or possibly a **status code**
- The protocol is **stateless**: it maintains no information between requests

Mail

- The **Simple Mail Transfer Protocol (SMTP)** is used to send email messages between mail servers
- User mail applications often use the more advanced **Internet Message Access Protocol (IMAP)** or **Post Office Protocol 3 (POP3)** to access messages

Security

- Many different Internet protocols and services are secured by the **Transport Layer Security (TLS)** protocol
- A client and server use a **handshake** to established a shared secret key to use for private and secure communication
- Key features:
  - **Privacy**: Messages cannot be read in transit
  - **Authentication**: Senders and receivers of messages can be verified
  - **Integrity**: Messages cannot be modified in transit

Webpage sequence

1. The operating system resolves the DNS record of the requested URL to retrieve the server IP
2. The browser sends an HTTP request packet to the server (over TCP/IP) through **router**, **modem**, and **Internet service provider (ISP)**
3. The server processes the request, loads resources, runs server-side code, etc.
4. The server replies to the browser with a status code HTTP 200/OK
5. The browser interprets and renders the returned HTML code