2.2 Interfacing Computers (Networking)

Network

- Nodes: Points in network that sends / receives data; end points
- Network: Interconnected system of nodes with links established via wired/wireless media
- Networking: Practice of linking two or more devices together for sharing of resources
    - Facilitate sharing of resources
    - Remote access
    - Consolidate information
- Benefits:
    - Efficiency in management of multiple machines
        - Reduce cost of maintenance / operation
    - Collaborative
        - Allows sharing of resources / data
        - No need for duplication of files / hardware
        - E.g. printer, storage, files, bandwidth
    - Convenient
        - Ease of access to resources and information
        - Allows for remote access
- Drawbacks:
    - Network failure: slow service
    - High cost due to hardware and high bandwidth required
    - Complicated set-up and maintenance
    - Expertise required
    - Security problems:
        - Controlled access
        - Intrusions
        - Virus infections
- **Ethernet**
    - A series of network devices connected together on a shared Ethernet cable
        - May or may not be connected to the Internet
    - Collision may occur when two or more devices try to send data simultaneously
    - Each device has a Media Access Control (MAC) Address
        - Physical address
        - 6 bytes

        - Unique for each device
    - Carrier Sense Multiple Access with Collision Detection (CSMA/CD)
        - Devices take turns to send and receive data
        - Process:
            1. Is my frame ready for transmission? Y - go to 2
            2. Is medium idle? N - wait until ready
            3. Start transmitting and monitor for collision during transmission
            4. Did collision occur? Y - go to Collision Detected Procedure
            5. Reset retransmission counter and end transmission
    - Collision Detected Procedure:
        - Used to resolve a detected collision
        - Complete when retransmission is initiated or retransmission is aborted due to numerous collisions
        - Procedure:
            1. Continue transmission until minimum packet time is reached to ensure all receivers detect collision
            2. Increment retransmission counter
            3. Was max number of transmission attempt reached? Y - abort transmission
            4. Calculate and wait random backoff period based on number of collisions
            5. Re-enter main procedure at stage 1 of transmission process
    - Methods to overcome collision:
        - Use switches instead of hubs: data sent to port that is meant only for device connected to that port
        - Cables:
            - Twisted pair cabling: separate cables for sending and receiving
            - Optic fibre: uses light transmission, bi-directional
- **Local Area Network (LAN)**
    - Connected to Intranet using Switches
    - Network that connects computers and devices in a limited geographical area e.g. home
    - WLAN: LAN using wireless signals
        - E.g. Bluetooth, Wi-Fi
    - Can be a part of WAN
    - Cheaper than WAN

    - Able to control security, lower risk of data leaks and viruses
    - Provides Intranet
        - Private network contained within an enterprise / organisation
        - Consists of many linked LANs
        - Use leased lines in WAN
        - Connections through one or more gateway computers to the Internet
        - Purpose:
            - Share information, resources, operational systems, computing services, etc. within organisation
            - Facilitate group work
            - Teleconferences
        - Tunnelling:
            - Virtual Private Network (VPN)
            - Send private data through public network
            - Uses public network with encryption/decryption and other security safeguards
        - Firewall:
            - Access to internet through firewall servers
            - Ability to screen data in both directions
            - Maintain company security:
                - Prevents viruses from entering
                - Prevents private information from being leaked
- **Wide Area Network (WAN)**
    - Connects to the Internet using Routers
    - Network that covers a large geographical area using a communications channel
    - Provides Internet
    - Devices use Internet Protocol (IP) Address
    - Combines many types of media
    - Larger volume of traffic
    - More expensive than LAN
    - Less secure due to larger exposure

Connecting Devices

- Purpose of connecting devices
    - Transferring data from one host to another
- Broadcast: receive from one and send to all
- Unicast: receive from one and send to another

- Multicast: receive from one and send to many (not all)
  - Controlling network traffic
- **Network Hub** (Physical Layer)
  - Used as network connecting device to connect all devices together
  - Basic broadcasting: replicate incoming data and forwards to all connected devices
  - Each device is responsible for determining which packets are destined for it, ignores others
  - Benefits:
    - Cheap
    - Simplicity
    - No error management: high speed
  - Drawbacks:
    - Wastes bandwidth: costs unnecessary traffic and collisions
    - Security leaks: every host/device on network gets access to data
- **Switch** (Data Link Layer)
  - Used in LAN / Intranet
  - Each device is connected to a unique port
  - MAC table: records MAC addresses of all the connected devices
  - Sends data to the addressed device (Unicast)
    - Packet sent to switch is read to determine which computer to send to
    - If switch doesn't recognise the destination MAC address, broadcast packet, each device determines if the packet is meant for it
  - Benefits:
    - Packet handling
      - Only sends packet to specified destination, better security
    - Collision management during high traffic
      - Creates connection between sender and receiver hosts
      - Improves performance and efficiency
    - Problem isolation
  - Circuit Switching
    - Two network nodes establish a dedicated communication channel through the network before nodes may

communicate
        - Entire circuits are switched to route traffic to correct destination
        - Benefits:
            - Circuit guarantees full bandwidth of channel, no interruption
            - Remains connected for duration of communication session
            - Highly reliable (than packet switching)
                - Ensures data gets across fully
        - Drawbacks:
            - Single point of failure cause full disruption in communications
            - Expensive and inflexible due to unused capacity
        - E.g. early analog telephone network
    - Packet Switching
        - Transmitting data by splitting it into smaller packets
        - Groups all transmitted data into suitably sized packets (broken up)
        - Each packet consist of header and payload
            - Header: IP address, destination MAC address
        - Benefits:
            - Efficient
            - Stable: prevents single point of failure
            - Packets are short
                - Communication links between nodes are only allocated to transferring a single message for short period of time while transmitting each packet
                - Longer messages require series of packets to be sent, but do not require link to be dedicated between transmission of each packet
            - Pipelining
                - Multiple transmissions that do not cause collision can occur simultaneously
        - Drawbacks:
            - Lagging due to high traffic
            - Interference
            - Less reliable: loss of packets resulting in data not fully transmitted
- **Router** (Network Layer)
    - Used for WAN / Internet

    - Connect networks to one another using IP address
    - Receives packet, router reads destination IP, forwards to destination device
    - Can assign IP addresses using DHCP
    - Can be used as gateway
- **Gateway**
    - System that joins two or more networks with different protocols
    - Connects Ethernet to Internet
    - Implementation:
        - Completely in software
        - Completely in hardware
        - Combination of software and hardware
    - Operates on every level of OSI model
    - Firewalls, VPNs, etc can be integrated into gateways
    - E.g. broadband router in households

Network Architecture

- **Client-Server**
    - Specific workstations/terminals that serve the requests of other systems
    - One or more computers act as server
    - Purpose:
        - Provides service to other systems
        - Dedicated to one server task
    - Client:
        - Request services from the specific servers
    - E.g. File server, Print server, Mail server, Proxy server, Domain Name server, Network Time Protocol server
    - Benefits:
        - Centralisation
            - Central servers
            - Help in administrating set-up
            - Access rights and resource allocations by server
        - Proper file management
            - All files stored in servers
            - Easy management
        - Back-up and recovery
        - Security
            - Rules of security defined when setting-up server

- Drawbacks:
  - Congestion
    - High volume of traffic overloads servers
    - Servers break down
  - Service unavailable
    - Service is down when servers fail
  - Maintenance
    - Professionals are required to maintain the set-up
- **Proxy Server**
  - Obscure client IP, provides anonymity
  - Bypass IP address blocking
  - Firewall: filters request to control incoming and outgoing data
    - Block malicious traffic
  - Log activities
  - Improve performance:
    - Browser send all HTTP request to cache.
    - If data in cache, proxy returns cache to client; else proxy fetch data from internet and returns data to client, and stores it in proxy cache
- **Domain Name Server**
  - Contain database of domain names and their IP addresses
  - Hierarchy of databases
  - Device sends domain name to DNS
  - Process:
  - DNS checks its cache if it contains requested domain's IP address:
    - If present, returns back to client
    - If not present, DNS queries Internet Service Provider (ISP)
      - If ISP does not contain requested domain:
        - Direct query to Root server
        - If Root server does not contain requested domain:
          - Direct query to Top Level Domain (TLD) server
- **Mail Server**
  - Outgoing:
    - Simple Mail Transfer Protocol (SMTP)
  - Incoming:

        - Post Office Protocol 3 (POP3)
            - Stores emails on client device
            - Delete email after forwarding to client
        - Internet Message Access Protocol (IMAP)
            - Stores copies of emails online
    - Process of sending mail:
        - Client sends mail to SMTP server of his own domain
        - SMTP server reads recipient address to determine domain
            - If sender and receiver have the same domain, SMTP forwards the email to the domain's POP3 or IMAP servers
        - Sender SMTP server looks for recipient SMTP server and forwards mail to it
        - Recipient SMTP server forwards email to POP3 for local storage or IMAP for online storage
        - Email ready for download when recipient client comes online
- **Dynamic Host Configuration Protocol (DHCP)**
    - Every device has a unique unicast IP address to access network
    - Centralised and automated TCP/IP configuration
    - Assigns IP addresses to connected devices automatically
    - Allocation of IP address (DORA):
        1. DISCOVER: Client broadcasts DHCPDISCOVER packet in subnet
        2. OFFER: Server responds with DHCPOFFER packet containing potential IP addresses for client
        3. REQUEST: Client responds with DHCPREQUEST packet containing server identifier, if multiple offer packets are received, client chooses the fastest response
        4. ACK: Server replies with DHCPACK packet to acknowledge client on requested IP address, stores IP address into database
    - DHCP servers maintain a pool of IP addresses and leases an address to a client when it connects to the network
    - Addresses that are no longer in use are automatically returned to the pool
    - Benefits:
        - Reliable

        - Minimises errors caused by manual configurations
      - Reduce network administration
      - Efficient
- **Peer-to-Peer (P2P)**
  - Each computer (peer) has equal responsibilities and capabilities.
  - No central server
  - All computers able to share resources without going through a server computer
  - E.g. bitTorrent, Napster
  - Benefits:
    - More resilient in case of failures and traffic bottlenecks
    - Lack of central server
      - Cheaper costs
      - No maintenance needed
    - More available resources
  - Drawbacks:
    - No control over shared data
      - Copyright infringements, piracy
    - Poor security
      - Virus
      - Illegal access to computer by others
    - User computer can be slowed down when accessed by others

Transmission

- **Rate of Transmission**
  - Measure pf the amount of data that can be transmitted through a connection over a given amount of time.
  - Every machine is connected by cable or other types of connection
  - Measure of bandwidth
    - Unit: bits per second (bps)
    - aka Baud Rate / Bit rate
- **Directions of Transmission**
  - Simplex:
    - Data transmission in one direction
    - E.g. keyboard: keyboard transmits user input to CPU, but CPU does not need to reply to keyboard
  - Half-Duplex:

        - Transmission in both directions, but only one direction will be allowed through at a time
        - Type of parallel interface
        - Consists of 8 lanes
        - E.g. printers, walkie-talkie
    - Full-Duplex:
        - Transmission in two ways simultaneously
        - E.g.:
            - Telephones: allow both people to hear each other at the same time
            - Computers: connected via Ethernet cable can send and receive data at the same time
            - I/O standards: USB / Thunderbolt
- **Synchronisation of Transmission**
    - Coordinating sending and receiving within the network
    - Serial transmission: transmission by single bits
    - Asynchronous transmission:
        - Sends only one character at a time
        - Character either an alphabet, number, or control character
        - Bit synchronisation between two devices:
            - Use of start bit and end bit
            - Indicated beginning and end of data
        - Idle time between transmissions of different data types
            - Responsibility of sender to separate bit stream into bytes of characters
        - Sender and receiver are not to be synchronised
        - Receiver has to synchronise with incoming bit stream when receiving
        - Benefit:
            - Low cost
        - Drawback: Slow transmission speed
    - Synchronous transmission:
        - Bit stream is combined into longer frames that may contain multiple bytes
        - No gaps between various bytes in data stream
        - Bit synchronisation established between sender and receiver by timing transmission of each bit
        - Sender and receiver operate at same frequency in order for receiver to receive data error-free
        - Responsibility of receiver to separate bit stream into bytes

so as to construct original information
        - Benefit:
            - Fast transmission speed
        - Drawback:
            - High costs

Cyclic Redundancy Check

- Purpose: Check that information is entered correctly / transmitted without corruption
- **Parity check**
    - Uses parity bit
    - Using bit patterns
        - Even parity check: Parity bit added to ensure even number of “1”s
        - Odd parity check: Parity bit added to ensure odd number of “1”s
    - Used for small blocks of data
    - Simple to check
    - Detects error when bit parity is wrong
    - Unable to detect error when two bits are altered
- **Check digit**
    - Attach weights to the digits
    - Sum the product of each weight to the corresponding digit of the code
    - Divide the sum using the modulo to find remainder
    - Check digit is the difference between modulo and remainder
    - Check digit added to the back of the code
    - E.g. Modulo 11
        - Weights: 7, 6, 5, 4, 3, 2
        - Code: 508795
        - Modulo: 11
        - Weighted sum: 7x5 + 6x0 + 5x8 + 4x7 + 3x9 + 2x5 = 140
        - Remainder: 140 / 11 = 12 R <8>
        - Check digit: 11 - 8 = 3
        - Code: 5087953
    - For checking:
        - Find weighted sum of the multiplication of code and weight, check digit has
        - Divide by modulo
        - Weighted sum should be exactly divisible by modulo (no

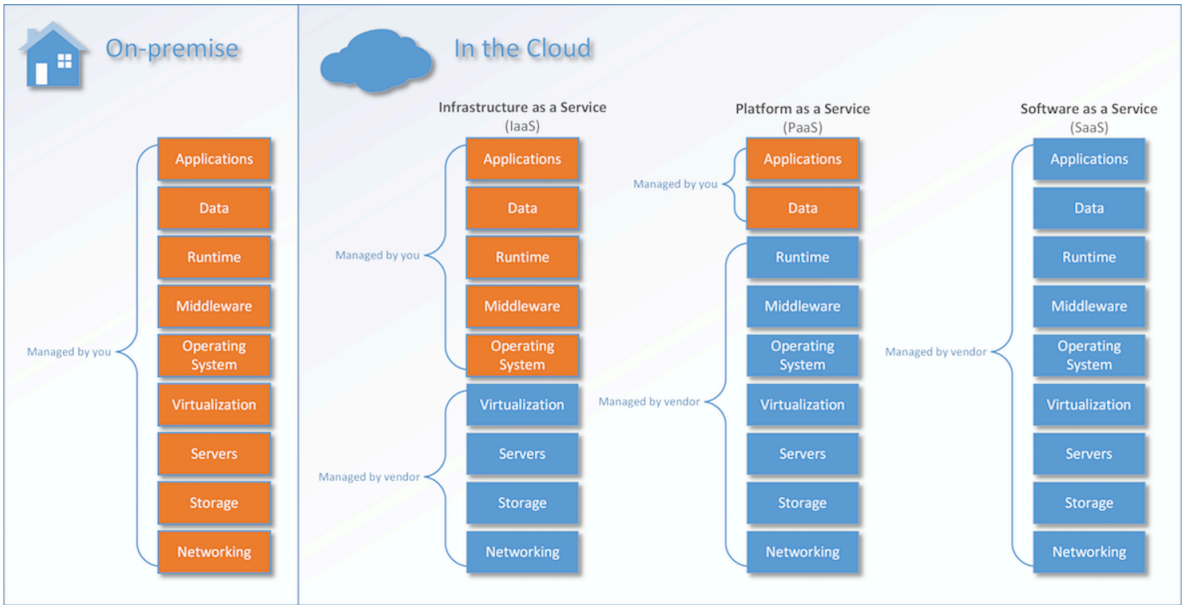
remainder)
        - Check digit has weightage of 1
        - E.g. Modulo 11
            - Code = 5087953
            - Weighted sum = 7x5 + 6x0 + 5x8 + 4x7 + 3x9 + 2x5 + 1x3 = 143
            - Remainder = 143 mod 11 = 0
            - Thus valid code
    - Used for small blocks of data
- **MD5 Checksum**
    - Hash function to check if file is legit and untampered with
    - 128 bits string
    - If original and checked MD5 checksums match, the file is legit
    - If MD5 strings do not match, there's a possibility that the file has been altered
- Most common approach after error detection: Retransmit

Cloud Computing

- **Traditional server**
    - Organisations own their own servers
    - Drawbacks:
        - High initial setup cost
        - Require maintenance
        - High level of administrative work
- **Cloud Computing**
    - Network computing approach whereby applications run on a server / group of servers owned by a service provider
    - Technologies that provide software, data access, and storage services
    - Not owned by user
    - Virtualisation:
        - Technique of running OS and software within another OS / software
        - Simulates real hardware
        - Allows multiple virtual machines to run on the same set of hardware
        - Foundation of cloud computing
    - Benefits:
        - Utility based usage

        - Pay-as-you-use approach
        - Use when you want to
        - Does not require user to configure or understand how the system works
    - Flexibility:
        - Scalability and Elastic capabilities: Support fluctuating workloads, users can request for more services
        - Control choices: Services offer different levels of control as they require
        - Security: Imbedded virtual private clouds, encryption, etc.
    - Efficiency:
        - Ease of access: Cloud based applications and data
        - Data security: Hardware failures do not result in data loss due to cloud back-ups
        - Pay structure: Utility based usage, pay for what you use
    - Strategic Value:
        - Collaboration: Worldwide access allows users to collaborate from various locations
        - Competitive edge: Ability to devote less resources to managing infrastructure
        - Economy: decrease in total cost as size of system grows
- Drawbacks:
    - Lack of control:
        - No ownership and control over hardware and infrastructure
        - Question of ownership: if data is owned by user or service provider
        - Freedom of usage limited by producer e.g. downed services
    - Security:
        - Data that used to reside locally is now stored and residing elsewhere
        - Data is now openly accessible as it is put on the Internet
    - High cost:
        - Cloud computing may be efficient for large companies
        - Small companies may lose money as drawbacks > benefits

- Cloud deployment models:
  - Private cloud
  - Public cloud e.g. Google Suite
- Cloud service models:
  - Software as a Service (SaaS) (Top Tier)
    - Allows users to run prebuilt online applications
    - Hardware and software provided and managed by service provider
    - Can't be customised more than provider allows
    - No administrative work needed
    - E.g. iCloud, Google Suite
  - Platform as a Service (PaaS) (Mid Tier)
    - Allows users to create, edit, maintain their own cloud applications using supplier-specific tools and languages
    - Hardware is provided and managed by service provider
    - Operating system and applications managed by user
    - Low administrative work: applications, data
    - E.g. Google App Engine, Pivotal CF
  - Infrastructure as a Service (IaaS) (Base Tier)
    - Allows users to run any application they please on cloud hardware of their choice
    - Grants users full access to hardware
    - Virtual machines
    - Hardware is provided and managed by service provider
    - High administrative work: applications, data, OS
    - E.g. Amazon Web Services; Google; Windows Azure


On-premise
In the Cloud
Infrastructure as a Service
(IaaS)
Platform as a Service
(PaaS)
Software as a Service
(SaaS)
Managed by you
Managed by vendor
Applications
Data
Runtime
Middleware
Operating System
Virtualization
Servers
Storage
Networking