7 Networks

7.1 Introduction

Networking Components

Parts	Function
Client	Give users access to the network
Server	Stores data and give it to clients over the network
Switch	Connects computers in a LAN
Router	Connects different networks

Types of Networks

Type	Feature	Function
LAN	Building, floor, room	A group of client or servers that share a circuit
BN	< few km	Connects multiple high-speed connection LAN via routers
MAN	> few km	Connects LANs and BNs across locations
WAN	>> few km	Wide range of MAN

Application Architectures

Types of Logic

Presentation Logic	How it presents (User interface)
Application / Business Logic	How it behaves (Application's job)
Data Access Logic	How it manages data (Data management)
Data Storage	How it stores data (Data base)

Types of Architectures

Logic	Client-based	Client-server	Thin-client	Server-based
Presentation	C	C	C	S
Application / Business	C	C	S	S
Data Access	C	S	S	S
Data Storage	S	S	S	S

C – Client S – Server

Architecture	Feature
Server-based	Problem: • easily result the server to jam, due to massive data • expensive upgrade
Client-based	Problem: • data must travel back and forth between server and client • waste a lot of time
Client-server	Advantage: • Balanced processing load
Thin-client	Advantage: • Only one server needs updating

Special Architecture (Advanced version)

1. Multi-Tier Architecture

Function: To handle more users as number of servers are insufficient

Client	Server 1	Server 2
Presentation	Application	Data Access, Data Storage

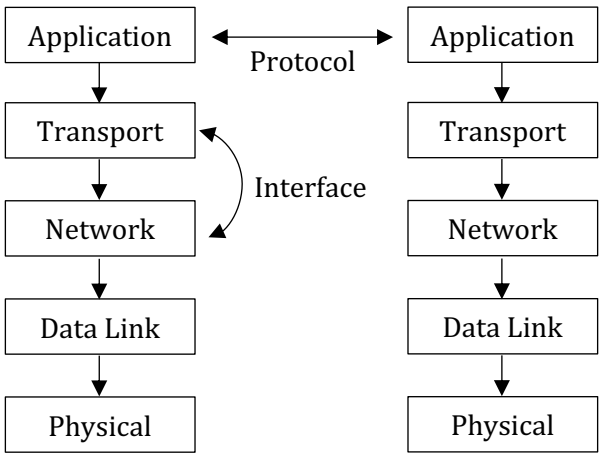
2. Peer-to-Peer Architecture

- Computers act as both clients and servers
- Directly connect to each other without connecting to server
- Example: Skype

7.2 Layers and Protocols

Layers of Abstraction (Internet Model)

Layers: **ATNDP**



Definitions

Interface	How each layer "talks" to each other
Protocol	How two same layers talk to different computers

Layer Functions

Application	Application that the user interacts with
Transport	• Break into packets and assemble at recipient's side • If packets have error, recipient will resend the packets
Network	Giving the directions for the packets to go
Data Link	Interface between hardware and software (connection with tables or waves)
Physical	Deals with hardware like cables, plugs, Wi-Fi, etc.

Message Encapsulation
Will be sent from one layer to another layer and transfer to physical layer of another computer

Layers	Protocol Data Unit (PDU)
Application	Message
Transport	Segment
Network	Packet
Data Link	Frame
Physical	Bit

PDU Properties
- Addresses (Sender / receiver)
- Error detection codes
- Protocol-specific information
- Special start and end symbols

7.3 Application Layer

HyperText Transfer Protocol (HTTP)

Definition	How browsers talk to each other
Request-Response Cycle	
Link	http://www.monash.edu/fit1047.html
Request	`GET: /fit1047.html HTTP/1.1` `host: www.monash.edu`

Response	`HTTP/1.0 200 OK`
	`Date: Fri, 21 Apr 2017 05:30:10 GMT`
	`Content-type: text/html`
	`Content-Length: 463`
	`Last-Modified: Fri, 21 Apr 2017 04:39:52 GMT`

Properties of HTTP

Problem	Stateless (server doesn't know same person requested)
Solution	1. Session identifier • An ID will be added at the end of the request • E.g. ……/11032 • 11032 is ID 2. Cookies • Server will attach a cookie to the request • Works like an ID badge • When client requests from server again, cookie will be sent along

Mail Protocols

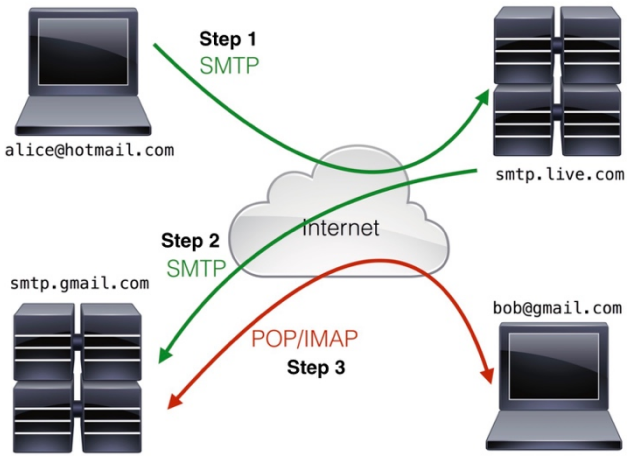
Protocol	Properties
Simple Mail Transfer Protocol (SMTP)	Transfer message between mail servers **handles plaintext**
Post Office Protocol (POP)	Download messages onto client and deleted from server
Internet Message Access Protocol (IMAP)	Few clients can access same mailbox as messages remain on server

Multi-Purpose Internet Mail Extensions (MIME)
- Attaches other file types
- Supports character sets (Unicode) to send non-Latin characters
- Have multi-part message bodies

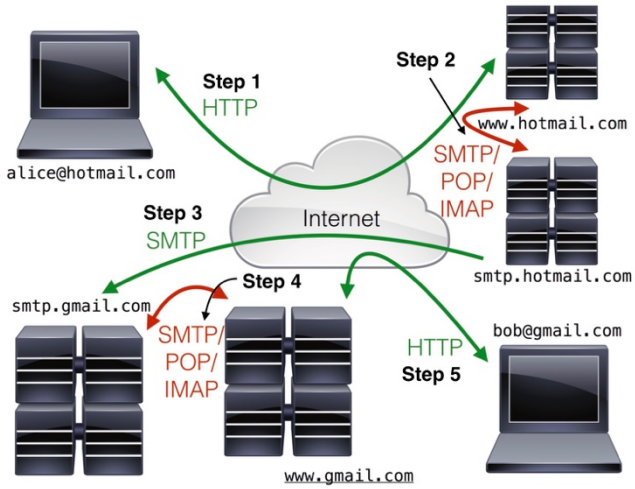
Tiers in Mail

	Two Tier	Three Tier
Type	Client-server	Thin-client access web application
Method	Client implements application logic (using SMTP & POP)	Server handles: → application logic Client handles: → server (via HTTP)
Feature	-	Access the mail on multiple devices

Two Tier



Three Tier



7.4 Physical Layer

Network Interface Card (NIC)

- Implements physical and data link layer

⇒ Includes unique data link layer address (MAC)

⇒ Provides physical connection to the network (socket for cable or antenna for radio signals)

⇒ Implements protocols (error detection, frames construction, modulation or encoding)

- Connection to the computer

⇒ Built into motherboards

Network Cables

1. UTP (Unshielded Twisted Pair, most common LAN type)
2. STP (Shielded Twisted Pair, metal covering the cables to prevent EM interference)
3. Optics fibre (used in underwater networking to transfer data)
4. Coaxial (used in old LANs)

** Modern ethernet uses UTP CAT 5 or better **

Signals

Definition	Information are transmitted through physical signals
Mediums	• Wires for electrical signals • Space for radio waves • Optics fibre (or space) for light waves

	Data	Signal
Digital	Discrete values (0 and 1 or alphabets)	Wave with discrete states
Analog	Continuous values (temperature, pressure)	Wave with sinusoidal shape (continuous states, like sin graph)

Digital Transmission

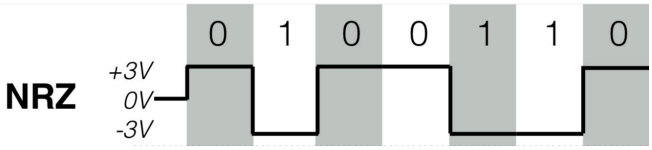
Unipolar	Only one polarity: • Positive polarity (from 0V to +V) • Negative polarity (from 0V to -V)
Bipolar	Two polarity (NRZ & NRZI): • Both positive and negative at the same time (0V to +V and -V)

Non-Return Zero encoding (NRZ)

Function: Switches position when there is change in polarity

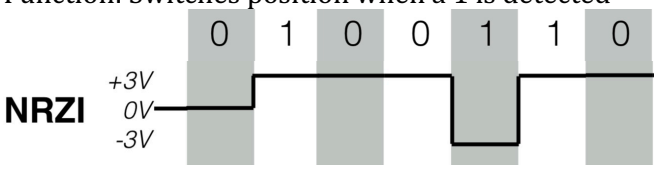
Properties:

- 0: from 0V to +V
- 1: from 0V to -V



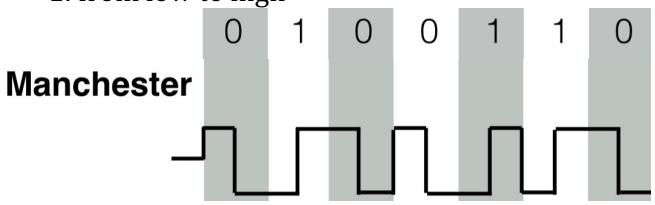
Non-Return Zero Inverted (NRZI)

Function: Switches position when a 1 is detected

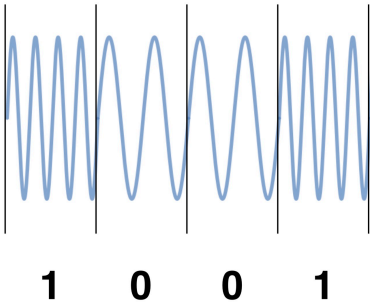
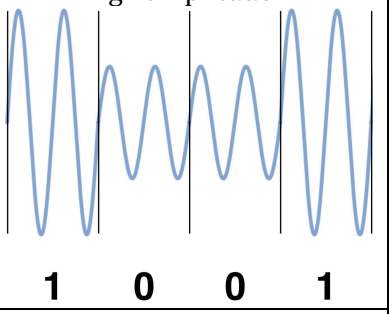
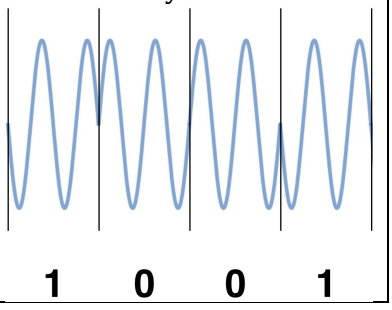


Manchester
Function: Switches position in the middle of the bit
Properties (reset)

- 0: from high to low
- 1: from low to high

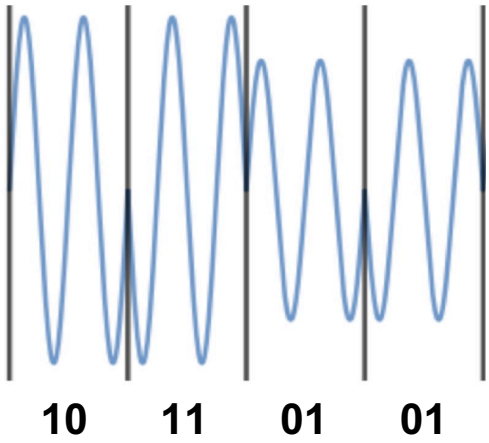


Analog Transmission

Modulation	Diagram
Frequency	• 0: low frequency • 1: high frequency 
Amplitude	• 0: low amplitude • 1: high amplitude 
Phase	• 0: start by upwards • 1: start by downwards 

Combination of amplitude and phase modulation

Amplitude	Phase
0: low amplitude 1: high amplitude	0: move upwards 1: move downwards

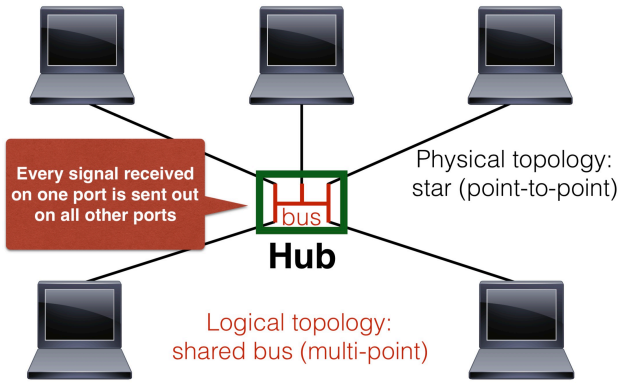


7.5 Data Link Layer

Ethernet MAC: CSMA/CD
Only one device sends a frame at a time

Carrier Sense (CS)	Only transmit when there is no other signal "sensed"
Multiple Access (MA)	Few devices share the same medium
Collision Detection (CD)	When other signal is detected: • Transmit jam signal as notification • Wait random time and re-transmit

Shared Bus Ethernet



Properties of Shared Bus

- One long cable, all devices connected to it
- All devices will receive the message transmitted (with destination address)
- Faulty device will affect the transmission

Half-duplex	Only one device can send a time
Broadcasting	All messages are sent to all devices
Limited network size	CSMA/CD limits size of network (collision domain)

Collision Domain: A set of devices connected to the same network, if two devices transmit simultaneously, frames collide

Switch Ethernet

Properties	• Looks like hub • Not a shared-bus but star • Message sent directly (not broadcasting) • Forwarding table stores the MAC address which the device is connected to a specific port
Function	1. Reads incoming frames 2. Checks MAC address 3. Send frame to correct port

Properties of Switch Ethernet

Full-duplex	Point-to-point connection (send messages directly), prevent collision
Buffer memory	Stores second frame until first frame transmission is done (Store and forward)

Difference between Shared Bus and Switch

	Physical Topology (how it looks)	Logical Topology (how it works)
Shared Bus	Shared	Shared
Hub	Star	Shared
Switch	Star	Star

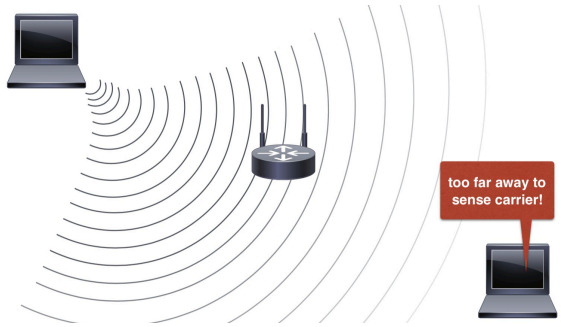
Wireless LANs

- WLAN NICs connect to Access Points (APs) using radio frequencies
- Higher frequency → higher transmission rate → higher attenuation
- 13 channels → each 22MHz wide & 5MHz apart
- APs are connected to wired LANs (or backbone)

WLAN MAC: CSMA/CA

Carrier Sense (CS)	Only transmit when there is no other signal "sensed"
Multiple Access (MA)	Few devices share the same medium
Collision Avoidance (CA)	Devices actively avoid collision

Hidden Node Problem



Solutions to Hidden Node

Automatic Repeat Request (ARQ) [Stop-and-wait ARQ]	• AP sends ACK after receiving a frame • Devices only send frame after receiving ACK for previous frame and wait for random time • Resends if ACK not received
Controlled Access	• Device "Request to Send" (RTS) • Only transmit when AP replies "Clear to Send" (CTS)

WLAN Topology
Basic Service Set (BSS)

	Independent	**Infrastructure**
Method	Talk directly	Connect & talk with one AP
Properties	Similar to original shared Ethernet but no hub	AP connects LAN (to gain internet)

Extended Service Set (ESS)

Method	Extends the range of mobility (roaming)
Properties	• Uses infrastructure BSS • APs communicate with each other to transmit traffic between BSSs

7.6 Network Layer

Properties

Function	Routing (mechanism for exchanging packets between LANs)
Protocol	Internet Protocol

IPv4

Properties	32-bits long
Subnet Mask	• Bits of IP addresses for network + subnet identifier • /24 → first 24 bits are the subnet including the bits for class

Network Classes

Class	Notation	Examples
A	/8	255.0.0.0 /8
B	/16	255.255.0.0 /16
C	/24	255.255.255.0 /24

IPv4 Bits Allocation
IP Address: 130.194.66.43 /22

Step 1: Identify the subnet mask
- Subnet mask is /22
- First 22 bits are network + subnet

Step 2: Subtract the highest class
- Highest class is class B, which is /16
- 22 – 16 = 6
- 16 bits for class, 6 bits for subnet

Step 3: Find hosts
- 32 – 16 – 6 = 10
- 10 bits for hosts

Step 4: Outcome

Dotted	130.194.66.43/22		
Levels	Network	Subnet	Hosts
Binary	10000010 11000011	01000010	00101011
Bits	16	6	10
Address	2^{16}	2^{6}	$2^{10} - 2$ Exclude: 00: network 11: broadcast

Subnets
- Each subnet corresponds to a single LAN
- Devices sending to a different subnet have to go through a gateway router
- These routers usually connected to a backbone network

IPv6

Properties	• 128-bits long • Prevent insufficient addresses

IPv6 Bits Allocation

IANA + RIR	ISP	Company	Subnet	Interface ID
23	9	16	16	64
/23	/32	/48	/64	/128

Address Resolution & DNS

AR Definition	Mapping of higher-layer address to lower-layer address
DNS Definition	Mapping of human-readable address to IP address
Types of DNS	
Iterative DNS	Host → ask root server → directs to TLD (Top Level Domain) → refers server IP
Recursive DNS	• Addresses are cached • Hosts request to perform the search in the server

Mapping IP Address to MAC Address
Step 1: Using Address Resolution Protocol (ARP). Device broadcasts ARP request packet to all devices

Step 2: Router will reply with its MAC address

Routing
- A layer 3 device
- Clients send packets to router if destination is not in their subnet
- Router use the IP address to send packets

Routing Table
- Packets look for its destination address
- Consults routing table
- If destination not in table, send to default gateway
- If no default gateway, packet can't be routed

Types of Routing

Static Routing	Fixed routing tables that are manually set
Dynamic Routing	Routers exchange information to form routing table

Dynamic Routing Algorithm

Type	Info Exchanged	Result
Distance Vector	Transmission distance	Shortest route
Link State	Transmission distance & quality of links	Fastest route

7.7 Transport Layer

Transmission Control Protocol (TCP)

Connection-oriented	• Virtual circuit between applications • Messages split into segments to transmit
Reliable	• Errors are detected & corrected • Segments reassembled in correct order
Examples (Application layer protocols)	• HTTP • SMTP • IMAP • SSH

TCP ARQ

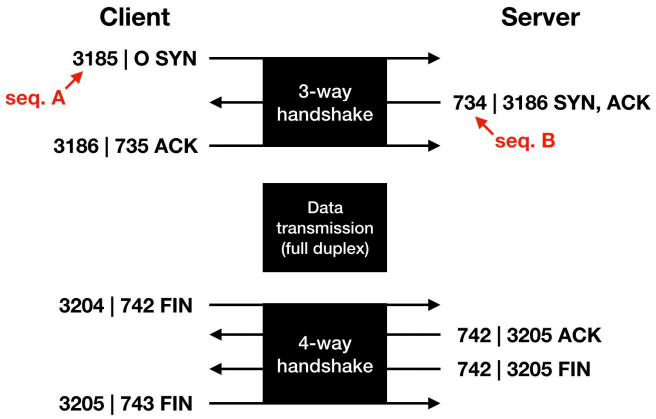
Goal: To ensure all packets arrived correctly

Numbers	Number of Bytes
Sequence (seq.)	Transmitted by A
Acknowledgement (ack.)	Received by B

Handshakes

	Three-way	Four-way
Function	Open connection	Close connection
Client sends	SYN (with seq. A)	FIN
Server replies	• SYN • ACK • Ack. A+1 • Seq. B	• ACK • FIN **can separate to get four steps**
Client sends	ACK (with seq. A+1 & ack. B+1)	FIN

TCP Session



TCP Parameters

Segment Size	1. Use "reasonable" MTU
	• Packets will be fragmented
	2. Use Path MTU Discovery
	• Routers send error message if packets too long • Increase packet length until error • Use last known error-free MTU
Transmission Speed	1. Send slowly
	• Send packets at slow rate • Wait for ACK • Increase packet size after each ACK • Fall back to slower speed if no ACK

** Maximum Transfer Unit : Transfer limit frames**

7.8 The Internet

Autonomous System

	Interior Routing	**Exterior Routing**
Packets Routing	Within AS	Between AS
Tools Used	• RIP • OSPF • EIGRP	Border Gateway Protocol (BGP)

Load Balancing

DNS-based	**Special Hardware**
Different location maps to different IPs	Load balancer accepts requests & routes them to different servers

Content Caching

Function	Duplicate frequently used web pages
Process	1. Use makes request 2. Route request to cache engine 3. If content exists, load from local cache
Supported By	• HTTP • HTTP headers: Expires : field • Cache only works for unexpired GET requests

Content Delivery Network (CDN)

- Improved version of Load Balancing
- Operate servers in multiple locations with high-speed network
- Servers usually closer to users' location