Computer Networks

Short notes for B.Tech CSE / IT · BCA · MCA · GATE CS

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1. Introduction

- **Computer network** = computers and devices connected to share data and resources.
- By size: **PAN** (few metres), **LAN** (building), **MAN** (city), **WAN** (country / world).
- Topologies: bus, star, ring, mesh, tree. Full mesh with n nodes needs $n(n-1)/2$ links.
- Transmission: simplex (one way), half duplex (both ways, one at a time), full duplex (both together).

➤ OSI vs TCP/IP

OSI layer	Job	Data unit	TCP/IP layer
7 Application	User services (HTTP, FTP)	Data	Application
6 Presentation	Encoding, encryption, compression	Data	Application
5 Session	Dialog control, sync	Data	Application
4 Transport	End-to-end delivery, ports	Segment	Transport
3 Network	Routing, logical (IP) address	Packet	Internet
2 Data link	Framing, MAC address, error control	Frame	Network access
1 Physical	Bits on the medium	Bit	Network access

REMEMBER "All People Seem To Need Data Processing" = layers 7 to 1.

Device	Layer
Hub, repeater	Physical
Switch, bridge	Data link
Router	Network
Gateway	All layers

2. Physical Layer and Delays

FORMULA Transmission delay $T_t = L / B$ (packet length / bandwidth). Propagation delay $T_p = d / v$ (distance / signal speed).

FORMULA Nyquist (noiseless): max bit rate $= 2 B \log_2 L$. Shannon (noisy): capacity $C = B \log_2(1 + SNR)$.

EXAMPLE $B = 3000$ Hz, SNR = 30 dB = 1000. $C = 3000 \times \log_2(1001) \approx 3000 \times 9.97 \approx 29.9$ kbps.

- SNR in dB $= 10 \log_{10}(SNR)$. So 30 dB means SNR = 1000.
- Switching: **circuit switching** (fixed path, phone), **packet switching** (datagram or virtual circuit).

3. Data Link Layer

➤ Framing and error detection

- Framing methods: character count, byte stuffing, bit stuffing (after five 1s, insert a 0).
- **Parity**: detects single-bit errors. **Checksum**: used in IP / TCP / UDP. **CRC**: strong, uses polynomial division.

EXAMPLE CRC. Data 1101, generator 1011 (degree 3). Append 3 zeros: 1101000. Divide (XOR): 1101 XOR 1011 = 110; bring down 0 → 1100 XOR 1011 = 111; bring down 0 → 1110 XOR 1011 = 101; bring down 0 → 1010 XOR 1011 = 001. Remainder = 001. Sent frame = 1101001.

- **Hamming code**: corrects 1-bit errors. Need r parity bits with $2^r >= m + r + 1$.
- Hamming distance d: detect up to $d - 1$ errors, correct up to $\lfloor (d - 1)/2 \rfloor$ errors.

Flow control (sliding window)

Protocol	Sender window	Receiver window	Note
Stop-and-Wait	1	1	Simple, low efficiency
Go-Back-N	2^k − 1	1	Resend all after the lost frame
Selective Repeat	2^(k−1)	2^(k−1)	Resend only the lost frame

- k = number of bits for the sequence number.

FORMULA Stop-and-Wait efficiency $\eta = 1 / (1 + 2a)$, where $a = Tp / Tt$. With window W: $\eta = \min(1, W / (1 + 2a))$.

EXAMPLE $Tt = 1$ ms, $Tp = 9.5$ ms. $a = 9.5$, $1 + 2a = 20$. Stop-and-Wait $\eta = 1/20 = 5\%$. Window needed for 100% = 20, so sequence bits = $\lceil \log_2 20 \rceil = 5$ (for GBN window 31 is allowed).

Medium Access Control

Protocol	Max efficiency
Pure ALOHA	18.4% (1/2e) at G = 0.5
Slotted ALOHA	36.8% (1/e) at G = 1
CSMA/CD	Used in classic Ethernet
CSMA/CA	Used in Wi-Fi (avoids collisions)

FORMULA CSMA/CD minimum frame size: $Tt >= 2\ Tp$, so $L >= 2 \times B \times Tp$. Classic Ethernet minimum frame = 64 bytes.

- **Ethernet** MAC address = 48 bits. **Token ring** avoids collisions by passing a token.

4. Network Layer: IP Addressing

- **IPv4** address = 32 bits, dotted decimal. **IPv6** = 128 bits, hex.

Class	First bits	Range of first octet	Default mask
A	0	0 – 127	255.0.0.0 (/8)
B	10	128 – 191	255.255.0.0 (/16)
C	110	192 – 223	255.255.255.0 (/24)
D	1110	224 – 239	Multicast
E	1111	240 – 255	Reserved

- Private ranges: 10.0.0.0/8, 172.16.0.0/12, 192.168.0.0/16. 127.x.x.x = loopback.

➤ Subnetting (CIDR)

FORMULA With /n prefix: host bits h = 32 − n. Total addresses = 2^h. Usable hosts = 2^h − 2 (network and broadcast addresses).

➤ Solved example

- IP 192.168.10.77 / 26.
- Host bits = 6, block size = 64. Subnets in the last octet: 0, 64, 128, 192.
- 77 falls in 64 – 127. Network = 192.168.10.64, broadcast = 192.168.10.127.
- Usable hosts = 2^6 − 2 = 62, from .65 to .126. Mask = 255.255.255.192.

➤ Other network layer topics

- **IPv4 header**: 20 to 60 bytes. TTL field stops packets looping forever.
- **Fragmentation**: fragment offset is in units of 8 bytes. Each fragment's data (except last) must be a multiple of 8.
- **ARP**: IP → MAC. **RARP / DHCP**: give IP to a host. **ICMP**: error and diagnostic messages (ping). **NAT**: private <→ public IP.

5. Routing

Distance Vector	Link State
Shares table with neighbours only	Floods link info to all routers
Uses Bellman–Ford	Uses Dijkstra
Slow convergence, count-to-infinity problem	Fast convergence
Example: RIP	Example: OSPF

- Fixes for count-to-infinity: split horizon, poison reverse.

- **BGP** = routing between autonomous systems (path vector).

6. Transport Layer

TCP	UDP
Connection-oriented	Connectionless
Reliable, ordered delivery	No guarantee
Flow and congestion control	None
Header 20 – 60 bytes	Header 8 bytes
HTTP, FTP, SMTP	DNS, DHCP, streaming, VoIP

- **Port number** = 16 bits. Socket = IP address + port.
- **3-way handshake**: SYN → SYN + ACK → ACK. Closing uses FIN and ACK (4 segments).
- SYN and FIN each use one sequence number.

➤ TCP congestion control

- **Slow start**: congestion window (cwnd) doubles each RTT until it reaches the threshold.
- **Congestion avoidance**: after threshold, cwnd grows by 1 MSS per RTT (additive increase).
- On timeout: threshold = cwnd / 2, cwnd = 1 MSS (TCP Tahoe). On 3 duplicate ACKs: fast retransmit and fast recovery (Reno).

EXAMPLE Threshold = 16 MSS, start cwnd = 1. cwnd per RTT: 1, 2, 4, 8, 16, 17, 18, ... After 4 RTTs cwnd reaches 16, then grows by 1.

FORMULA Max throughput of TCP = window size / RTT. Wrap-around time = 2^32 / bandwidth (bytes per second).

7. Application Layer

Protocol	Port	Transport	Job
HTTP	80	TCP	Web pages
HTTPS	443	TCP	Secure web
FTP	20 (data), 21 (control)	TCP	File transfer
SMTP	25	TCP	Send email
POP3	110	TCP	Download email
IMAP	143	TCP	Email kept on server
DNS	53	UDP (TCP for big replies)	Name → IP
DHCP	67 / 68	UDP	Gives IP automatically
Telnet / SSH	23 / 22	TCP	Remote login

- **DNS**: recursive and iterative resolution. Hierarchy: root → TLD (.com) → authoritative server.
- HTTP is stateless. Cookies keep state. HTTP/1.1 uses persistent connections.

8. Network Security (basics)

- **Symmetric key**: one shared key (AES, DES). **Asymmetric**: public and private keys (RSA).
- **Digital signature**: sign with sender's private key, verify with sender's public key.
- **Firewall**: filters traffic by rules. **VPN**: secure tunnel over a public network.

EXAMPLE RSA with $p = 3$, $q = 11$: $n = 33$, $\phi = 20$. Choose $e = 3$, then $d = 7$ ($3 \times 7 = 21 \equiv 1 \bmod 20$). Encrypt $M = 4$: $C = 4^3 \bmod 33 = 64 \bmod 33 = 31$.

9. Most Asked Questions (practice)

1. Explain OSI and TCP/IP models and compare them.
2. Find the CRC for given data and generator.
3. Compare Stop-and-Wait, Go-Back-N and Selective Repeat. Find efficiency.
4. Derive the efficiency of pure and slotted ALOHA.
5. Find network address, broadcast address and host range for a CIDR address.
6. Distance vector vs link state routing. What is count-to-infinity?

7. TCP vs UDP. Explain the 3-way handshake.
8. Explain TCP slow start and congestion avoidance with a graph.
9. How does DNS work? List common ports.
10. Explain Hamming code with an example.

TIP GATE CN numericals: subnetting, sliding window efficiency and sequence bits, CRC, TCP congestion window, and delay calculations. Keep units (bits vs bytes, ms vs µs) straight.