Communication Networks

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Comm. Net. Summary.

*LEC.(1):

IP ≡ Internet Protocol.

Def. of Comm. Net:

- Arrangement of Hardware & software that allows users to exchange information.
- A set of nodes that are interconnected to permit exchange of information.

Layers:
physical → Datalink → Network → transport → session → presentation → Application.

- point to point Networks → Advantages: perfect connectivity & reliability.
  → Disadvantages: Expensive & Low utilization.
  → for N nodes ⇒ $\frac{N(N-1)}{2}$ Links.
- Shared links → Advantages: Low cost & Higher Utilization.
  → Disadvantages: security, reliability, wait your turn & maintain comm. nodes & cost.

*Methods of sharing resources:

① ckt switching → Ex. PSTN, POTS

② msg switching → Ex. small number of Data Networks & Email gateways.

③ PKt switching → connection oriented vs connectionless, (Internet).
→ most popular.

④ Virtual ckt switching → Ex. { ATM ≡ Async. Transfer Mode. MPLS ≡ Multiprotocol label switching.

*CKt switching:

- only available option for analog, also works for digital.
- signal channel is reserved between src & dest.
- ch. can't be used by other during conversation.
- ch. can be one TDM or one FDM.

PCM stream ⇒ 64Kbps.

Max delay for voice: 500msec round trip.
or 300 msec round trip.

* Msg & PKt switching:

- segmentation: process of dividing msg into smaller chunks.
- Msg & PKt use concept of "statistical Multiplexing", "store & Forward".
  - ↳ higher utilization than TDM.

- PKt switching:
  - ↳ the path is shared.
  - ↳ 2-PKts can go through 2 different paths.
  - ↳ paths are NOT reserved (No dialing before sending traffic).
  - ↳ it has initial phase.

connection oriented; ex: TCP.   connectionless; ex: UDP.

* Dialing: Terminal nodes → comm. nodes → reserve path.
* session (connection) establishment: Terminal Nodes —(Tx → Rx)→ Terminal Nodes → initialization (Reset).

- for PKT & Msg:

$$\text{Total Time} = \text{Trans} + \text{Prop.} + \text{Queue.} + \text{proc.}$$

$$\text{Prop. Time} = \frac{\text{distance (Km)}}{C\ (\text{Km/s})}$$ for Both Msg & PKt.

$$\text{Trans} = (N+1)T$$ for Msg.

$$\text{Trans} = N\frac{T}{K} + T$$ for PKt.

where: $$T = \frac{\#\text{of bits}}{\text{DataRate}}$$

* Virtual switching:

- it is hybrid between cKt & PKt switching.
- resource reservation is done before sending traffic.

* Advantage: Easier to provide Q.O.S ⇒ guarantee avg. delay, Min BW, Max jitter
  - jitter: variation in delay.

* Disadvantages: Expensive & requires storing state info all across the Network.

* Advantages of CKt switching:

- Min. Time delay, it doesn't utilize store & forward (No queueing Time) also No Need for Processing Time (No PKt header).
- No overhead added to each PKt (header).
- No congestion since extra traffic blocked before entering the Network.

* in Telephony: → cKt switching: we call L.E & M.E.
  → PKt " : routers switches.

* Advantages of PKt switching:

- statistical multiplexing is more efficient than TDM.
- No Need for dialing stage before sending traffic.
- No Blocking of incoming traffic.
- since paths are Not reserved, No need to store Network-wide states (difficult & expensive)
- routers are much cheaper & consume less power compared to L.E & M.E.
- Multiple users sharing link can interleave their PKts & thus maintain cont. comm. concurrently.

these previous advantages for Both PKt & Msg vs cKt switching.

⇒ Now advantages of PKt vs Msg switching:

- PKt switching more efficient than Msg switching, since intermediate node do NOT waste time in storing & forwarding whole msg in seq, which reduces Time delay especially: N↑ ⇒ Time delay of PKt ↓.
- Bit error during transmission of on PKt, Not the whole msg.
- Probability of a single bit error in msg > probability of a single bit error in PKt.
- for multiple paths, some PKt can send through one path & other take anothe path which reduce congestion, provide redundancy & survivability.

※ Internet:

⇒ it is a wordwide collection of Networks.
starts by group of U.S universities & DOD = U.S Department of Defence
, DARPA = Advanced Research Project Agency.

reasons: ① Building a survivable Network & ② connect to expensive main frames.

in 1960's called (ARPANET) ⟶ Internet.

* How many people use internet? 3.8 billion.
* order of countries for using internet: ① Asia. ② Europe ③ latin America /the Caribbean.

* Type of growth for internet ⇒ Exponentially.

* order of Internet word penetration: ① North America (88.1%) ② Europe. ③ Australlia/oceania

* Top language in the internet:
① English. ② Chinese. ③ Spanish. ④ Arabic.

* Compare between Jordan & Qatar:

	Population	penetration
Jordan.	7.8 million.	80%.
Qatar.	2.3 million.	94.3%

※ LEC(2):

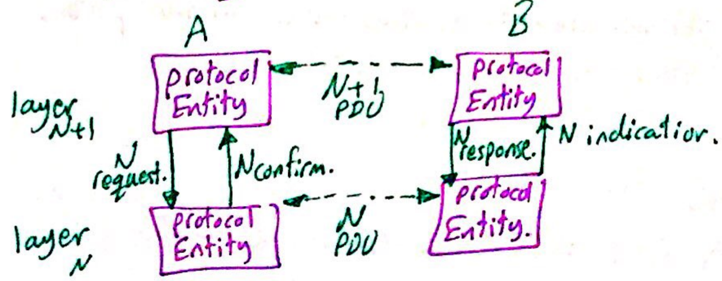
- Def. Protocol: set of rules specify format of msg & appropriate action for each msg.
- service script: it runs the protocol (execute).

* Main layered model: OSI ≡ Open Systems Interconnection Reference Model.
  ↳ developed by: ISO ≡ International Organization for standardization.

transport to transport (Segment)
Network to Network (PKt).
Data link to Data link (Frame).
phys. to phys. (Bit stream).

- seven layers called Protocol entity.

PDU ≡ Protocol Data Unit.



it is a full duplex process.
A → B
B → A.

FEC ≡ Forward Error Correction.

PHY. Layer1 ⇒ FEC
Layer 4 ⇒ ask for Re-transmission.

*OSI layers:

① Physical Layer:

Functions: • Mod. / De-mod. • coding / decoding.
• clock synch.

② Data link layer:

part of it, sublayer called: MAC ≡ Medium Access Control.
⇒ responsible for controlling access.

③ Network layer:

- it find the best path for PKt.
- deals with global address assignment.
- Control QOS.

⇒ 2-main architectures for deliver QOS guarantees in the internet:

① Diff. serv ≡ Differential Services → simpler / more popular.

② Int. serv. ≡ Integrated services. → complex / powerful.

↳ RSVP ≡ reservation Protocol.

④ Transport layer:

- handles dividing msg into smaller segments.
- uses ACKS ≡ AcKnowledgements.
- Responsible for: Retransmission, Numbering the trans. segments, Re-arrange out-of-order segments, flow Control & Congestion Control.

⑤ Session layer:

Ex. SIP ≡ Session Initiation Protocol. (for VoIP)
TCAP ≡ Transaction Capabilities Application Part → TCAP: part of SS7 signaling System #7.

Functions: • handle setup & management.
• Negotiating connection parameters.
• Authentication of users using passwards.

⑥ Presentation layer:

Functions:

- Handles formatting. Ex. ASCII ≡ American Standard Code for Info. Interchange.
  EBCDIC ≡ Extended Binary Coded Decimal Interchange Code.
- Handles Encyption & Compression.

⑦ Application layer:

Top of the Network, Ex. file transfer, Web browsing, VoIP & email.

※ Encapsulation (Headers):

- L1 header: clock sync. Info. ≡ preamble.
- L2 header: Framing delimiters, CRC.
- L3 header: src IP address, dest. address.
- L4 header: seq., ACK.
- L5 header: session ID.

※ TCP/IP stack:

stack ⇒ group of layers.

- L5 App.
- L4 Transport.
- L3 Internet. ⟶ as Network.
- L2 Network Interface. ⟶ as DATA Link.
- L1 phy.

※ Advantages of layered architecture for protocols:

① simple to design the Network since layers can be designed independantly.

② Compatibility, due to independancy. Ex. VoIP designed to run over Ethernet then used over WIFI.

③ Easier to upgrade software packages.

④ Possibility of multiple instances of a layer running @ the same time.

※ Standards & standardization:

① ITU-T: ⟶ physical Layer.

Ex. Dial-up modem {V.90, V.24.}   SDH ⇒ {G.707, G.708}

② IEEE: ⟶ Layer 2.

Institute of Electrical & Electronics Engineers.

Ex.
- Ethernet (IEEE 802.3)
- WiFi (IEEE 802.11)
- Bluetooth (IEEE 802.15)
- WiMAX (IEEE 802.16)
- Cognitive Radio (IEEE 802.22)

③ IETF: ⟶ layer 3&4. ⇒ Internet Engineering Task Force.

Ex. IPv4 (RFC 791) & TCP (RFC 793)   RFC ≡ Request For Comment.

※ LEC (3):

Wireless
Copper
Coax.
O.F & W.G.

(↓ more expensive & more BW.) (↑ more attenuation.)

*Fiber:
- use DWDM.
- Main Technique SDH/SONET.

*Satellite: contain transponders ⇒ receive signal from earth station, amplify it & retransmit to another station.

LEO → 1000 Km
MEO → 10,000 Km.
GEO → 36,000 Km.

Ex. GEO → Thuraya, Inmarsat & TV Broadcasting.
MEO → GPS, Glonass, Galileo, North & south satellites.
LEO → Iridium, Globalstar & Teledesic.

- GPS ≡ Global Positioning System.

*Network protection:
using SDH ≡ Synch. Digital Hierarchy. "Europe".
SONET ≡ Synch. Optical. NETWORK "U.S".

*FLAG: ≡ Fiber Link Across the Globe.
↳ parts in Middle East: FEA ≡ FLAG Europe-Asia.
FALCON ≡ Flag Alcatel-Lucent Optical Network

*FEA:
- 2 fiberpair → 1 wavelength / fiber pair → 10 Gbps / wavelength ⇒ 20 Gbps.
- 2 " " → 2 " " → 5 Gbps / " " ⇒ 20 Gbps.
- 2 " " → 4 " " → 10 Gbps / " " ⇒ 80 Gbps.

*FALCON:
- Initial Launch Capacity: 50 Gbps.
- MAX. design Capacity: 1.28 Tbps.

⇒ AEconnect: 40 Tbps.
MAREA: 160 Tbps.

※ Clock synch:

*Asynch.: Advantages: simple & inexpensive.
Disadvantages: work for short distance comm., Low data rate is possible.
, send short bursts (8-10 bits).

*Plesiochronous: Advantages: opposite to Asynch. disadvantages.
Disadvantages: complex & expensive.
(clock @ Tx. counter & PLL @ Rx.)

⇒ self-synchronizing codes: done in Plesiochronous using special bit-encoding that carry clock info with bit info.

⇒ Buffering @ High Data Rate: use PLL.

* Synch.: Tx clock & Rx clock & any other devices are controlled by main clock.

Ex. SDH / SONET.

Advantages: High data rate, min. buffering & flexible Multiplexing.
disadvantage: Expensive.

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* LEC(4):

* Internet access technologies: ⇒ most popular:
  - xDSL ≡ Digital Subscriber Line.
  - Fiber (FTTx) ≡ Fiber to the X.
  - Cable TV (CATV) Networks.
  - Cellular.
  - WiMAX.
  - PLC ≡ Power Line Communication.
  - leased lines.

* Broadband in different regions:
  - Highest population penetration: North America & Europe.
  - Highest Growth: East-Asia.

* Global Fixed Broadband subscribers by speed: [25-100] Mbps.

* Top Broadband Countries: ① China. ② U.S. ③ Japan.

* Global Fixed Broadband subscribers: (Fixed ≡ Not mobile / Not cellular / Not wireless).
  Cable: 20%. Copper (DSL): 40%. Fiber (FTT): 38%.

* Most popular fixed Broadband Internet access Tech. in:
  - Africa & Europe ⇒ Copper (DSL).
  - Asia ⇒ Fiber (FTT).
  - America ⇒ Cable.

* The fastest in Growth: (FTTH) ⇒ fiber to the home.

* 1Km of copper ⇒ BW = 1-2 MHZ.

* Dial-up Modems vs. XDSL Modems:
  - Advantages: No need for new infrastructure. (very low cost to ISP).
  - Disadvantages:
    ① Lower data rate, Because of Lower BW. ⇒ downstream 9.6 Kbps. 33.6 Kbps. 56 Kbps.
    ② Not Always on Internet Access.
    ③ You can't make a phone call & access the internet @ the same time.

* in L.E: Anti-aliasing LPF: $f_s = 8KHZ$, $B_{LPF} = 4KHZ$.

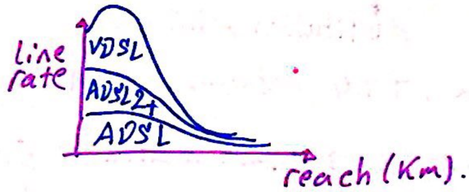
- In Europe: → L.E. , in U.S: → end office.
- In Europe: → M.E. or Tandem Exchange. , in U.S: → Central office or Toll office.

ISP ≡ Internet Service Provider.

* L.E → DSLAM → ISP , DSLAM ≡ DSL Access Multiplexer.

RADSL ≡ Rate Adaptive DSL.

- downstream (ISP → Home)
- upstream (Home → ISP)



Name	standard	Downstream	upstream
ADSL	ANSI T1.413	8 Mbps.	1 Mbps
ADSL2	ITU-T G.992.3 Annex J	12 Mbps	3.5 Mbps
ADSL2+M	ITU-T G.992.5 Annex M	24 Mbps	3.3 Mbps
VDSL	ITU-T G.993.1	55 M bps	3 Mbps
VDSL2-V+	ITU-T G.993.2	300 M bps	100 Mbps
G.fast	ITU-T G.9700 & G.9701	1 Gbps	100 Mbps

- Downstream ⇒ ADSL2: 1.1 MHZ. - - - → 2.2 MHZ.

BW of ADSL2: 12 MHZ, 30 MHZ.
BW of VDSL2: (8.5, 17.664, 30) MHZ.
BW of Gfast: 106 MHZ with 212 MHZ for future.

* G.fast:

distance	performance target
<100 m, FTTB	500-1000 Mbps
100 m	500 Mbps
200 m	200 Mbps
250 m	150 Mbps
500 m	100 Mbps.

*ADSL:
standard (Annex A)
it use DMT ≡ Discrete Multi Tone.

- ADSL divides local loop BW (~1.1 MHZ) into indep. channels of 4KHZ.

DMT: ① OFDMA ② QAM ③ Adaptive ④ DSP.

* Baud rate of each ch. : 4000 sym/sec.

* Channels:

- ch. 0 → Voice calls (POTS)
- ch. (1-5) → guard band.
- remain 250 ch's : → 32 ch's used for upstream data.
  → the rest used for downstream data.

* QAM in each ch. : 4000 sym/sec baudrate & max of 15 bits/sym.

* DSP in ADSL used for: create OFDM, peform error correction, echo cancellation & Equalization.

- ADSL2 & VDSL2 use FDD, G.fast use TDD.
  → symmetry ratios of 90/10 (U/D) upto 10/90 (U/D).

* FTTdp associated with G-fast, FTTN associated with VDSL2
  dp → distibution point. N → Neighborhood.

* FTTdp between FTTN & FTTH., distance 200-300 m.

- ADSL2 ⇒ DSIAM located @: 5Km.
- VDSL2 ⇒ DSLAM 〃 〃 : 1Km.

MDF ≡ Main Distribution Frame.

* FTTN: copper ≥ 300m * FTTC: copper ≤ 300m.

* FTTX Architectures:
  → VDSL2 or G.fast: used in FTTN, FTTC, some FTTB.
  → PON ≡ Passive Optical Network: used in FTTH, som FTTB.

- Advantages of passive splitters in PON: "low Cost"
  ① one leaser shared for 32 or 64 users. ② flexible splite Ratio.
  ③ No powersupply needed @ the intermediate node. (green cabine).

- Disadvantages of passive splitters in PON:
  ① Security (solved by encryption) ② BW is shared.

* standards:
  OLT ≡ optical Line Terminal → located in L.E.
  ONT ≡ optical Network Terminal → 〃 〃 green cabinet.

* Main standards for PON:

Name	standard	Max split ratio	D.S capacity	U.S capacity	Layer2 encapsulation
BPON	ITU-T G.983	1:32	1.25 Gbps	622Mbps.	ATM
GPON	ITU-T G.984	1:64	2.5 Gbps	1.25Gbps.	ATM & Ethernet.
10GPON	ITU-T G.987	1:128	10 Gbps	2.5Gbps.	Ethernet
EPON	IEEE 8023ah	1:32	1.25 Gbps	1.25Gbps	Ethernet
10G-EPON	IEEE 802.3 av.	1:64	10 Gbps.	1.25Gbps.	Ethernet.

Note: you can find capacity for each user: ex. $\frac{1.25 Gbps}{32} \simeq 40 Mbps$.

* HFC ≡ Hyprid Fiber Coax.

* Headend or optical node: CMTS ≡ Cable Modem Termination System.

* Home: CM ≡ Cable Modem.

* Coax. BW:

Upstream ≃ (5-40) MHZ.
TV ≃ (50-80) MHZ.
FM ≃ (80-100) MHZ.
TV ≃ (100-550) MHZ.
downstream (550-750) MHZ.

* DOCSIS: "Data Over Cable Service Interface Specifications".

Name	standard	6MHZ ch. D.S	6MHZ ch. U.S	8MHZ ch. D.S	8MHZ ch. U.S
DOCSIS 1.1	J.112 AnnexB	40Mbps	10 Mbps	D.S of 6MHZ * 8/6	Same as 6MHZ ch. U.S
DOCSIS 2.0	J.122	40Mbps	30Mbps		
DOCSIS 3.0	J.222	340Mbps	120Mbps		
DOCSIS 3.1	2017.	10 Gbps.	10 Gbps		

* BWA: "Broadband Wireless Access"

↳ IEEE 802.16 or WiMAX. → most popular.

↳ it use WiMAX SS (subscriber station) instead of CM & WiMAX BS (Base station) instead of CMTS.

* LOS ≡ Line of Sight.

Wifi ⇒ LAN ≡ Local Area Network.
WiMAX ⇒ MAN ≡ Metropolitan Area Network.

- advantages WiMAX vs. Fiber: No need to dig the ground
- Disadvantages WiMAX vs. Fiber: Need High Power & very high Att. under bad weather.

* IEEE 802.16 standards (WiMAX):

- IEEE 802.16a-2003: 10 GHZ–60 GHZ, Max range 50Km, 6 MHZ ch's. 42Mbps (D.S) & 10Mbps (U.S) for each ch.
- IEEE 802.16e-2005: No LOS @ 3.5GHZ or lower, 5MHZ for each ch. per ch. Uplink/Downlink = 70Mbps/70Mbps.
- IEEE 802.16m-2011: Data rate 100Mbps mobile & 1Gbps fixed.
- IEEE 802.16-2012: Rollup of 802.16h, 802.16j & 802.16m

*MDU ≡ Multi-point Distribution Unit.

* PLC standards:

- → HD-PLC : High Definition, led by Panasonic.
- → HomePlug : Home Plug Power line Alliance
  - → HomePlug 1.0 (14Mbps).
  - → Home plug AV (200Mbps).
  - → Home Plug AV2 (1Gbps & 1.3Gbps)
- → IEEE 1901 : support both HD-PLC & HomePlug.
- → ITU-T G.hn / G.9960 : 1Gbps.

* PDH :

- European standard: (A-low)

carrier	Multiplex.	Data Rate	MUX level
E0	1 ch. (voice)	64 Kbps	—
E1	30 speech + 1 framing + 1 signaling ch's.	2 Mbps	1st level
E2	$E_1 \times 4$ + framing	8 Mbps	2nd 〃
E3	$E_2 \times 4$ + 〃	≃32 Mbps	3rd 〃
E4	$E_3 \times 4$ + 〃	≃140 Mbps	4th 〃
E5	$E_4 \times 4$ + 〃	≃560 Mbps	5th 〃.

- U.S standard: (M-low)

Carrier	Multiplex.	Data Rate	MUX level
T0	1 ch (voice).	64 Kbps	
T1	24 x PCM + framing	1.5 Mbps	1st level
T2	$T_1 \times 4$ + 〃	≃6 Mbps	2nd 〃
T3	$T_2 \times 7$ + 〃	≃42 Mbps	3rd 〃
T4	$T_3 \times 6$ + 〃	≃270 Mbps.	4th 〃

* SDH & SONET:

- European standard:

optical carrier	Multiplex	Data rate.
STM-1	Basic	≃155 Mbps.
STM-4	4 x STM-1	↳ x4
STM-16	4 x STM-4	↳ x4
STM-64	4 x STM-16	↳ x4
STM-256	4 x STM-64	↳ x4
STM-1024	4 x STM-256	↳ x4

- U.S standard:

optical carrier	Electrical carrier	Multiplex	Data Rate
OC-1	STS-1	Basic	≃50 Mbps.
OC-3	STS-3	3 x OC-1	↳ x3
OC-12	STS-12	4 x OC-3	↳ x4
OC-48	STS-48	4 x OC-12	↳ x4
OC-192	STS-192	4 x OC-48	↳ x4
OC-768	STS-768	4 x OC-192	↳ x4
OC-3072	STS-3072	4 x OC-768	↳ x4

* STM-n ≡ Sync. Transport Module - level n
- SDH is an ITU-T std (G.707, G.708, G.709).
* STS-n ≡ sync. Transport Signal - level n.
* OC-n ≡ optical Carrier - level n.

SDH/SONET vs PDH:
↳ simpler & High data rates & flexible multiplexing.

* Cellular Telephony:

standard		Name (Tech.)	D.S rate	U.S rate
2.5G	GPRS	General Packet Radio Service (TDMA)	54 Kbps.	27 Kbps.
3G	UMTS	Universal Mobile Telecomm. System (CDMA)	384 Kbps	128 Kbps.
	HSPA	High Speed PKt Access (OFDMA)	7.2 Mbps	3.6 Mbps.
3.75G or 3.5G	HSPA+Rel.6	Evolved High speed PKt Access Release 6 (OFDMA + MIMO)	14.4 Mbps	5.76 Mbps.
	HSPA+Rel 9	" " " " " " 9 (")	84.4 Mbps.	11.5 Mbps.
	LTE	Long Term Evolution (OFDMA + MIMO).	100 Mbps	50 Mbps.
4G	LTE Advanced	" " " Advanced (")	1 G bps.	500 M bps.

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Abbreviations

* All abbreviations in Second Material provided as follows:

- HDLC ≡ High-Level Data Link Control.
- PPP ≡ Point to Point Protocol.
- FCS ≡ Frame Check Sequance.
- DLE ≡ Data Link Escape.
- CRC ≡ Cyclic Redundancy Check.
- FDDI ≡ Fiber Distributed Data Interface.
- LAN ≡ Local Area Network.
- WAN ≡ Wide Area Network.
- NFC ≡ Near Field Communications.
- MAN ≡ Metropolitan Area Network.
- PAN ≡ Personal Area Network.
- UWB ≡ Ultra Wide Band.
- DEC ≡ Digital Equipment Co-operation.
- LLC ≡ Logical Link Control.
- CSMA/CD ≡ Carrier Sense Multiple Access with Collision Detection.
- LBT ≡ Listen Before Talk.
- CRA ≡ Contention Resolution Algorithm.
- LAA ≡ Locally Administered Address.
- NIC ≡ Network Interface Controller.
- OUI ≡ Organisationally Unique Identifier.
- SOF ≡ Start Of Frame.
- MTU ≡ MAX. Transfer Unit.
- MDIX ≡ Media-Dependent Interface Crossed.
- THP ≡ Tomlinson Harashima Precoded.
- LDPC ≡ Low Density Parity Check.

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Comm. Net
Summary

※ LEC. (5):

* PDU of L3 ⇒ Packet. * PDU of L2 ⇒ Frame

* Main jobs of L2:
  - framing: identifying the start & the end of each frame.
  - Error checking & sometimes correction.
  - Coordinate access: to shared medium (MAC).

* Bit-Oriented vs. Byte-Oriented:
  - Bit-Oriented → Ex. HDLC Protocol.
  - Byte-Oriented → Ex. PPP.

※ Job 1 (framing):

① insert time gaps of N transmission periods between frames.
- Ex. Async. Tx. in RS-232 & Ethernet.
- Advantage: Easiest Method.
- Disadvantages: Low Utilization (BW wasted) & Unreliable for long distances.

② Character Count.
- other names: Frame length / Byte Count.
- Used mainly in Byte-Oriented.
- Advantage: High Utilization.
- Disadvantage: frame Slip. (difficult to recover after frame slip).

③ Frame Delimiters.
- Used in Bit Oriented & Byte oriented. Ex. Ethernet.
- Advantage: Difficult to have a frame slip & easy to recover after frame slip.
- Form:

Flag	address	Control	Data	FCS	Flag
8	8	8	≥0	16	8 Bits.
Header			payload.	Trailer.	

* Bit stuffing:

⇒ used in Bit-oriented.

To prevent flags occurring in middle of a frame.

- ↳ Tx: adds 0 after five ones.
- ↳ Rx: perform destuffing By replacing (111110) By (11111).

* Byte Stuffing:

⇒ Byte Oriented.

for each FLAG or DLE we want to Keep, just add DLE before it so that Rx remove the added DLE & Keep the one you need.

- Advantage: difficult to have frame slip & easy to recover after frame slip.
- Disadvantage: using alot of DLE ⇒ LOW Utilization ⇒ LOW efficiency.

※ Job2 (Error Detection & Correction):

① → **Parity**: add 1 or 0 after the msg to indicate even parity (even # of 1's) or odd parity (odd # of 1's).

- Advantage: Simple.
- Disadvantage: weak detection especially for a burst of errors.

Ex. on using Parity: RS-232.

② → **CheckSums**: if both checkSums of Tx & Rx are matched then No errors.

- advantage: more powerful than parity.
- checkSums used in → TCP header ⇒ L4.
  ↳ IP header ⇒ L3

③ → **CRC**: ⇒ G ≡ generating polynomial, Msg (M). ⇒ M/G, remainder ≡ CRC

↳ Msg CRC/G → if remainder 0 (No error).
↳ if Not (error occur).

- Advantage: most powerful due to:
  1) CRC can be implemented in Hardware using shift register & XOR gates ⇒ fast & inexpensive.
  2) CRC can detect Burst errors.
  3) used in HDLC & PPP & Ethernet.

- CRC ⇒ 4-bit
- CRC (16-bit) ⇒ 17G
- CRC (32-bit) ⇒ 33G
- G ⇒ 5 bit.

Ex. $G = 10011 \equiv x^4 + x^1 + 1$
↳ for feedback.

- Number of XOR's = Number of ones in G without feedback.

G = 10011 → 2 XOR's.
G = 10111 → 3 XOR's.
G = 10001 → 1 XOR.

※ LEC.(6):

* Network Types:

1. → LAN: single Building or campus. Ex. Ethernet, IBM Token Ring, FDDI & IEEE 802.11 WiFi.
2. → MAN: city or part of a city. Ex. IEEE 802.16 WiMAX.
3. → WAN: Large geographical area (country or Continent). Ex. ATM & Frame Relay.
4. → PAN: single room & connect personal devices. Ex. Bluetooth, NFC & UWB.

* LAN Network Topologies: Bus, Star, Ring:

⇒ each LAN utilizes single High BW shared medium (cable), to which many computers are attached (reduces cost & increase utilization).

⇒ Different computers take turns (coordinate) among each other to send frames on the shared medium. Handled By MAC sublayer. (L2).

- Ex. on Ring Topology: IBM Token Ring.
- Note: SDH/SONET is cct switching NOT LAN.
- Ethernet: Was: Bus. Topology., New: star topology. • ALOHA: Bus.
- WiFi: popular: star (infrastructure Mode), Available: Bus (ad hoc).

* Ethernet & ALOHA:

- ALOHA was the first LAN created. • Ethernet inspired by the ALOHA.
- Data rate of ALOHA when it was created: 9.6 Kbps, used shared wireless medium.

※ Ethernet:

- it is widely used LAN, it also being expanded into MAN & WAN.
- Invented: @ Xerox Palo Alto Research center.
- Operation Rate: 10 Mbps, was called DIX Ethernet (DEC, Intel & Xerox).
- it use coaxial cable called Ether ⇒ originally., Later versions used UTP cables with → hubs ⇒ Bus Topology.
  → & switches ⇒ star Topology.
- Another Version FAST Ethernet ⇒ 100 Mbps & very popular.
- Next version Gigabit Ethernet (GigE or GbE) ⇒ 1 Gbps.
- Next version (10 GigE or 10 GbE) ⇒ 10 Gbps.

- standard in IEEE for Ethernet IEEE 802.3.
- Higher data rate mostly use optical fiber.

IEEE 802.3bm → 100G/40G ethernet for optical fiber.
IEEE 802.3bs → 200Gbps over single mode fiber, 400Gbps over optical physical media.
IEEE 802.3av → 10G-EPON.

* Ethernet over SDH (EoSDH or EoS), Ethernet over SONET.
* Ethernet classified under L2 protocol.
* Hub: acts like zero length coaxial cable.

* Ethernet MAC protocol known as CSMA/CD. * interframe gap time $= 9.6 \mu s$.

- if a collision is detected, Then station stop transmitting immediatly.
- Note: Wifi ⇒ CSMA/CA → Avoidance.

* Jamming Signal: once a collision is detected 32 to 48 randomly chosen bits sent.
* Delay Calculated from CRA.

* CRC used in CSMA/CD is Binary Exponential Backoff Algorithm.

we choose K from the set $\{0, 1, 2, \dots, (2^m - 1)\}$, $n < 16$
station must wait for K x 512 bit time (one bit time $= \frac{1}{10M} = 10^{-7}$ sec).

* Time needed to detect a collision after starting to transmit
⇒ called Max. Collision Detection Time $\equiv 2\tau$.
τ = Max. end to end PROP. delay $= \frac{dist.}{speed}$.

in Ethernet: 

⇒ Max end-to-end PROP. Time = 225 bit time.

* Min. frame Length in Ethernet = 512 bits = 64 Bytes.
* Max. " " " " = 1500 Bytes + 18 Bytes (Header & Trailer) = 1518 Bytes.
* Max. Collision Detection Time $= 2\tau = 2$ PROP. $= 2 * 225 = 450$ Bit Time.
* Max. Collision & Clearing of the channel. $= 2\tau +$ JAM $= 450 + 48 = 498 \simeq 512$ Bit Time.

※ Types of Persistance:
- → 1-persistent.
- → P- persistent.
- → Non-persistent.

• which Type doesn't continue listening until the channel is idle? Non-persistent.
⇒ rather it waits a Random amount of time & then re-sense again.

※ Performance Parameters vs. Load:

① Throughput (S): # of successful bits sent in a period of time / that time period.

② Delay (D): Time Period needed for the frame to reach its dest. successfully. (we calculate usually Average Delay).

③ Utilization (U): proportion of the channel time, used by traffic which arrives at it.
⇒ Percentage of Busy slots.

④ Frame Drop Probability (P): proportion of Total frames Sent by the src that are not received By the dest..

* Load ≡ L ≡ G ≡ Total Attempts.

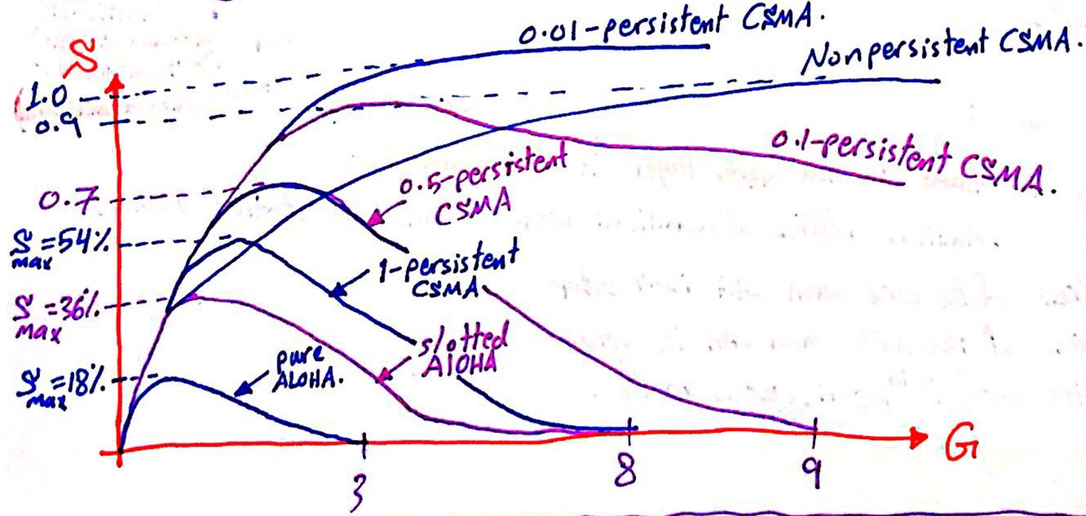
* sent M frames
received M-2 frames
⇒ $P = 2/M$

* for delay: find $delay_{frame1}$, $delay_{frame2}$, ...
using Delay = PROP + TRANS + QUEUE + PROC.
Then add them ÷ N. (find average).

* We need S↑, U_{max} = 100%. U↑, D↓, P↓.
if P↓ ⇒ prob. of collision ↓

S↑ Good   D↑ Bad   U↑ Bad.

※ Throughput for ALOHA & CSMA:



※ LEC. (7):

* Typically Communications involve ⇒ one source & one destination.
  ⇒ MAC Addresses allow a frame to reach its destination.

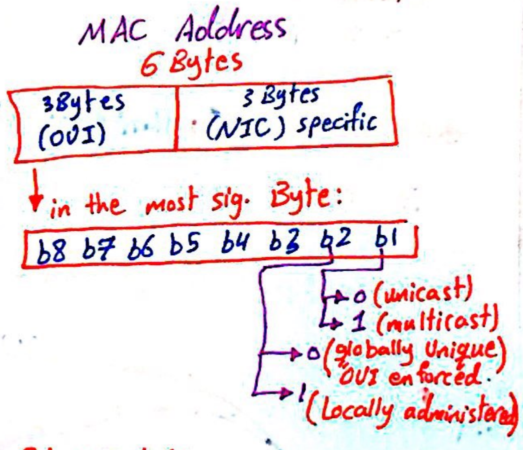
* Ethernet uses 48 Bit ≡ 6 Bytes MAC address / Phy. address / Hardware address.

* Types of Ethernet MAC addresses:
  - Unicast Address
    - → Global Address (static Address)
    - → Local Address (configurable address) "LAA"
  - Multicast Address
  - Broadcast Address

  Multicast Address and Broadcast Address } Group Address.

* Group Address:
  - LSB of the dest. address is 1.
  - Used when one source sends one frame that needs to be read by multiple dest.
  - Broadcast address: FF-FF-FF-FF-FF-FF
  - Multicast address: other addresses with LSB of 1.

* Unicast Address:
  - LSB of the dest. address is 0.



* Note: MAC has to be Unique Locally.

* How many global unicast MAC addresses Available?

  2^{46} addresses.

* Rules of reading frames:

ethernet card passes the frame to the upper layer if DA equal to:
- Broadcast address.
- Multicast address of a multicast group to which the station belongs.
- Global unicast address of the card when LAA isn't setup.
- LAA unicast address of the card when LAA is setup.
- Any address if the card is in promiscuous mode.

* Ethernet Headers & Frame Format: (Type II vs. IEEE 802.3)

• Type II:

6+6+2 (Header), +0 (Pad), +4 (CRC) = 18 headers.

Bytes:	7	1	6	6	2	0-1500	0-46	4
	preamble	SOF	DA	SA	Type	Data	Pad	CRC

- preamble, SOF → phy. Layer.
- DA, SA, Type → Header.
- Data → L3 PDU packet (payload).
- Pad, CRC → Trailer.

• IEEE 802.3:
format is the same as Type II, just replace "Type" with "Length".

* Data never starts @ 0.
* Pad never reaches 46.

Data ⇒ | LLC header | L3 data |

Ex. Length = 8 ⇒ means length NOT type (≤1500) → 8 bytes LLC header. → 0 Bytes L3 PDU.

Ex. length = 1500 → 8 LLC → 1492 L3 PDU. ⇒ This is IEEE 802.3.

Ex. Length = 0800h = 2048 decimal ⇒ Type : IPV4.

* SOF: one Byte with the bit pattern 10101011
* preamble: 7-Bytes each Byte containing bit pattern 10101010
* L2 → MAC ⇒ for sharing. → LLC ⇒ for demultiplexing & decide where to send.

MAC header	LLC header	L3 PDU PKt.

$MTU_{802.3}$ = 1492 Bytes. $MTU_{Type II}$ = 1500 Bytes.

protocol	Type field.
IPv4 PKt	0800h.
IPv6 PKt	86DD

⇒ All type values > 05DCh. = 1500 decimal.

* LLC header is 8-Bytes (defined in 802.2) → 3 AA-AA-03 → 3 xx xx xx → 2 Type.

* CRC: 32-bit error detection.

※ LEC. (8):

* Ethernet Hub:

- used connecter: RJ-45 connecter.
- Look Like star Topology (Phy. Topology), But Behave as Bus Topology (Logical Topology).

* Manchester ⇒ 10Base-T , MLT-3 ⇒ 100 Base - TX. (100 → 100Mbps, Base → Baseband, T → twisted pair)

* Twisted pair 10Base-T, 100 Base-TX, 1000Base-T.
* Fiber optics: 10 Base-F, 100 Base-FX, 1000Base-LX.
* Wiring Closet:
  - → Yellow ⇒ single mode fibers.
  - → Orange & Blue ⇒ multi-mode fibers → 50/125 μm OM2, 50/125 μm OM3
  - → Grey ⇒ twisted pairs.

* Each machine connected to the hub through: UTP or optical fiber.
* Hub does NOT buffer incoming frames. Instead if a voltage appears on one ports the hub retransmits the same voltage on all other ports.
  ⇒ Hence the hub acts like zero-length shared Bus.

* Coax → phy.: Bus. → Logical: Bus. * Hub → phy.: Star. → Logical: Bus.

- Etherne Hub → old name Repeater. • switch → old name Bridge.

- Hub ≡ repeater ≡ regenerator ≡ L1 device ≠ switch.

* Max. Run Length (cable run) between Hub & PC: 100 m (due to Noise & Att.).
* Max. Dist. Between any 2 PC's 2.5 Km, when fiber used for Longer runs.

※ Non-switched (Hub-based) Ethernet Limitations:

1. Half duplex Transmission (collissons) } ⇒ solved by buffers.
2. MAC protocol considerations. }
3. Single strength considerations. ⇒ solved by fiber.
4. Heavy Load affects throughput.
5. Broadcast storms are possible.

※ The Ethernet switch:

- switch buffers any frame it receives on one of its ports into its memory (RAM)
  ⇒ send the frame on High speed backplane (switching fabric).
- Each port has its own collision domain.
- sometimes switch connected to the PC through 2-pairs of twisted wires (4 wires)
  ⇒ full-duplex.
  Ex. full duplex 100Mbps. ⇒ 200Mbps Link speed instead of 100Mbps.
- switch used to connect LAN segments or interface between 2 different technologies, ex. ethernet & WiFi.
- Bridge ≡ Switch ≡ L2 Device ≠ hub ≠ Router.
- switch splits collision domain.
- Cost of Low-end switches 10$ - 100$
  & Medium-end " 300$ - 1000$
  & High-end " 2000$ - 60000$
  ↳ Ex. Cisco Catalyst 3500 series, HPE, Juniper EX series
  " " 6500 " , Huawei, Arista.

※ LEC (9):

*Ethernet Switch Features: ① Self-learning (Backwards-Learning)
② Spanning Tree Protocol (STP) → IEEE 802.1D
③ Virtual LAN (VLAN) → IEEE 802.1Q

- Flooding: when a frame arrives @ one port of a switch, the switch forwards that frame for all other ports. (But it wastes resources).

* The port of the switch doesn't has a MAC address, An exception is if there is a controller in the switch, then this controller will has MAC address.

- Forwarding: The switch forwards the frame to only one port where the M/C is connected.
  ↳ advantages: reduce # of PKts processed by each switch port & enhances privacy.

[1] Self-learning (Backward-learning) switches:

* Problem: How the switch Know the MAC address of each M/C?
By Table LooKup of MAC addresses connected to each of the switch ports.
↳ Time consuming, Error prone, Moving station from one LNA to another requires maintenance of the tables.

[2] STP : * This feature avoids loops.
* in the tree you always have a path.

[3] VLAN:
. ethernet LAN:
the same broadcast domain cover all the hosts, when host received a broadcast results that same host transmitting a broadcast of its own, this will lead to all broadcasts snow ball into a broadcast storm.

⇒ using VLAN isolate broadcast domains, By splitting an Ethernet switch into multiple virtual switches.
⇒ which reduces overall traffic, avoids broadcast storms, improve security by isolating traffic & improves privacy.

* All done by Software.

* No inter-VLAN traffic on the switch unless router(L3 device) is involved.

** Approaches to assign VLAN membership:
- Static VLANs:
  assign port on a switch to a VLAN, automatically the device assume the VLAN of the port.
- Dynamic VLANs:
  Created through Software package (VLAN Management Policy Server) here the administrator assigns VLAN dynamically based on information like source MAC address of the device connected to the port or username used to log onto that device.

※ LEC (10):

* Classical Ethernet: (10Mbps)
  - 10 Base-5 thick coaxial. (500m segment length)
  - 10 Base-2 thin coaxial. (200m " ").
  - 10 Base-T Twisted Pair.

. classical Ethernet used Manchester Encoding:
  - advantage: self clocking.
  - disadvantage: $BW = 2f_0 = 20MHz$.

. Fast Ethernet (100M bps) & Giga Ethernet (1000M bps) DO NOT use Manchester.
⇒ required BW = 200MHZ, 2000 MHZ.

※ Fast Ethernet:
. Fast Ethernet use: MLT-3., Fast Ethernet standardized as IEEE 802.3u.
. Fast Ethernet & Classical are Backward Compatible (same 48bit MAC address & same CSMA/CD rules.
⇒ Main difference: bit time reduced from 100ns to 10ns.

- In Fast Ethernet: coaxial Not used (only twisted pairs & O.F).
  Half duplex & full duplex are possible

↳ Half duplex (with hubs) & full duplex (with switches)

Half duplex → has collisions (Enable CSMA/CD)

Full duplex → No collisions (Disable CSMA/CD)

CAT7
CAT6
CAT5
CAT3

↑ Better, But more expensive

Name	Cable	Max. segment	comments
100 Base-TX	UTP (CAT5)	100m	Half duplex or full duplex
100 Base-FX	F.O	2Km	only Full duplex (Long runs)

Max. segment ↳ dist. from hub/switch to the M/C.

- CAT5: has 4 pairs (8 wires) of copper
  each pair carry 125MHZ BW.
  Manchester Not use here ($BW = 2f_0 = 200MHZ$); we use 4B/5B followed by MLT-3 Line encoding: ($BW = 0.9 f_0 = 0.9 \times \frac{5}{4} \times 100M = 112.5MHZ$)

* To create CAT5 Cable (straight-through or crossover) we need → RJ45 crimper. → CAT-5 Tester.

* Ethernet Cable can be
- → straight-through (or patch) cable.
- → crossover cable.
- → Up Link port (Tx on 1 & 2) ⇒ called WAN port.
- → Normal port (Tx on 3 & 6) ⇒ called LAN port.

uplink		Normal	
Tx^+	①	①	Rx^+
Tx^-	②	②	Rx^-
Rx^+	③	③	Tx^+
Rx^-	⑥	⑥	Tx^-

rest of the pins Not used.

PC (uplink) ⟵ Hub/switch (Normal). "straight-Through" or Patch

PC (uplink) — PC (uplink) "crossover"

*Ethernet Ports:
- PC/laptop → Uplink port.
- Modem ADSL, cable, etc → Normal port.
- Ethernet core → Normal port
- switch → uplink port & Normal ports.
- Hub → Normal ports.
- aggregation switch → Normal port.

- Straight-Through:

wire	Becomes
1 →	1
2 →	2
3 →	3
6 →	6

pin#	wire color
1	orange/white.
2	orange
3	green/white.
4	blue.
5	blue/white.
6	green.
7	brown/white.
8	brown.

- crossed over:

wire	Becomes
1 →	3
2 →	6
3 →	1
6 →	2

pin#	wire color
1	green/white
2	green
3	orange/white.
4	blue.
5	blue/white
6	orange
7	Brown/white
8	Brown.

*Advance Switch Ports:

- Auto-Sensing: Automatically sense (negotiate) data rate (100 or 1000 Mbps etc)
- Auto-Configure: Automatically negotiate duplexity (half or full) using short circuit in the port called "Loop back".
- Auto-UplinK: Automatically adjust the port (Normal or uplink port) using built-in analog switches "called Auto-MDIX"

※ Gigabit Ethernet:

- it was standardized as IEEE 802.3Z.
- backward compitable with other Ethernet Standards.
- 1000 Base-T is IEEE 802.3ab

Name	Cable	Max. segment	comments
1000 Base-T	UTP	100m	Deployed CAT5e or CAT 6 UTP.
1000 Base-SX	O.F	550m	Multimode fiber.
1000 Base-LX	O.F	5Km.	Single or Multimode fiber
1000 Base-LH	O.F	10Km.	single mode fiber.

* 1000 Base-T Encoding:

- Uses 8B1Q4: 8 bit to 1 four quinary "five" symbol combined with 4D-PAM5: Four dimensional Pulse Amplitude Modulation 5 levels.

Ex. using 8B1Q4: (10)(11)(10)(01)

2bit 2bit 2bit 2bit

convert into 3bit for FEC ↓

101 111 100 010 → called quinary symbol.

using 4D-PAM5 → line encoding ⇒ each symbol mapped into one of five possible voltage levels.

⇒ data bits rate = 8 * 125 M symbol.

Total bits rate = 12 * 125 M symbol.

※ 10 Gigabit Ethernet:

- LAN PHY.:

Name	Max. seg.	comments
10GBase-SR	26m-82m	short Range over deployed multimode fiber
10GBase-LR	10Km	Long Range over single mode fiber (1310nm)
10GBase-ER	40Km-80Km	Extended " " " " " (1550nm)

- WAN PHY.: (SDH/SONET)

Name	Max. seg.	comments
10G Base-SW	26m-82m	short Range over deployed multimode fiber.
10G Base-LW	10Km	Long Range over single mode fiber (1310nm)
10G Base-EW	40Km-80Km	Extended " " " " " (1550nm)

* 10GBASE-T:

⇒ IEEE 802.3an.

- 10Gbps over UTP or STP cables over distances up to 100m.
- use CAT-6A (or CAT-7) cable, or 55m with older CAT-6 cables.
- Encoding: THP version of PAM with 16 discrete levels (PAM-16) as DSQ128 (Double Square128)
- Powerful LDPC Linear error correcting code
- IEEE 802.3bm ⇒ 100G/40G Ethernet for O.F.
- IEEE 802.3bs ⇒
  - → 200Gbps over single mode fiber.
  - → 400Gbps over optical physical media.

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※ LEC(11):