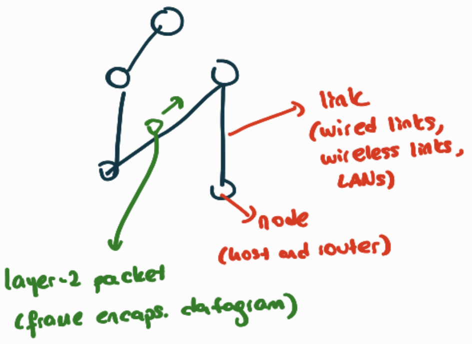
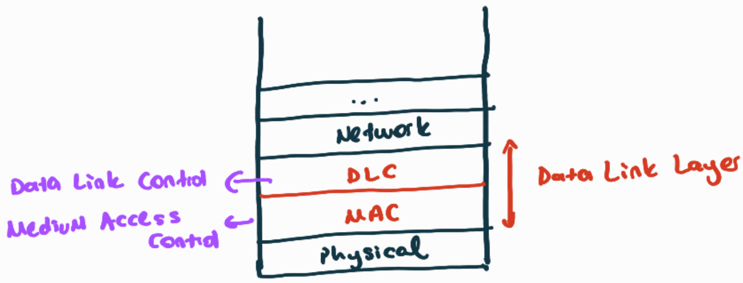
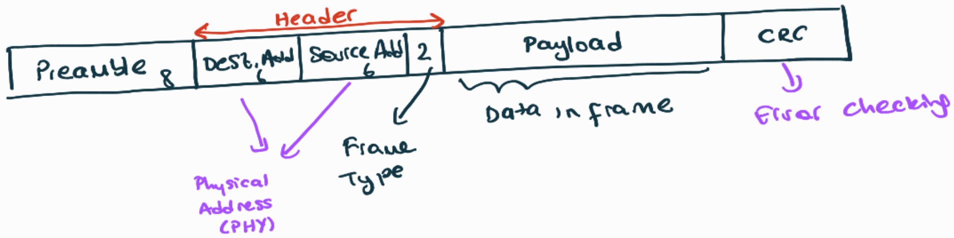
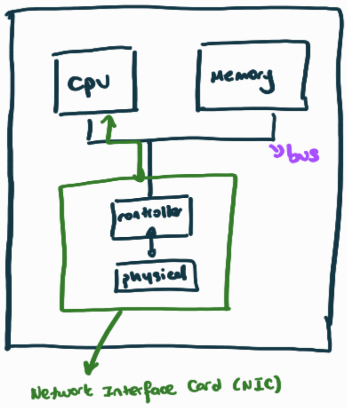
DATA LINK





Frames and Packets





IP Addresses ≠ Physical Address (MAC)

IP Addresses ↓ global identification
Network Layer address

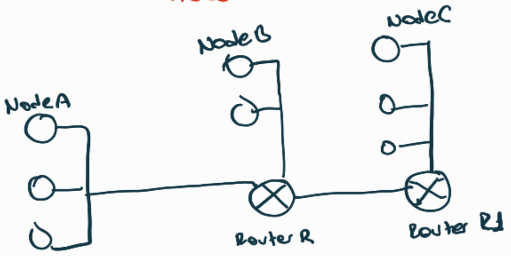
Physical Address (MAC) ↓ identification in the subnet
Physical Address

Routing

1) obtain the IP address of the destination
2) Destination IP address is obtained through DNS
3) Source check if the destination is in the same subnet as the source

Dest. subnet add = Source subnet (Direct Delivery)
Dest. subnet add ≠ Source subnet (Indirect Delivery via Router)

How to determine the router for indirect delivery → Default Gateway



Router Side

Node A - Node B ⇒ Direct delivery to the dest. node

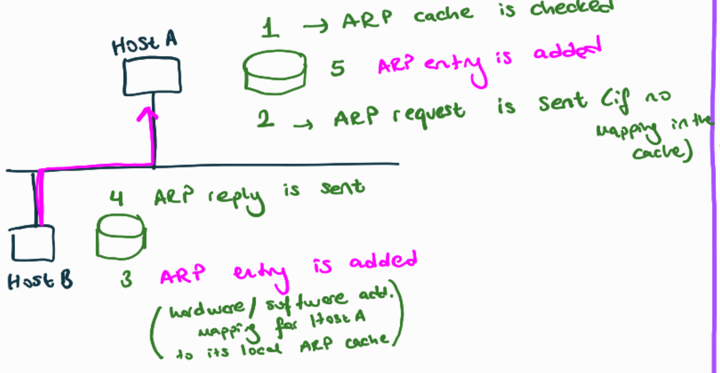
Node A - Node C ⇒ Indirect delivery to the next router

Reference: Ece Güran Schmidt EE444 Slides

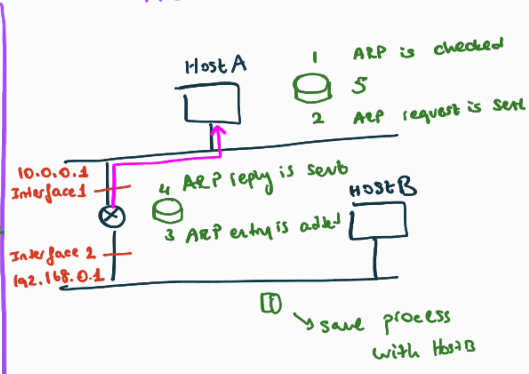
Address Resolution Protocol (ARP) [MAC → IP]

ARP: Direct Delivery

(Host A, B are on the same physical network



ARP: Indirect Delivery



Framing and Error Handling

Bit patterns for frame delimiting

$$[\underbrace{01111110}_{\text{flag}}]\ [\underbrace{\cancel{01111110}}_{\text{message}}]\ [\underbrace{01111110}_{\text{flag}}]$$

↳ we don't want the flag appear in message

↙

thus, apply bit stuffing

↙

ex. CAN Bus bit stuffing

* A bit of opposite polarity is inserted after five consecutive bits of the same polarity

Error Control

Polynomial codes → cyclic redundancy check (CRC)

Message: 1 0 1 1 0 1 1 (with exponents 6 5 4 3 2 1 0 above)

$M(x) = x^6 + x^4 + x^3 + x + 1$

F(x) based on M(x) and P(x) st F(x) is divisible by P(x)

$$x^r M(x) = P(x)\cdot \cancel{Q(x)} + \boxed{C(x)}$$

$$F(x) = x^r M(x) + C(x) \quad \text{(divisible by } P(x)\text{)}$$

Ex M(x) = 110011
P(x) = 11001
4 bit redundancy

$x^r M(x)$ = 110011 0000

to find C(x) divide $x^r M(x)$ to P(x) XOR

```
       11001 10000
(XOR)  11001
       00000
            11001
            01001 = C(x)
```

$F(x) = x^r M(x) + C(x)$ = 11001 01001

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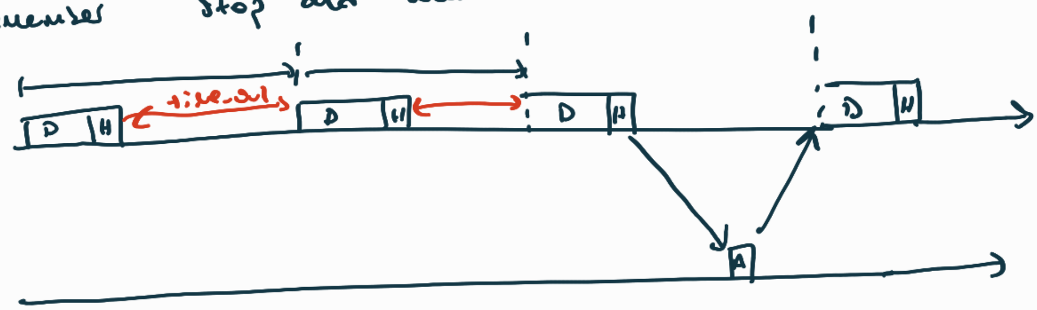
error-detecting codes

CRC → can detect all burst errors less than r+1 bits

Error Control
↗ Automatic Repeat Request (ARQ) (CRC, checksum, ...) → for major errors
↘ Forward Error Correction

Remember stop and wait with error



p = D + H

$$\eta = \frac{D/b_{sr}}{k\left(\frac{p}{b_{sr}} + \text{Timeout}\right) + \left(\frac{p}{b_{sr}} + t_{sr} + \frac{A}{b_{is}} + t_{is}\right)}$$

unsuccessful

$P_{success} = 1 - L = (1-P_1)(1-P_2)$

$P_1 = (D+H)\,E_{sr}$ loss from data packet

loss from ACK $P_a = A\,E_{is}$

$k = \frac{1}{1-L} - 1 = \frac{L}{1-L}$

expected # of retransmission

where to use which approach?

- high bit error → ARQ
- large RTT → X ARQ
- no enough buffer → X ARQ
- no return channel → X ARQ
- app. requires low error rates → ARQ

Medium Access Control

Shared Communication → like cabled Ethernet, shared RF (WiFi)...

↳ Single shared broadcast channel

Medium Access Control Methods

independent of user activity

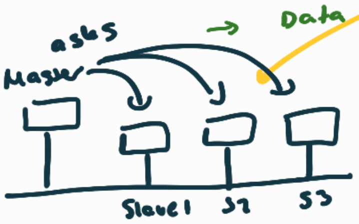
→ collision-free access

no-collision

- Static Channel Allocation (TDM, FDM, WDM)
- Demand Assignment Protocol (Polling, token, bit map) → only for active users

→ Reservation / Arbitration mode

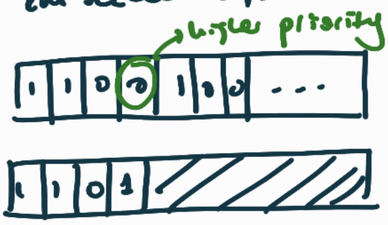
→ Data transmission mode



collision

→ Deterministic collision-resolution

Real-time embedded systems → ex. CAN Bus



→ Access with collision

→ Dynamic Channel Allocation (ALOHA, CSMA)

Pure ALOHA Model

Frame time = t

Mean frame generation rate = N $\Big\}$ Rate $\lambda = \frac{N}{t}$ → $0 < N < 1$

↳ Poisson distributed

$$P[k \text{ events in interval } \tau] = \frac{e^{-\lambda\tau}(\lambda\tau)^k}{k!}$$

P[k total new frames are generated by all users within a frame time t]

$$P[k] \quad \frac{\left(\frac{N}{\cancel{t}}\cancel{t}\right)^k e^{-\frac{N}{t}t}}{k!} = \frac{N^k \cdot e^{-N}}{k!}$$

$$P[k] = \frac{G^k e^{-G}}{k!}$$

($G > N$ in general)

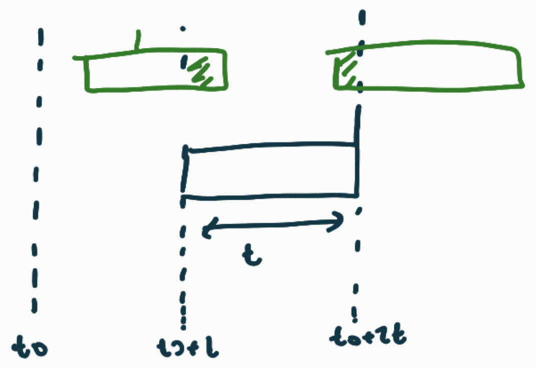
↳ retransmission + new

Throughput: $S = G P_0$

G: offered load

P_0: prob of successful transmission

How to find P_0



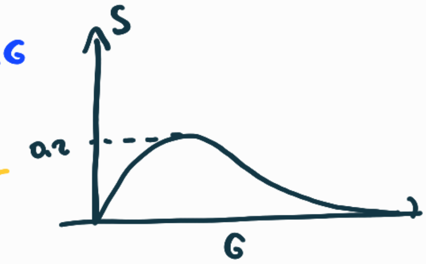
→ There're ∞ users

vulnerable period = 2 frame times

Efficiency

$$P[\text{No frames in two frame times}] = P_0 = \frac{\left(\frac{G}{t}2t\right)^0 e^{-\frac{G}{t}2t}}{0!} = e^{-2G}$$

$$\text{Throughput}: S = P_0 G = G e^{-2G}$$



How to improve this

Slotted ALOHA

Only frames that are transmitted at the same time collide!

Vulnerable period = 1 frame time → throughput should increase

P(empty) = P [no frames in one frame time] $= P_0 = \dfrac{e^{-\frac{G}{t}t}\left(\frac{G}{t}t\right)^0}{0!} = e^{-G}$

P(collision) = 1 − P(empty) − P(success)

Increasing G ?

ex P(success) $= e^{-G}$

P(success @ k attempts] $= P_k = e^{-G} \cdot (1-e^{-G})^{k-1}$

$E = \sum_{k=1}^{\infty} k P_k = e^G$!