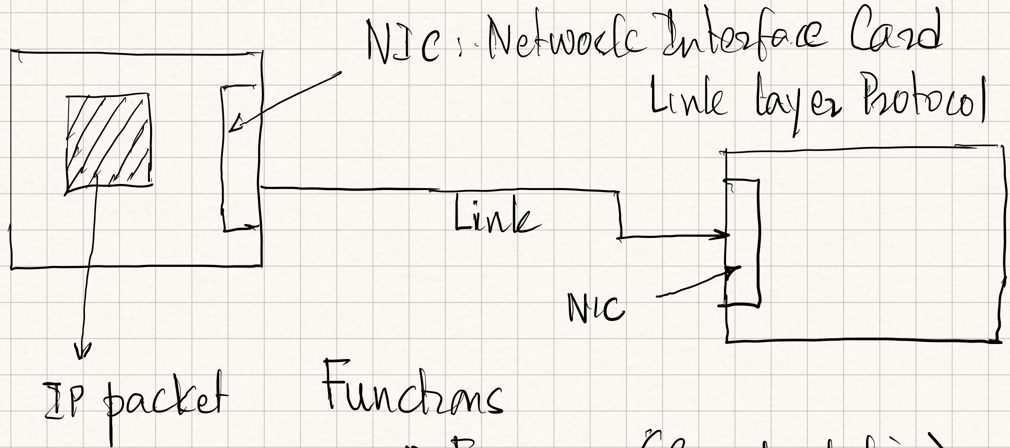
Link Layer

- Link Layer Functions & Services
- Types of links
- Broadcast links
- Medium Access Control

Communication between two nodes that share the same link



Functions

→ Framing (Encapsulation)
→ Error detection / correction
→ Reliable Transfer
→ Medium Access Control

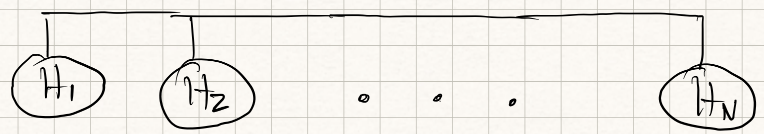
Types of links

→ Point-to-point links: one sender one receiver

Full duplex ⇄ both simultaneously

Half duplex —— One at a time

→ Broadcast



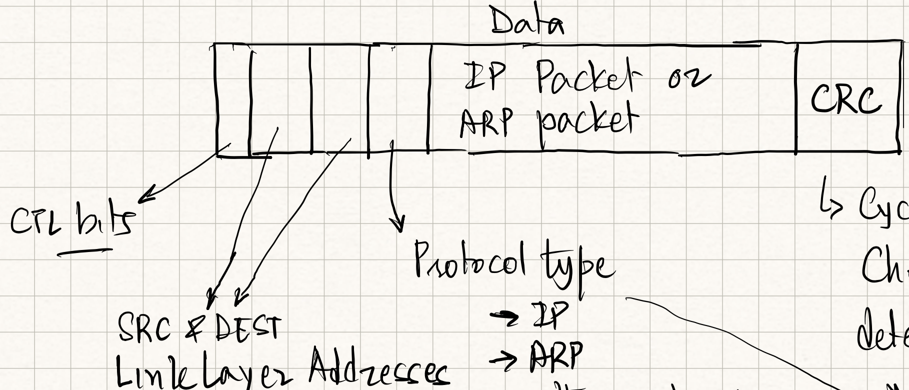
a) All the host share a common channel (common wire or common freq)

b) When a node transmits all node can hear

c) When more than 1 node transmit's at same time, there will be collision and the transmissions will be garbled

1. Framing/Encapsulation

- A network layer pkt (IP packet) is encapsulated in a frame

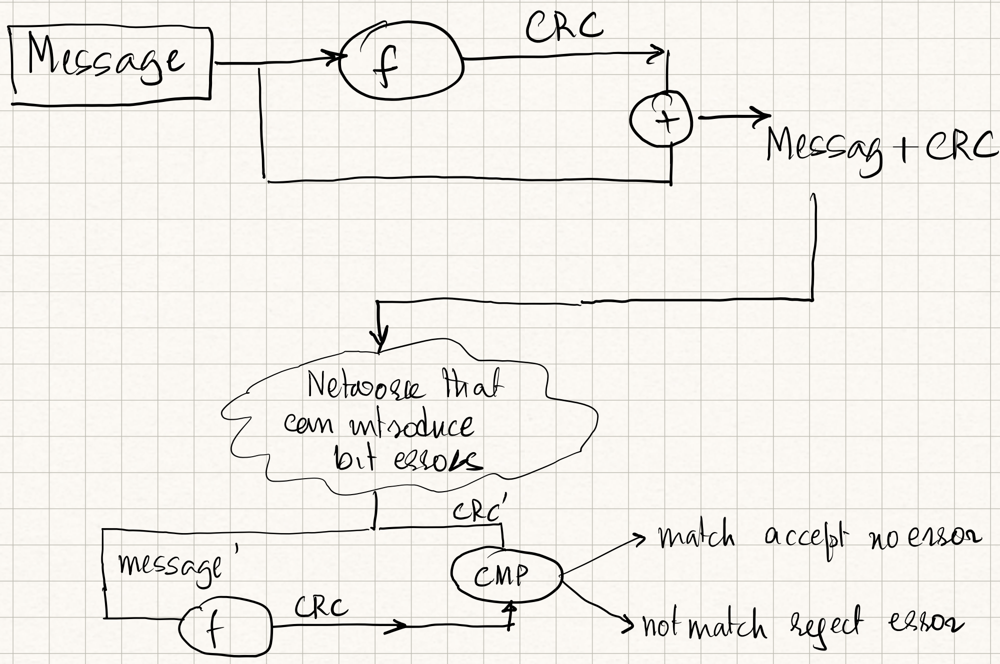


↳ Cyclic Redundancy Check for error detection

"who should receive the data"

{ Ethernet address
{ MAC Address → 48 bits long

2. Error Checking



3. Reliable Transfer Protocol

- The link layer can implement a reliable transfer protocol
  - Use Ack, Sequence Number, Timer, Retransmission achieve reliable transfer over the link.
  - We will study how it is done when we look at the transport layer
  - Very few link layer protocols implement reliable transfer protocol

4. Medium Access Control (MAC) protocol

- How a node accesses the link to transmit data

- Particularly important in broadcast links

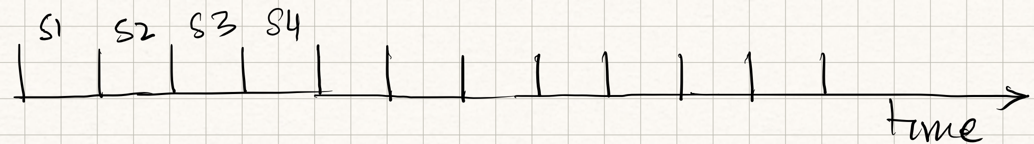
- 3 broad classes
  - Random Access
  - Taking Turns
  - Channel Partitioning

Random Access MAC Protocol

- Node transmits data when it is available
- If more than 1 node transmits there is collision
- Methods to reduce collision and reduce the waste when there is collisions.

Slotted Aloha

- We will assume that time is slotted and the slot time is greater than the pkt transmission time. We ignore propagation delay
- We will assume that all transmission attempts are made at slot boundaries



- We will assume a node is active in a particular slot (has a pkt to transmit) with probability p
- Outcome of a slot can be one of a) Idle (I) b) collision (C) and c) Successful (S)

<u>Example:</u>

	S1	S2	S3	S4	S5	S6	S7	S8	S9
Host 1	T			T				T	
Host2		T	T				T	T	
Host3	T			T				T	
Host4				T				T	
	C	S	S	C	I	I	S	C	

→ time

T: The host is active. All nodes start transmission at begining of the slot boundary

A slot is idle (I) if no node is active in the slot.

The throughput of the slotted Aloha system is the probability that a slot is successful

$$\eta = P(S) = P(\text{only 1 node is active in a slot})$$
$$= \binom{n}{1} p^1 (1-p)^{n-1} = np(1-p)^{n-1}$$

$$P(S) = 1 - P(I) - P(C)$$

$$= 1 - \binom{n}{0} p^0 (1-p)^{n-0} - \sum_{i=2}^{n} \binom{n}{i} p^i (1-p)^{n-i}$$

Probability that 2 or more nodes are active

- In the above derivation we have used the Binomial distribution

$$X \sim \text{Binom}(n, p)$$

$$P(X=k) = \binom{n}{k} p^k (1-p)^{n-k} \quad \leftarrow \underline{\text{pmf}}$$

$$k \in \{0, 1, 2, \ldots, n\}$$

X is the number of successes in n independent Bernoulli trials with probability of success p

- We did not state before but the nodes (hosts) are assumed to be independent

- We can find p that maximizes the throughput

$$\eta = np(1-p)^{n-1}$$

$$\frac{d\eta}{dp} = n(1-p)^{n-1} + np(n-1)(1-p)^{n-2}(-1)$$

$$\frac{d\eta}{dp} = 0 \Rightarrow n(1-p)^{n-1} = np(n-1)(1-p)^{n-2}$$

$$\Rightarrow p^* = 1/n$$

- This result is intuitive. If $p^* > 1/n$ then there will be more collisions. On the other hand, if $p^* < 1/n$ then more slots will go idle.

$$\eta_{max} = n \cdot \frac{1}{n}\left(1-\frac{1}{n}\right)^{n-1}$$
$$= \left(1-\frac{1}{n}\right)^{n-1}$$

to show that it is max you need to show that $\left.\frac{d^2\eta}{dp} < 0\right|_{p^*}$

$$\lim_{n\to\infty} \eta_{max} = \lim_{n\to\infty} \left(1-\frac{1}{n}\right)^{n-1}$$

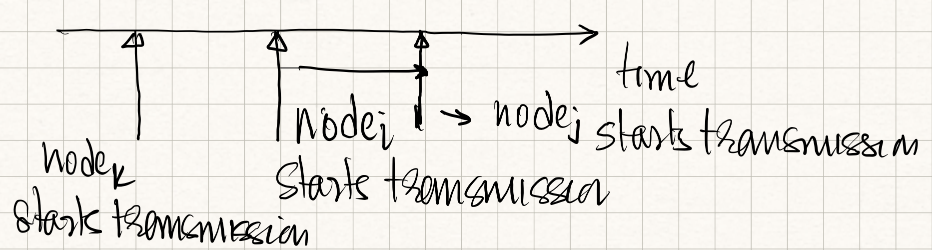
$$= \lim_{n\to\infty} \left(1-\frac{1}{n}\right)^{-1} \cdot \left(1-\frac{1}{n}\right)^{n}$$

$$= \lim_{n\to\infty} \left(1-\frac{1}{n}\right)^{n} \quad \text{as} \lim_{n\to\infty} \left(1-\frac{1}{n}\right)^{-1} \to 1$$

$$= 1/e = 37\%$$

Unslotted Aloha

- In the unslotted case a node will transmit as soon as it has a pkt to transmit
- If we consider the transmission time of the pkt to be the same as the slot time



- Ignoring the propagation delay, the vulnerability zone is now 2 slot time
  1. node$_i$ transmission can collide with node$_k$ transmission that started little less than a slot time ago
  2. node$_i$ transmission can collide with node$_j$ transmission that will start little less than a slot time later
- This suggest that for unslotted Aloha

$$\lim_{n \to \infty} \eta_{max} = 1/2e$$

CSMA: Carrier Sense Multiple Access

- One way to reduce collision is to sense the channel before transmitting.
  - → Transmit only if the channel is idle
- This would reduce collisions but not eliminate it
- Because of the propagation delay, a node can sense a channel to be idle only because the signal from another node that is already transmitting has not yet reached it.

CSMA/CD: Carrier Sense Multiple Acces with Collision Detect

- If a node detects that its transmission has collided
  - ⇒ abort transmission
- If the collision is detected quickly, then this would reduce the time the channel is wasted due to collision
- How is the collision detected ?

A) When signal collide there will be constructive and destructive interference

B) A node compares the transmit signal strength with what it receives (requires the interface to transmit & receive simultaneously)

⇒ If there is significant difference then there is collision