Multiple access

- multiple access link: multiple nodes send & receive over a shared channel
  - eg Ethernet, wireless

- multiple access protocols regulate transmissions to achieve fair & efficient channel sharing
  - ideally, if the shared channel has capacity $R$, when $M$ nodes have data to send, each should get an average rate of $\frac{R}{M}$
  - can be classified as
    a) channel partitioning: TDM, FDM, CDMA
    b) taking turns: eg
      - polling — master node polls other nodes in a round robin fashion
      - token passing — a small, special purpose token frame is passed around in a fixed order; a node with data to send holds the token to reserve the channel for transmission of up to some maximum no. of frames at a time
    c) random access: eg ALOHA, CSMA (Carrier Sense Multiple Access)
      - generally work well under lightly loaded conditions
• Aloha (pure Aloha / unslotted Aloha)
  - earliest random access protocol; developed by Abramson 70 for a wireless packet radio network
  - each node, upon receiving a new packet, transmits it immediately
  - if 2 packet transmissions overlap in time at a receiver node, the receiver experiences a collision (detected via CRC)
  - eg. nodes on a line, unit packet transmit time

![Space-time diagram](image)

• space-time diagram
  - packet transmission starts at space-time point TS & ends at TE; packet reception at intended receiver starts at RS & ends at RE; striped area shows propagation of packet
  - dotted area gives collision cone sharing all (location d, time t) pairs s.t. if a transmission is started at time t at point d, a collision occurs at the receiver
  - if a packet is involved in a collision, it is retransmitted after a random delay
- **Slotted Aloha**
- Simple improvement over pure Aloha by restricting transmissions to occur in fixed timeslots.
- Slot length is set equal to packet transmission time + maximum propagation delay.
- Nodes begin transmissions only at slot boundaries.
  - Transmission & reception of a packet are completed in 1 slot.
  - Packets collide only if they are transmitted in the same slot.
- A packet that has suffered a collision is called a backlogged packet; it is retransmitted with some probability in each successive slot until successfully transmitted.
- When the no. of nodes is large, for stability (i.e., finite expected delay per pkt), retransmission prob should be chosen adaptively.
- If the arrival rate of new packets & the number of backlogged nodes were known at the start of each slot, the optimal retransmission probability (that maximizes the success probability in the slot) could be calculated.
- In practice, the retransmission probability is 1/2 when an idle slot occurs, & 1/4 when a collision occurs.
- if the retransmission probability were fixed instead of adaptive, then for sufficiently large number of backlogged nodes, the number tends to \( \lambda \) (in expectation) & the system becomes unstable.

- instead of randomized retransmissions, other collision resolution strategies can be used to improve efficiency.

- slotted Aloha is used in satellite communications (since propagation delays are very large, carrier sensing is not so useful).

- GSM cellular networks on the mobile to base station control channel (small messages generated at a low rate compared to the channel bandwidth).
Carrier Sensing protocols

- for networks where propagation delays are small compared with packet transmission times

  → if a node senses that the channel is busy, if it transmits it is likely to cause a collision.

Carrier Sense Multiple Access (CSMA) protocol:

- each node listens to the channel before beginning to transmit, & defers to an ongoing transmission.

- a collision occurs only if 2 nodes begin transmitting within a short time (less than the propagation delay between them) of each other.

- max collision duration is pkt transmit time + 2 * max propagation delay.
CSMA with collision detection (CSMA/CD)

- A node continues to monitor the channel after beginning transmission; if it senses a collision, it stops transmitting.

- Collision duration is reduced.

- CSMA/CD was developed for Ethernet (Metcalfe & Boggs, 73-75)
  - 100- & 1000-Mbps Ethernet are used in switched configurations with point to point links.

- 10-Mbps Ethernet

  - Any signal put on the Ethernet by a host is broadcast over the entire network.
    - Signal is propagated in both directions & forwarded by repeaters (which join Ethernet segments) on all outgoing segments.

  - Each host is connected to the network via an adapter which has a unique address.
an Ethernet adapter receives all frames, & passes to the host frames addressed to itself, frames addressed to the broadcast address, frames addressed to a multicast address specified by its host, or, if it is in promiscuous mode, all frames.

- when a node has a frame to send & the line is idle, it transmits immediately (upper bound of 1500 bytes).
- when a node has a frame to send & the line is busy, it waits until the line goes idle & then transmits (with probability 1, so Ethernet is called a 1-persistent protocol).
- while transmitting, a node monitors the energy level on the medium; if it is higher than that of a single transmission, a collision is detected — the node transmits a 32-bit jamming sequence & stops the transmission.
- every frame is at least 512 bits (64 bytes) long (corresponds to max round trip delay of 51.2 μs on a 10-Mbps Ethernet which is ≤2500 m long with ≤4 repeaters between any 2 hosts) — if sender does not detect
a collision while it is transmitting, it knows for sure that its transmission did not collide.

- If a node detects a collision & stops its transmission, it first delays 0 or 51.2 μs (selected randomly) before retrying; after the n-th consecutive failed attempt, the delay interval is 51.2k μs, where k is chosen randomly from \{0, 1, 2, ..., 2^{k-1}\}. The strategy is called exponential backoff.