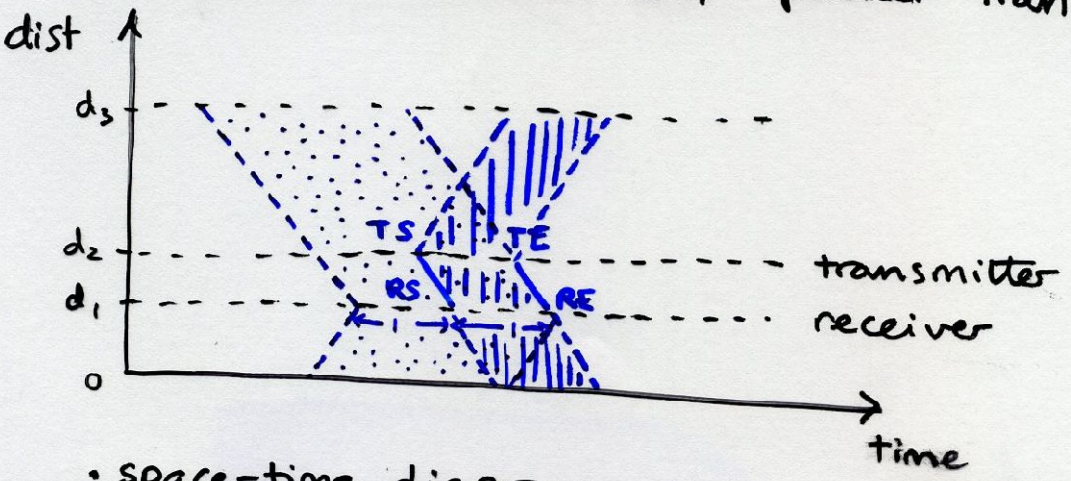
Multiple access

- 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



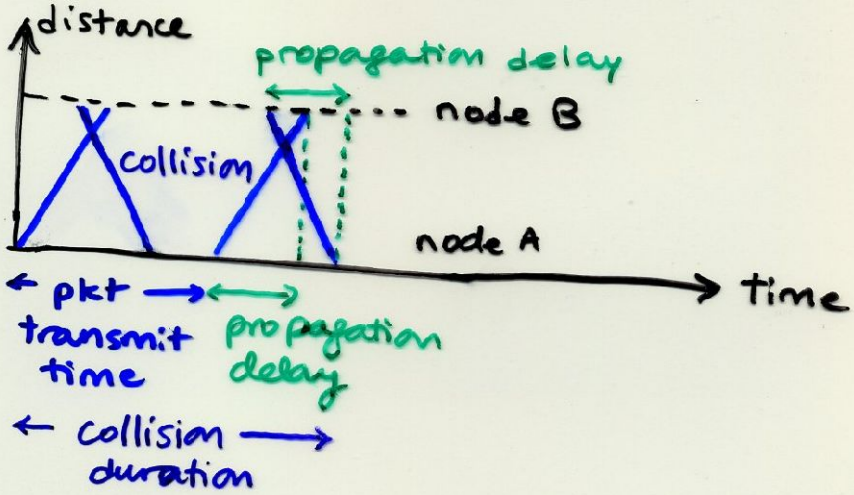
  - space-time diagram
  - packet transmission starts at space-time point TS & ends at TE; packet reception at intended receiver starts at RS & ends at RE; striped area shows propagation of packet
  - dotted area gives **collision cone** showing all (location d, time t) pairs s.t. if a transmission is 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 (ie 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 ↑d when an idle slot occurs, & ↓d 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 ↑ (in expectation) & the system becomes unstable
- instead of randomized retransmissions, other collision resolution strategies can be used to improve efficiency

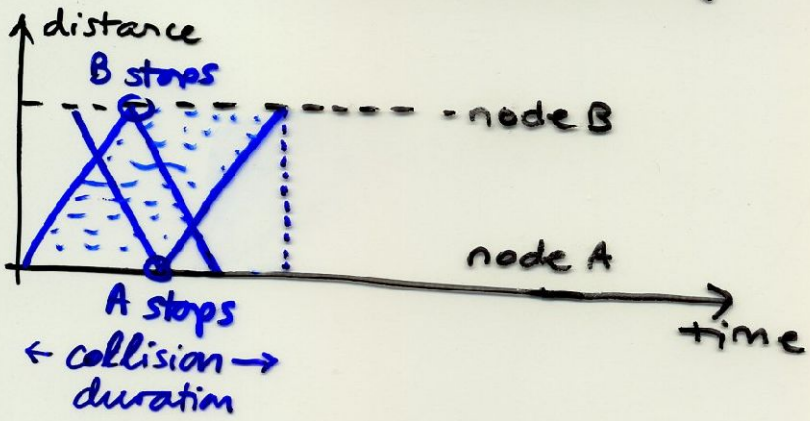
- slotted Aloha is used in
  - satellite communications (since propagation delays are very large, carrier sensing is not so useful)
  - GSM cellular networks on the mobile to base station control channel (small messages generated at a low rate compared to the channel bandwidth)

- 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 adaptor which has a unique address

- an Ethernet adaptor 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 $\{0, 1, 2, \ldots, 2^n - 1\}$
  - strategy is called <u>exponential backoff</u>