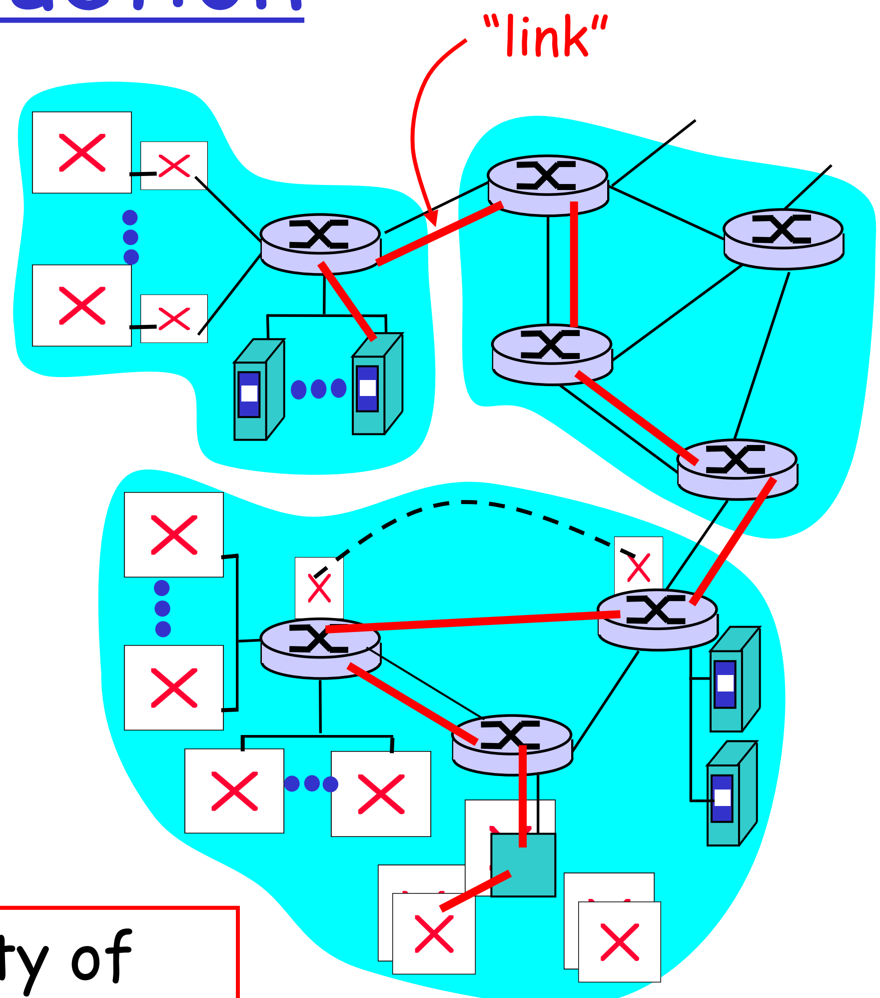
Link Layer

- 5.1 Introduction and services
- 5.2 Error detection and correction
- 5.3Multiple access protocols
- 5.4 Link-Layer Addressing
- 5.5 Ethernet
- 5.6 Hubs and switches
- 5.7 PPP

Link Layer: Introduction

Some terminology:

- hosts and routers are **nodes**
- communication channels that connect adjacent nodes along communication path are **links**
  - wired links
  - wireless links
  - LANs
- layer-2 packet is a **frame**, encapsulates datagram



data-link layer has responsibility of transferring datagram from one node to adjacent node over a link

Link layer: context

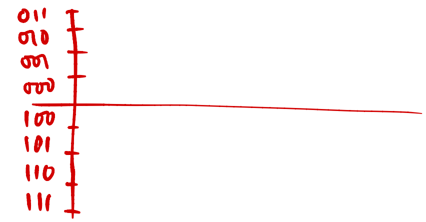
- Datagram transferred by different link protocols over different links:
  - e.g., Ethernet on first link, frame relay on intermediate links, 802.11 on last link
- Each link protocol provides different

Traffic lights,
Airport control,
Platform scheduling,

transportation analogy

- trip from Princeton to Lausanne
  - limo: Princeton to JFK
  - plane: JFK to Geneva
  - train: Geneva to Lausanne
- tourist = datagram
- transport segment = communication link
- travel agent = routing algorithm
- transportation access = link layer protocol

Link Layer Services

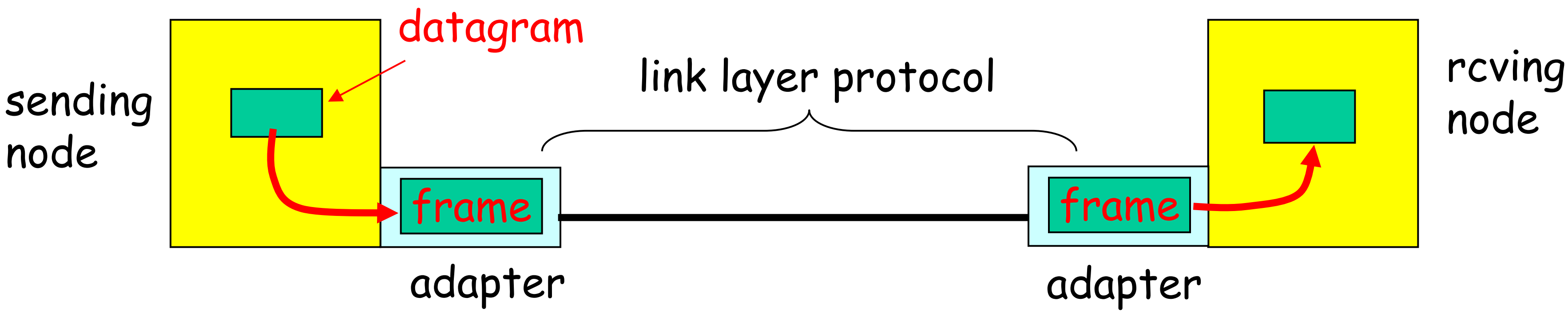


- Framing, link access:
  - encapsulate datagram into frame, adding header, trailer
  - channel access if shared medium
  - "MAC" addresses used in frame headers to identify source, dest
    - different from IP address!
- Reliable delivery between adjacent nodes
  - we learned how to do this already (chapter 3)!
  - seldom used on low bit error link (fiber, some twisted pair)
  - wireless links: high error rates
    - Q: why both link-level and end-end reliability?

Link Layer Services (more)

- *Flow Control:*
  - pacing between adjacent sending and receiving nodes
- *Error Detection*:
  - errors caused by signal attenuation, noise.
  - receiver detects presence of errors:
    - signals sender for retransmission or drops frame
- Error Correction:
  - receiver identifies *and corrects* bit error(s) without resorting to retransmission
- *Half-duplex and full-duplex*
  - with half duplex, nodes at both ends of link can transmit, but not at same time

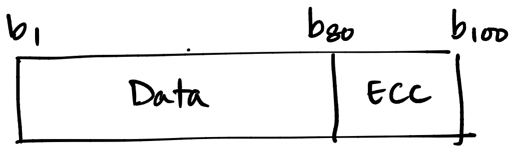
Adaptors Communicating



- link layer implemented in “adaptor” (aka NIC)
  - Ethernet card, PCMCI card, 802.11 card
- sending side:
  - encapsulates datagram in a frame
  - adds error checking bits, rdt, flow control, etc.
- receiving side
  - looks for errors, rdt, flow control, etc
  - extracts datagram, passes to rcving node
- adapter is semi-autonomous
- link & physical layers

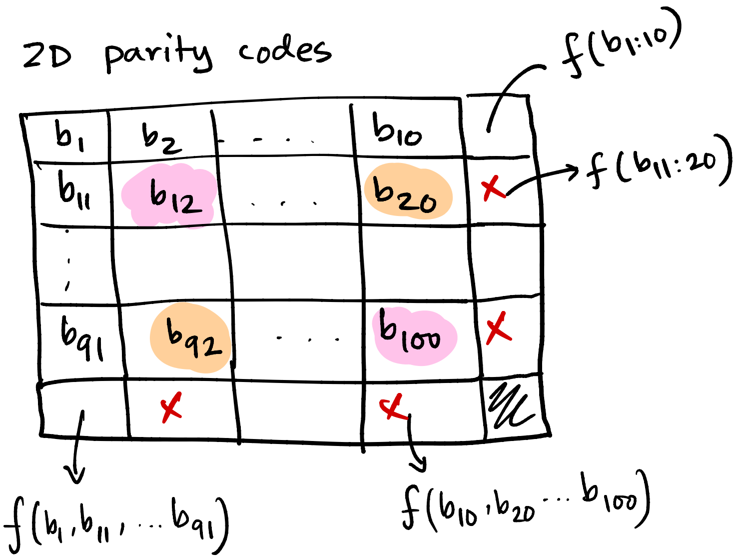
1. Error Detection
2. MAC problem / tradeoffs
3. MAC protocols
   - Partition
   - Random
   - Polling
4. CSMA/CD → Ethernet

Error Detection



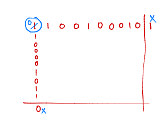
$$f(b_1 - b_{80}) == (b_{80} - b_{100})$$

2D parity codes



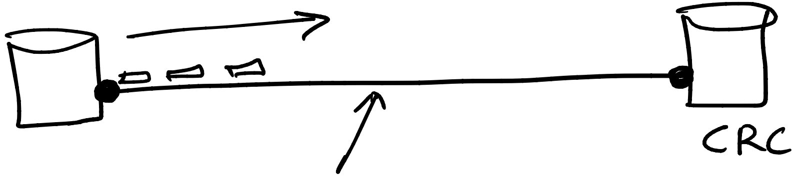
CRC

Cyclic Redundancy Check

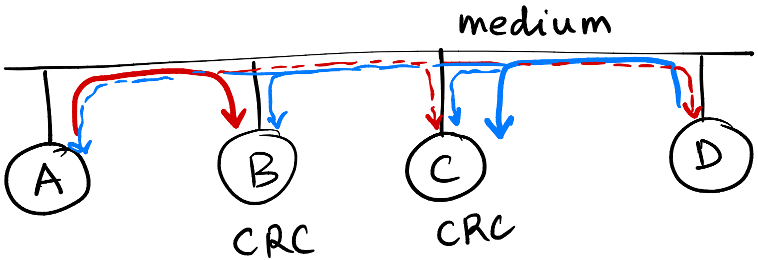


Medium Access Control (MAC)

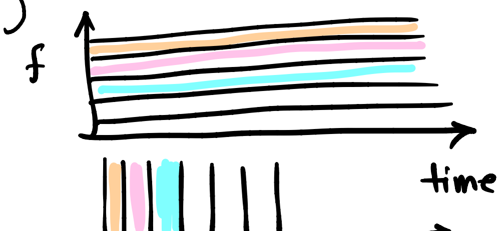
Problem Statement



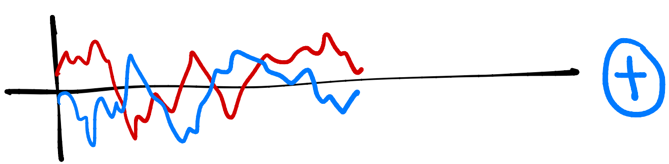
unicast networks

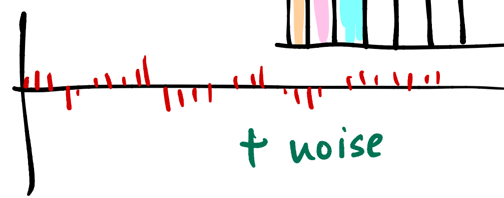


Broadcast network



Maximize utilization (throughput) under fairness constraints.

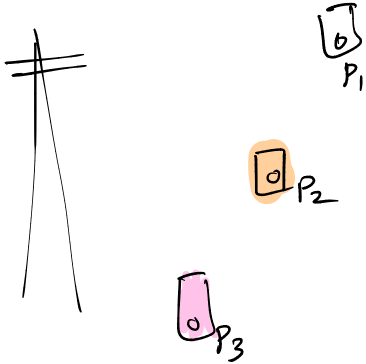


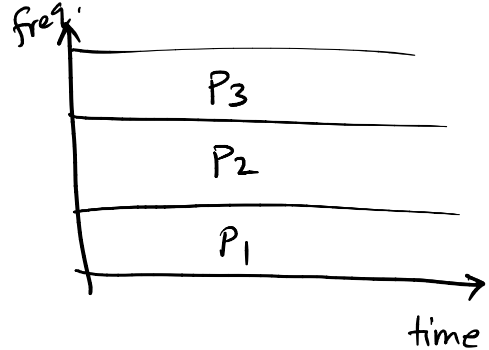


MAC protocols

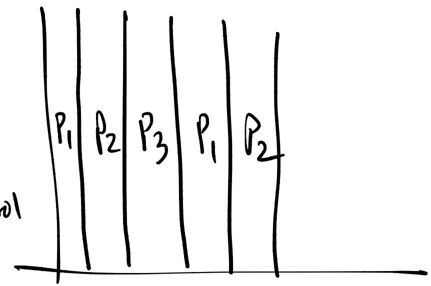
- Partition
- Random
- Polling

Partition (TDMA / FDMA)



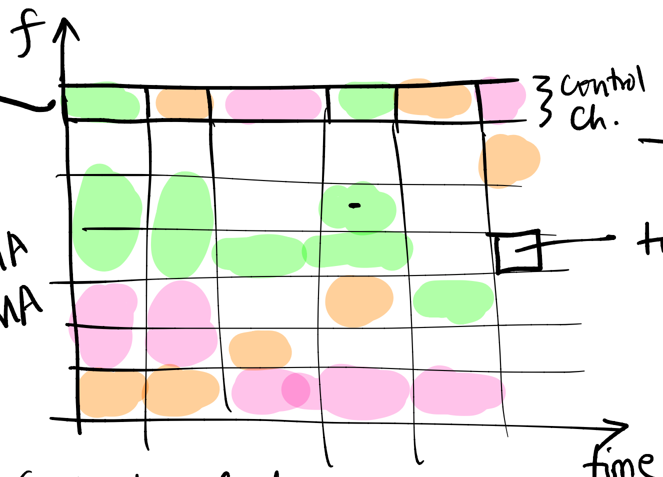


FDMA



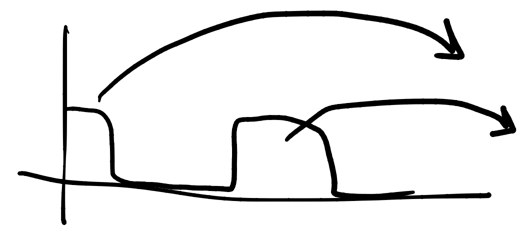
TDMA

control channel



Joint TDMA FDMA

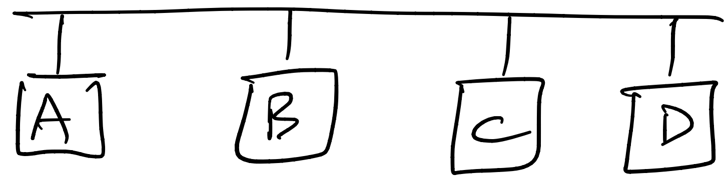
time - frequency blocks.



Centralized link layer MAC protocols.

Random Access

Slotted ALOHA



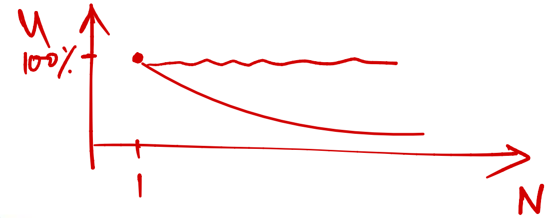
Assumptions

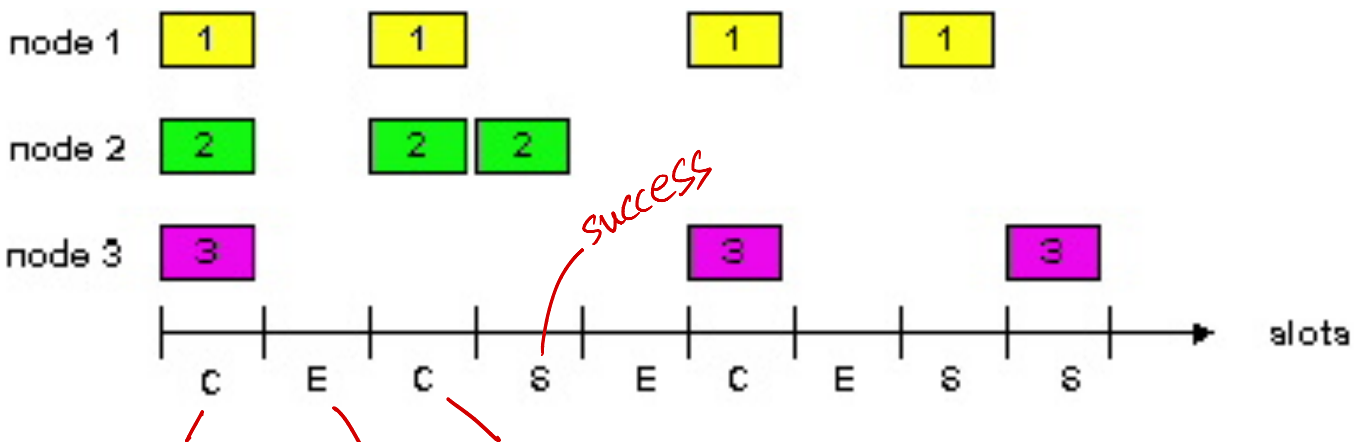
- all frames same size
- time is divided into equal size slots, time to transmit 1 frame + ACK
- nodes start to transmit frames only at beginning of slots
- nodes are synchronized
- if 2 or more nodes transmit in slot, all nodes detect collision

Operation

- when node obtains fresh frame, it transmits in next slot
- no collision, node can send new frame in next slot
- if collision, node retransmits frame in each subsequent slot with prob. p until success

Slotted ALOHA





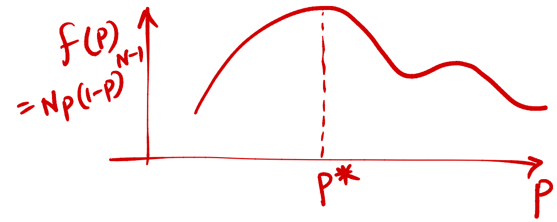
Pros

- single active node can continuously transmit at full rate of channel
- highly decentralized: only slots in nodes need to be in sync
- simple

Cons

- collisions, wasting slots
- idle slots
- nodes must be able to detect collision in less than time to transmit packet
- clock synchronization

Slotted Aloha efficiency



Efficiency is the long-run fraction of successful slots when there are many nodes, each with many frames to send

- Suppose N nodes with many frames to send, each transmits in slot with probability *p*
- prob that node 1 has success in a slot $= p(1-p)^{N-1}$
- prob that any node has a success $= Np(1-p)^{N-1}$

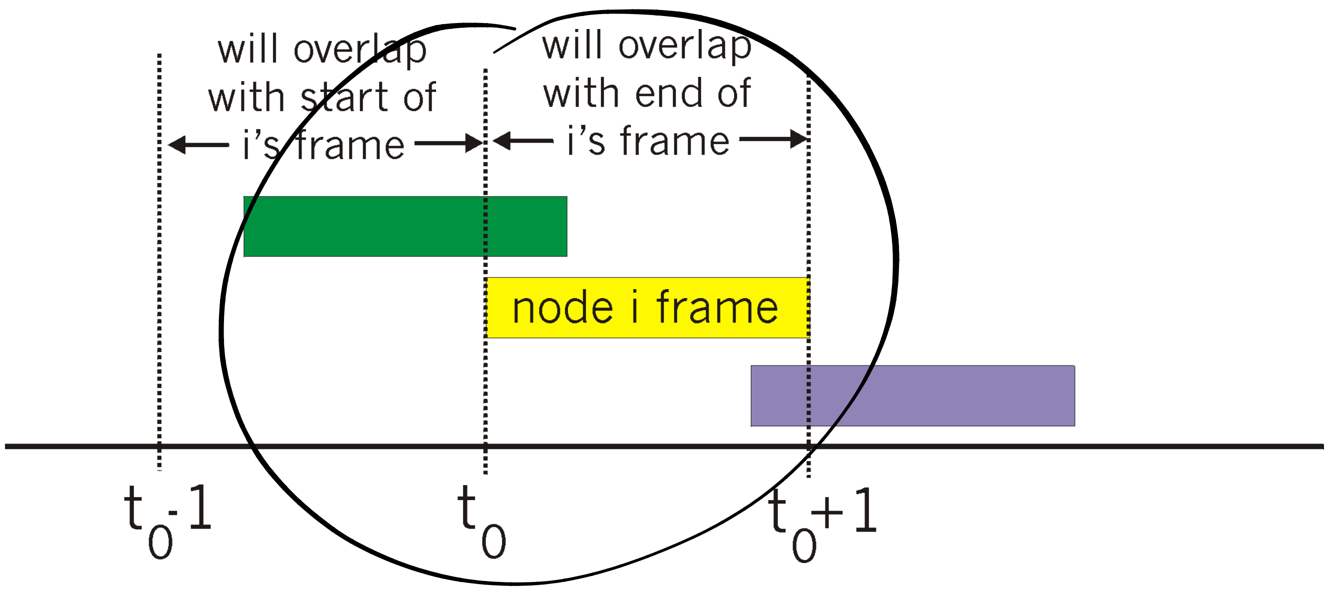
$\lim_{N \to \infty} Np^*(1-p^*)^{N-1}$

- For max efficiency with N nodes, find p^* that maximizes $Np(1-p)^{N-1}$
- For many nodes, take limit of $Np^*(1-p^*)^{N-1}$ as N goes to infinity, gives $1/e = .37$

At best: channel used for useful transmissions 37% of time!

Pure (unslotted) ALOHA

- unslotted Aloha: simpler, no synchronization
- when frame first arrives
  - transmit immediately
- collision probability increases:
  - frame sent at t_0 collides with other frames sent in $[t_0-1, t_0+1]$



Pure Aloha efficiency

P(success by given node) = P(node transmits) $\cdot$

P(no other node transmits in $[t_0\text{-}1,t_0]$ $\cdot$

P(no other node transmits in $[t_0,t_0\text{+}1]$

$= p \cdot (1-p)^{N-1} \cdot (1-p)^{N-1}$

$= p \cdot (1-p)^{2(N-1)}$

... choosing optimum p and then letting n -> infty ...

Even worse !

$= 1/(2e) = .18$

Carrier Sense Multiple Access (CSMA)