COMP28512
Mobile Systems

Lecture 7
Multiple access
&
medium access control (MAC)

Steve Furber & Barry Cheetham

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Broadcast networks: multiple access protocols

1. Station Model
   - N independent stations
     - each generating packets for transmission at random times.
2. Single Channel
   - all stations can transmit and receive on it
     - NB not true for limited-range wireless – see later
3. Collision Assumption
   - if two frames overlap in time they are both garbled (lost)
     - stations can detect collisions; there are no errors except packet loss
4. Time
   - (a) Continuous Time: packets can be sent at any point in time
   - (b) Slotted Time: time is divided into discrete intervals
5. Can stations detect current transmission?
   - (a) Carrier Sense: station can detect busy channel
   - (b) No Carrier Sense: station cannot detect busy channel
     - just transmit, & determine success later

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Multiple access

- Communication links by wire or radio generally provide access to several users at once.
- Multiple access techniques used by mobile phones include:
  - Frequency division multiple access (FDMA),
  - Time division multiple access (TDMA),
  - Code division multiple access (CDMA),
  - Orthogonal frequency division multiple access (OFDMA)
  - Spatial division multiple access (cellular radio)
- Several of these are combined
  - e.g. 2G-GSM uses FDMA, TDMA & cellular
- In principle, provide ‘connection-oriented’ channels that do not interfere with each other.

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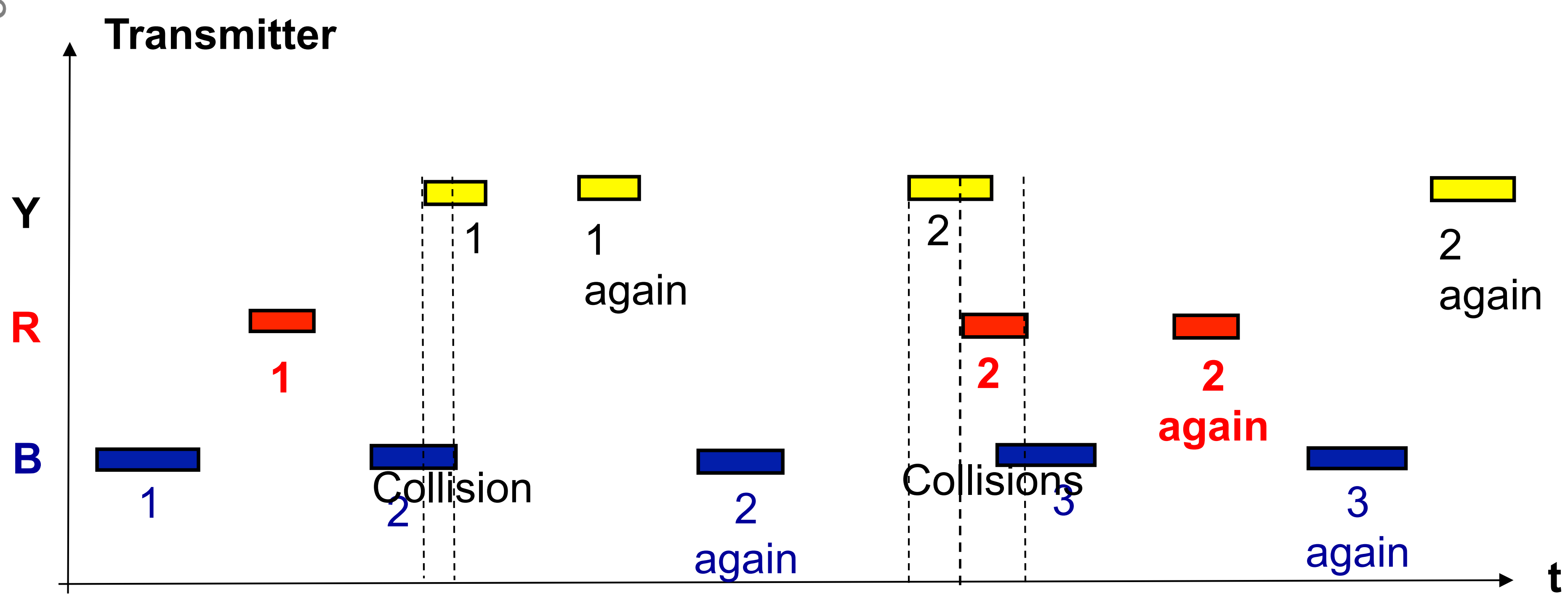
Pure ALOHA (1970s)

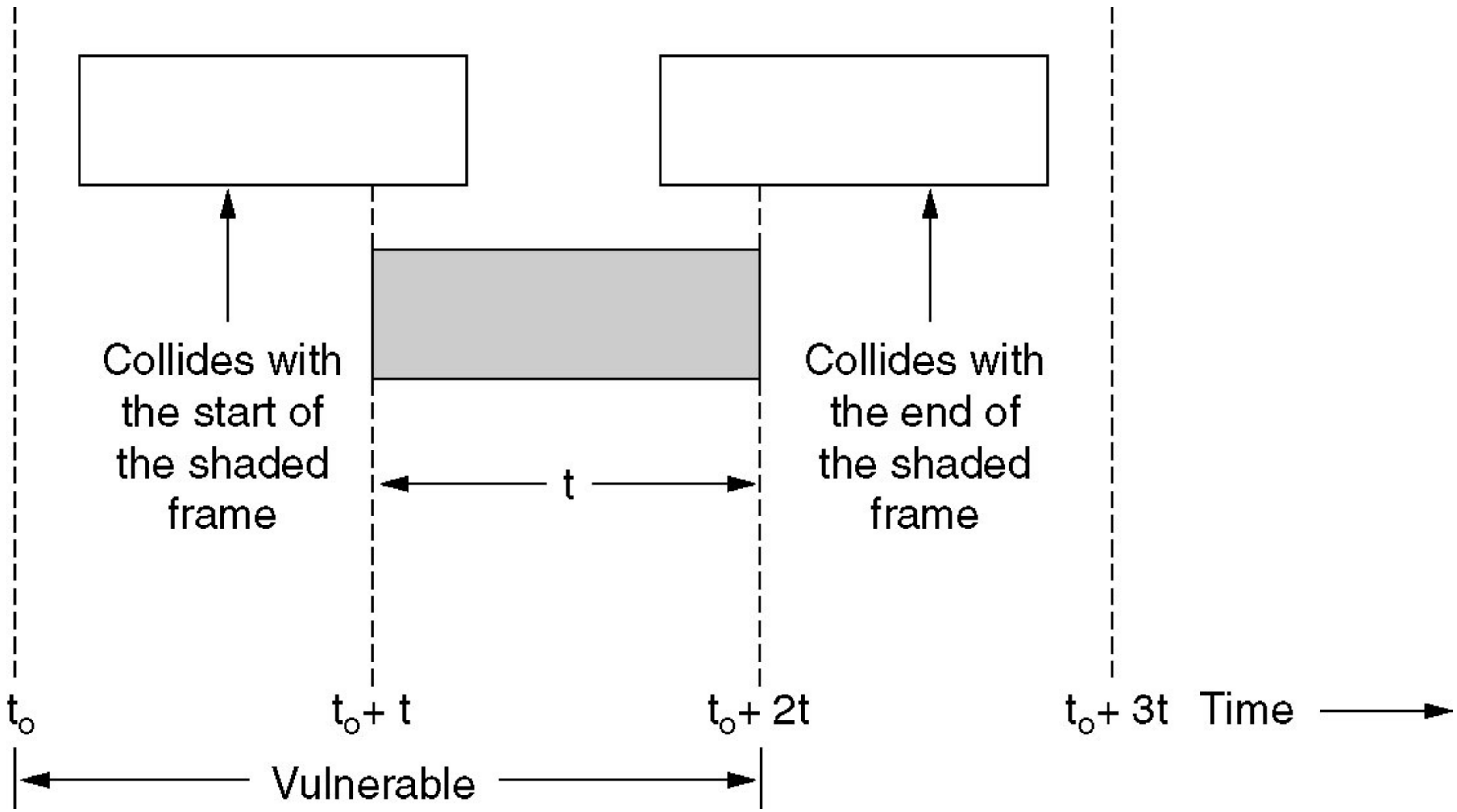
- Stations transmit whenever they have data to send
- Success is detected by
  – listening to channel while transmitting
  – or by acknowledgement
- If frame is destroyed
  – retransmit after a random delay
    - random delay avoids repeated collision
- This is a ***contention*** system

Pure ALOHA (illustrated)



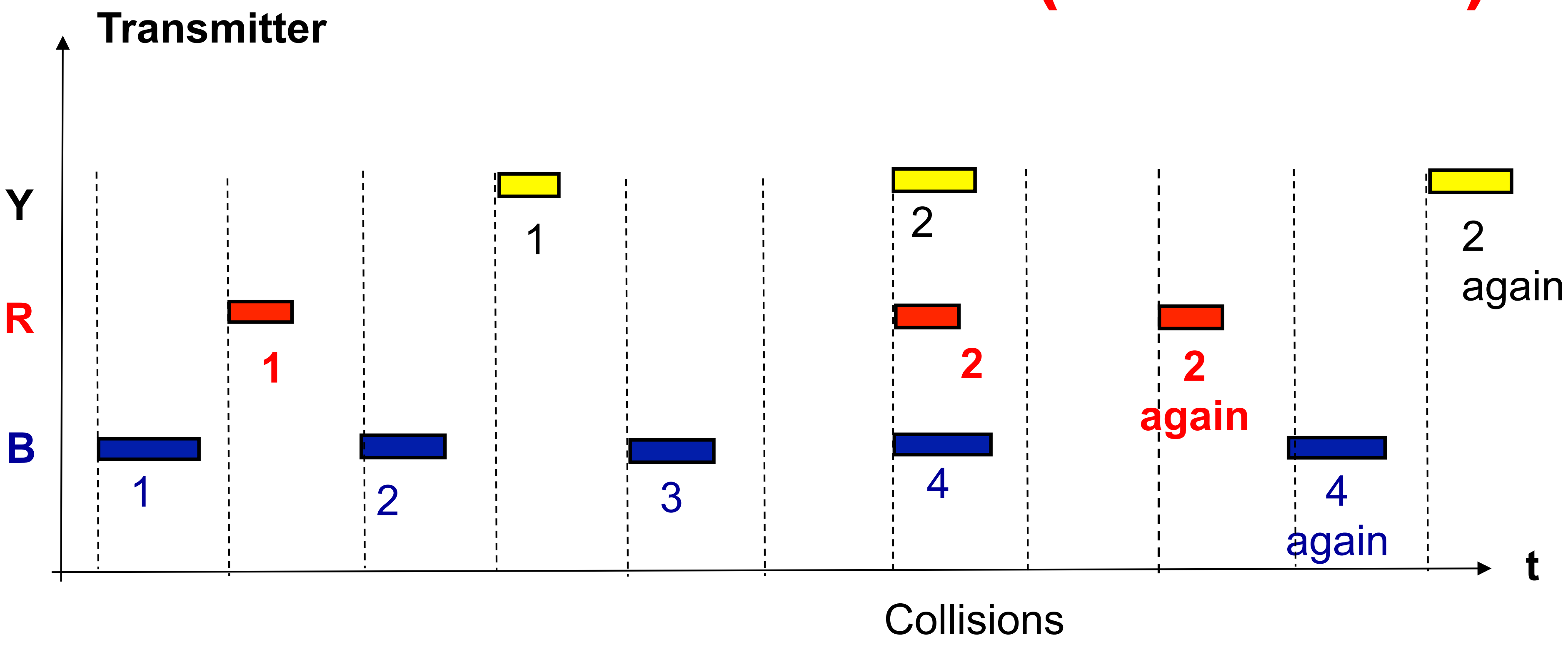
- In pure ALOHA, frames are transmitted at completely arbitrary times

Pure ALOHA



- Vulnerable period for the shaded frame
  - 3x frame length

Slotted ALOHA (illustrated)



- **Time domain is now divided into slots**
- **Each transmitter must wait until the start of a new slot before sending.**
- **Fewer collisions occur**

ALOHA performance

- Stations generate traffic
  - mean of N new frames per frame time
    - normally $0 < N < 1$
      - N > 1 means demand exceeds channel capacity
  - mean of G transmission attempts/frame time
    - includes new frames and retransmissions, so $G \geq N$
  - assume Poisson distributions for N and G
    - prob. of k frames in a given frame time $\boxed{p(k,G) = \frac{e^{-G}G^k}{k!}}$
    - $p(k=0) = e^{-G}$
  - throughput $S = G.P_0$
    - where P_0 is the probability a frame sees no collision
      $S = G\ e^{-2G}$
  - Slotted ALOHA: synchronize frame starts: $S = G\ e^{-G}$

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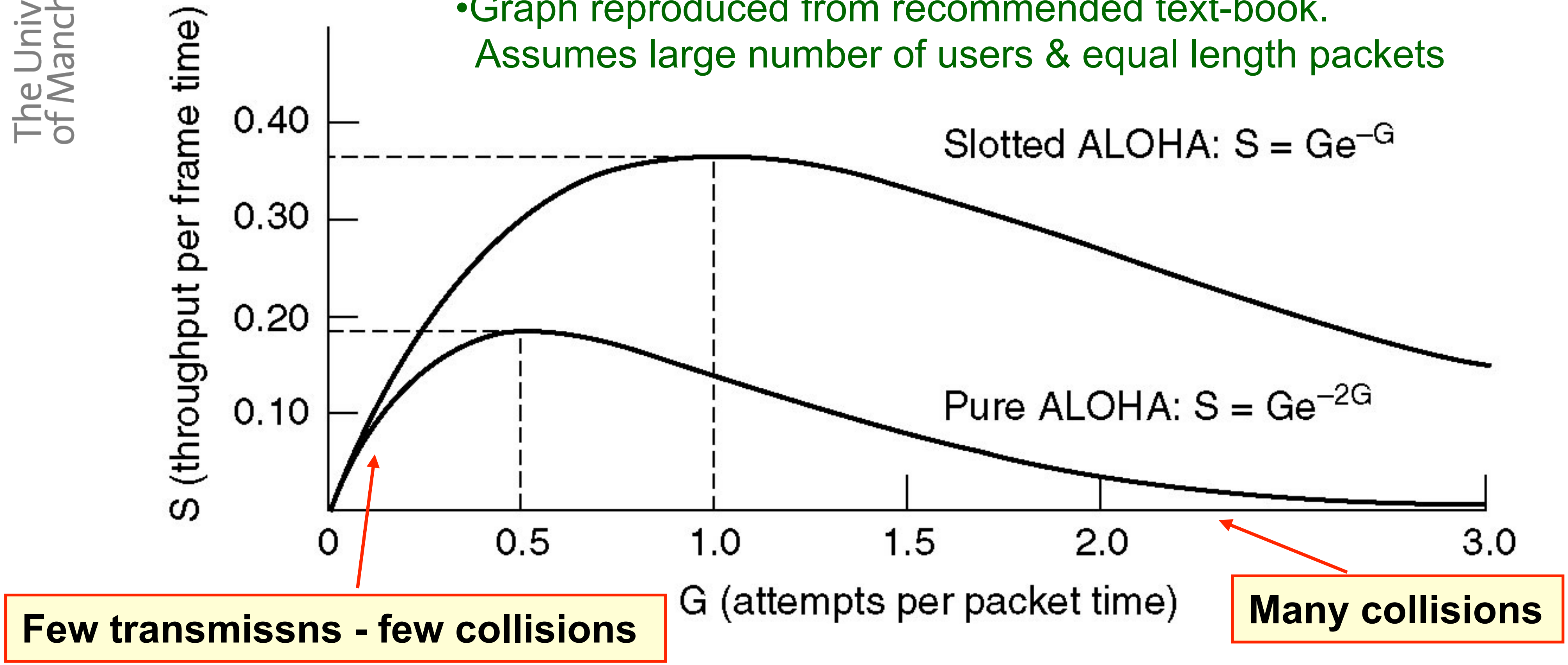
Efficiency of ALOHA

•Graph reproduced from recommended text-book.
Assumes large number of users & equal length packets

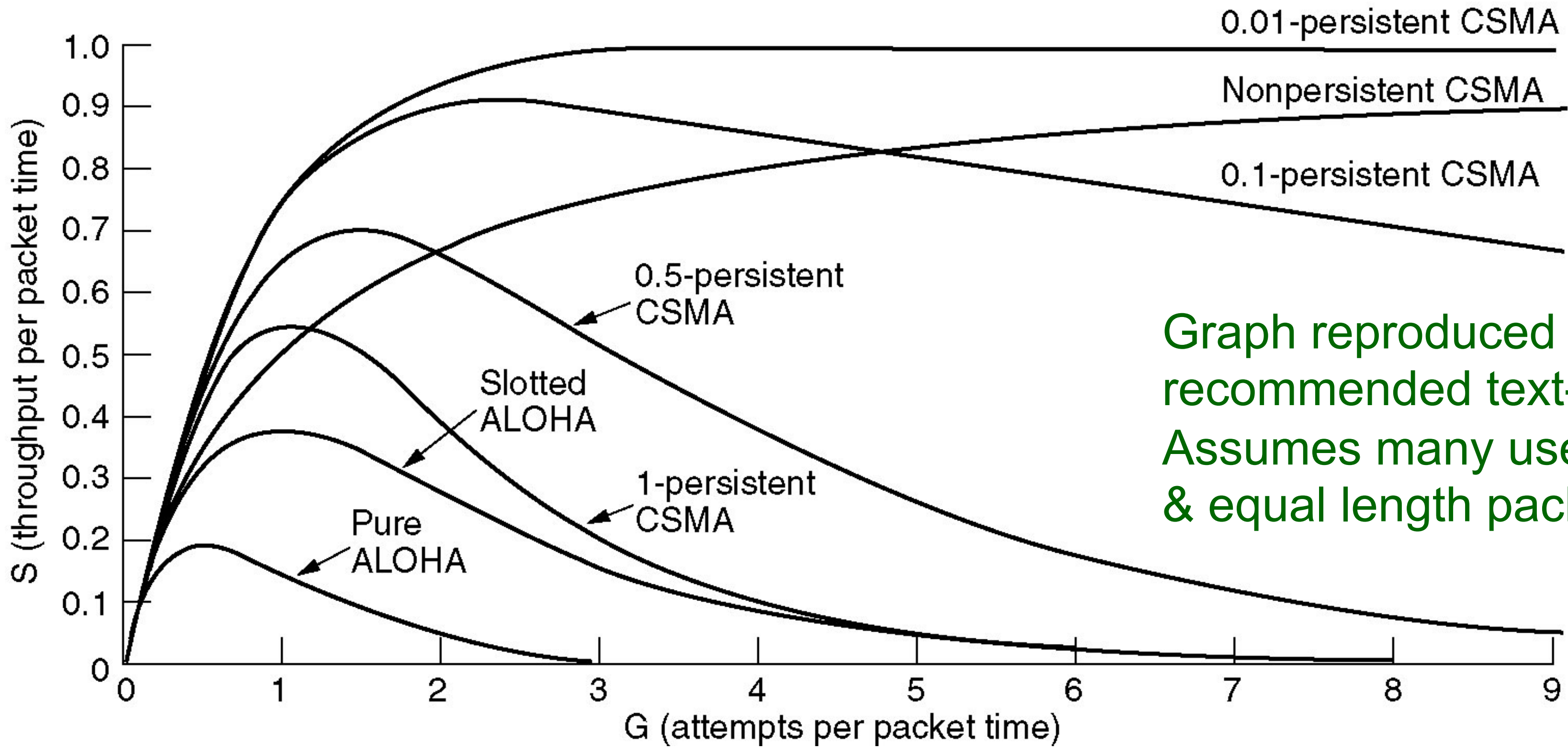


- Pure ALOHA achieves max 18% channel utilization
- Slotted ALOHA achieves max 37% utilization
  - plus 37% empty, 26% collisions

Carrier Sense Multiple Access (CSMA)

- Listen before you speak!
  - if someone is talking, wait until they finish before you speak
    - 1-persistent CSMA
  - start to speak in the next slot with prob. *p*
    - *p*-persistent CSMA
- If someone is talking
  - wait a random time and check again
    - non-persistent CSMA

Persistent and non-persistent CSMA



Graph reproduced from recommended text-book. Assumes many users & equal length packets.

- Comparison of the channel utilization versus load for various random access protocols.

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Comment

- Seem to be getting close to 100% efficiency with very low persistence.
- But we have not considered how long it takes packets to get through - delay
- 0.01 persistent CSMA only uses 1 op out of every 100.
- The network seems efficiently used for a lot of users.
- But to any individual user it will be V E R Y S L O W.

CSMA with collision detection

- Transmitter must monitor its own transmissions
- Abort transmission as soon as a collision is detected.
- Saves time, power & transmission capacity.
- Used by wired Ethernet.
- Carrier detection is phy layer process.
- Result used by 'Medium Access Control sub-layer'
- It is part of the data-link layer.
- MAC sub-layer makes decisions about when to transmit, when to back-off, etc.

CSMA with collision avoidance

- CSMA/CD is fine for wired systems but not for wireless.
- Wireless transmitter cannot easily monitor its own transmissions.
  - it is either transmitting or receiving, but not both at same time
- Also, it is not appropriate, since what matters is collision at seen the receiver.
  - this may be different from what is observed at the transmitter.
- With wireless, emphasis is on avoiding collision.
- IEE802.11 supports 2 transmission modes:
  - non-contention mode (PCF) using centralised control
  - contention mode (DCF) using CSMA/CA
- PCF is optional & not widely used.
  - Concentrate on DCF.

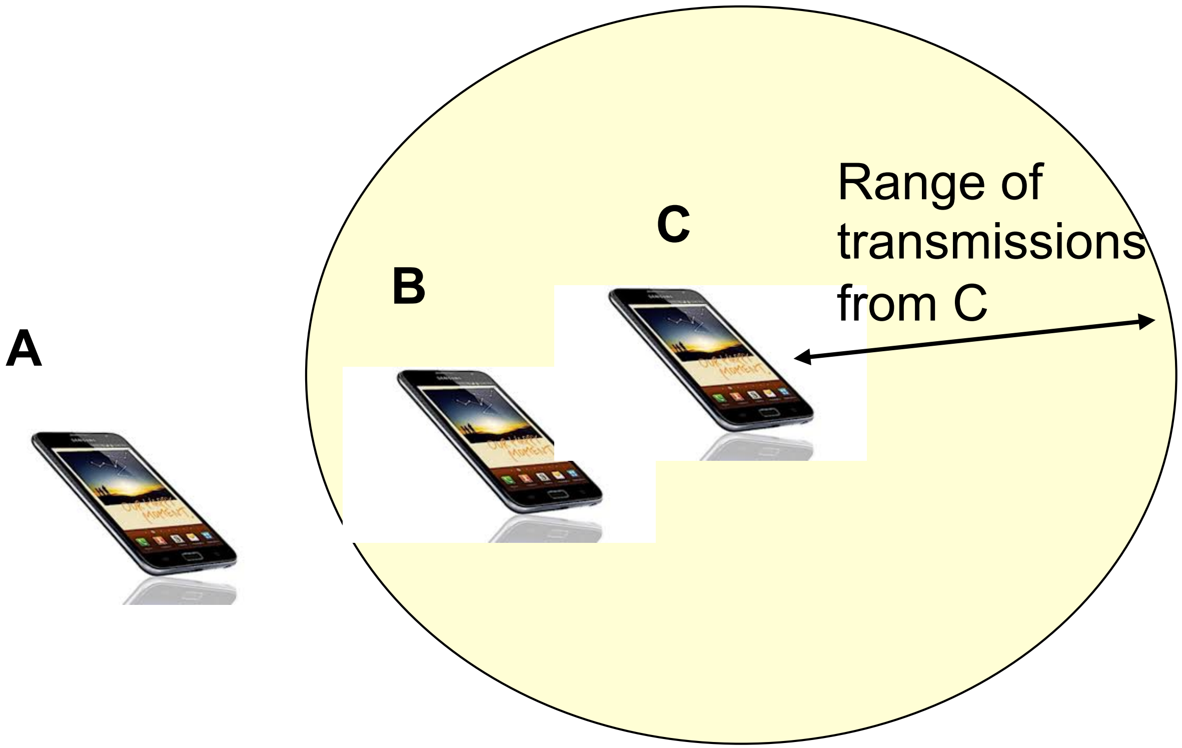
Wi-Fi contention mode

- Uses real channel sensing, i.e.
  - Sense the channel, & if it is free just start transmitting.
  - Collisions sensed at receiver at end of transmission.
  - Retransmission (with back-off) requested when needed.
- And virtual (RTS/CTS) channel sensing, i.e.
  - If A wants to transmit to B, it sends a short 'RTS' (request to send) control frame
  - If B is ready, it sends back a 'CTS' (clear to send) control frame.
  - A now sends its message frame & starts an ACK timer
  - When B receives frame, sends an ACK.
  - If A does not receive an ACK in time, it re-transmits.
  - When other users hear RTS or CTS, they set a 'network allocation vector flag (NAV) for a period of time.
  - No transmissions allowed while NAV is set. Devices can 'sleep''.

NAV

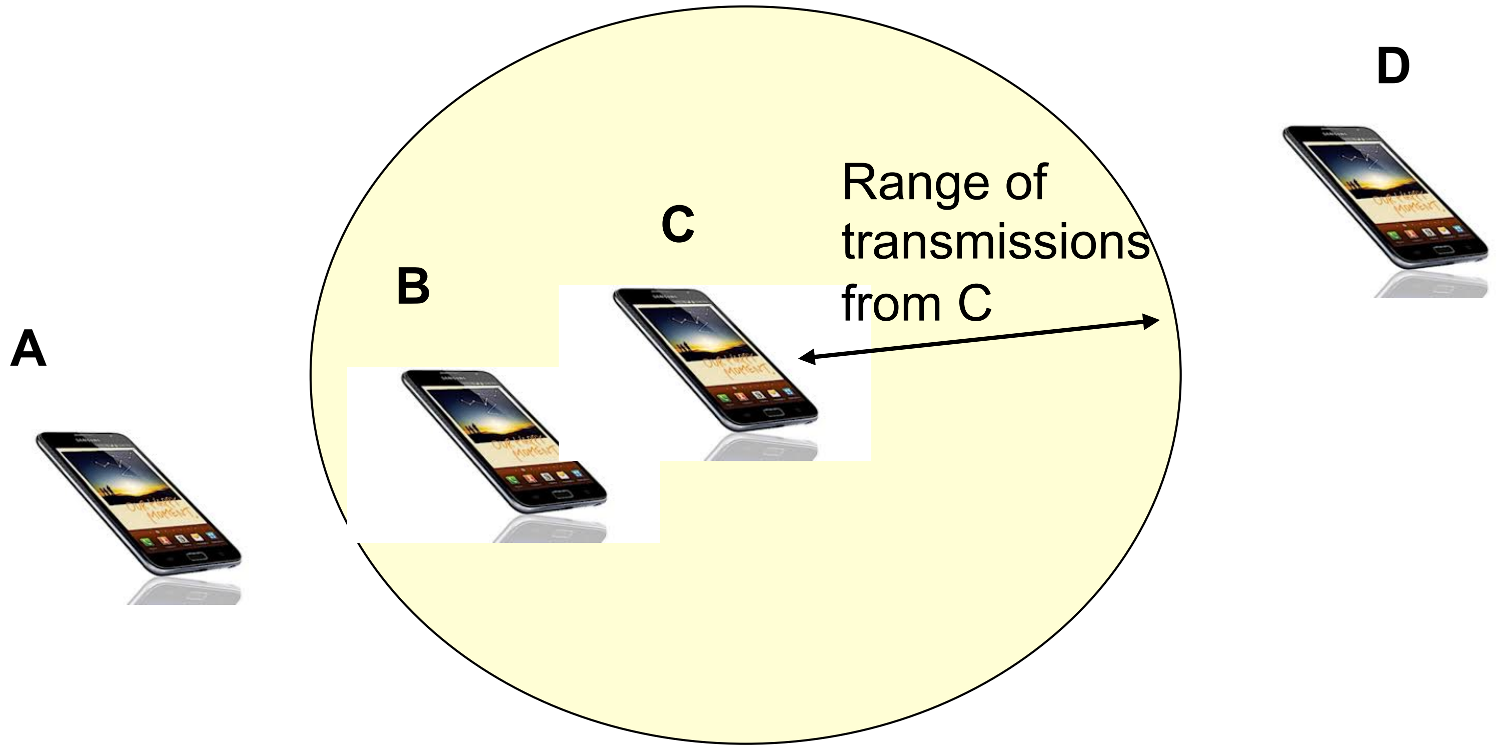
- NAV is a virtual ‘carrier sensing’ flag.
- The other devices are not sensing the carrier
- They are told to assume that the channel is busy.
- RTS/CTS also solves hidden & exposed device problems

Hidden device (station) problem



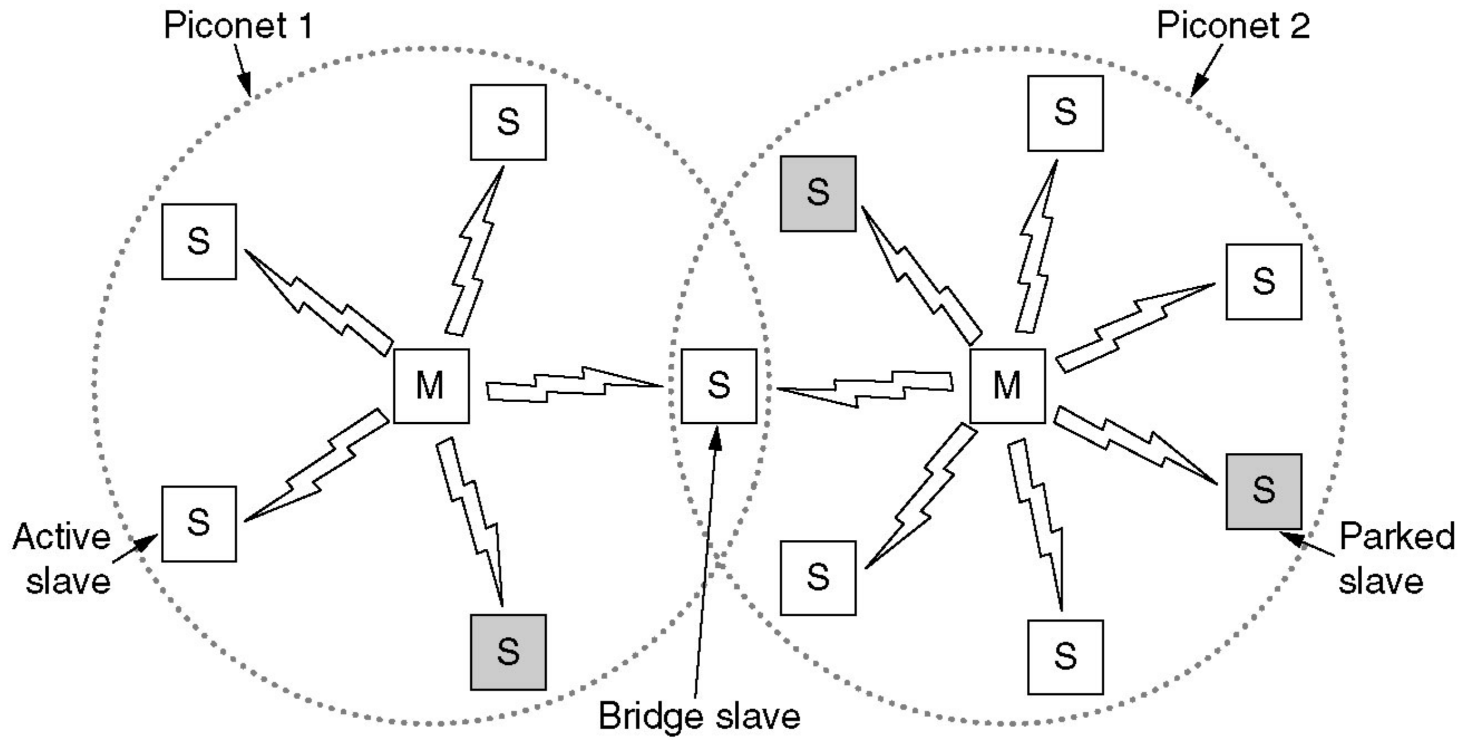
- A wants to transmit to B, but will not hear any transmissions from C.
- It may just assume channel is free and transmit.
- Messages from A and C will cause collision at B. This is bad.
- But assume A sends RTS to B while B is talking to C.
- B will not send a CTS, so there will be no transmission until B is ready.

Exposed device (station) problem



- B wants to transmit to A, who will not hear any transmissions from C.
- C may be transmitting to another station D
- B will assume channel is not free and than it cannot transmit.
- But it can transmit to A without interfering with C’s transmission to B
- Must think about this.

Bluetooth Architecture

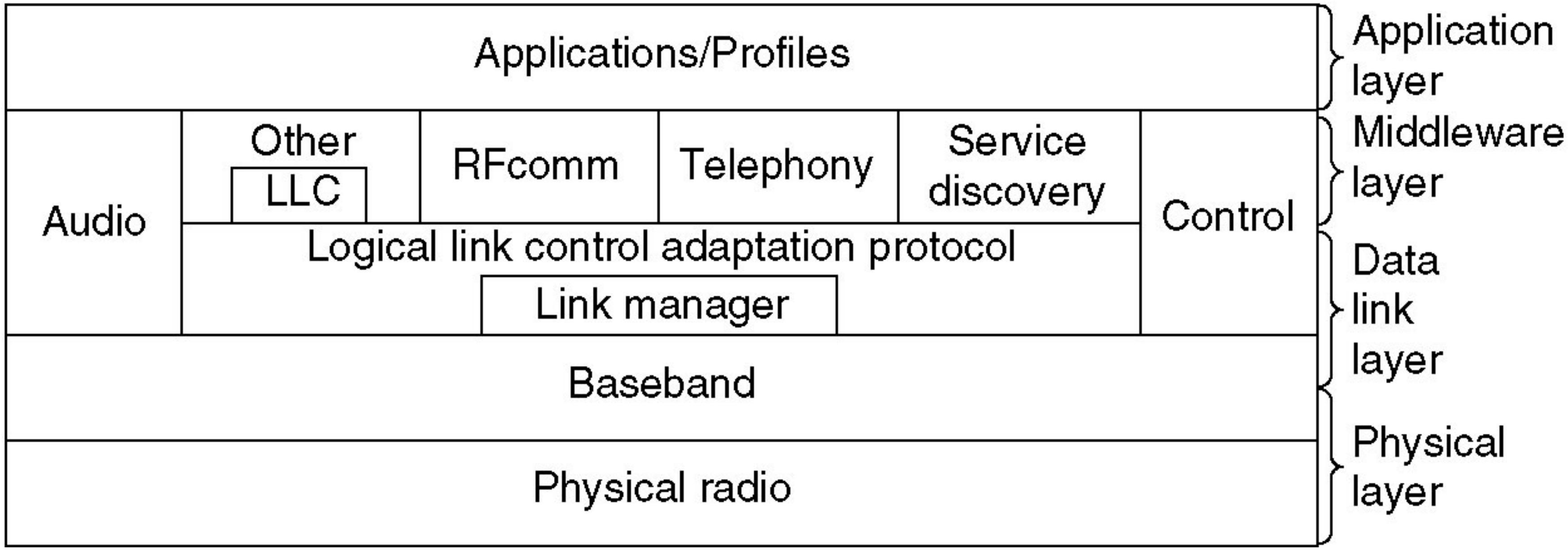


- Basic unit of a Bluetooth system is a pico-net
- Consists of a master node
- And up to 7 slaves within 10 m.
- Two piconets can be connected to form a ‘scatternet’
- See recommended text-book Tanenbaum
- PP 311-317 in Version 4.   PP 320-325 in Version 5

Bluetooth 'Profiles'

Name	Description
Generic access	Procedures for link management
Service discovery	Protocol for discovering offered services
Serial port	Replacement for a serial port cable
Generic object exchange	Defines client-server relationship for object movement
LAN access	Protocol between a mobile computer and a fixed LAN
Dial-up networking	Allows a notebook computer to call via a mobile phone
Fax	Allows a mobile fax machine to talk to a mobile phone
Cordless telephony	Connects a handset and its local base station
Intercom	Digital walkie-talkie
Headset	Intended for hands-free voice communication
Object push	Provides a way to exchange simple objects
File transfer	Provides a more general file transfer facility
Synchronization	Permits a PDA to synchronize with another computer

The Bluetooth Protocol Stack



The 802.15 version of the Bluetooth protocol architecture.

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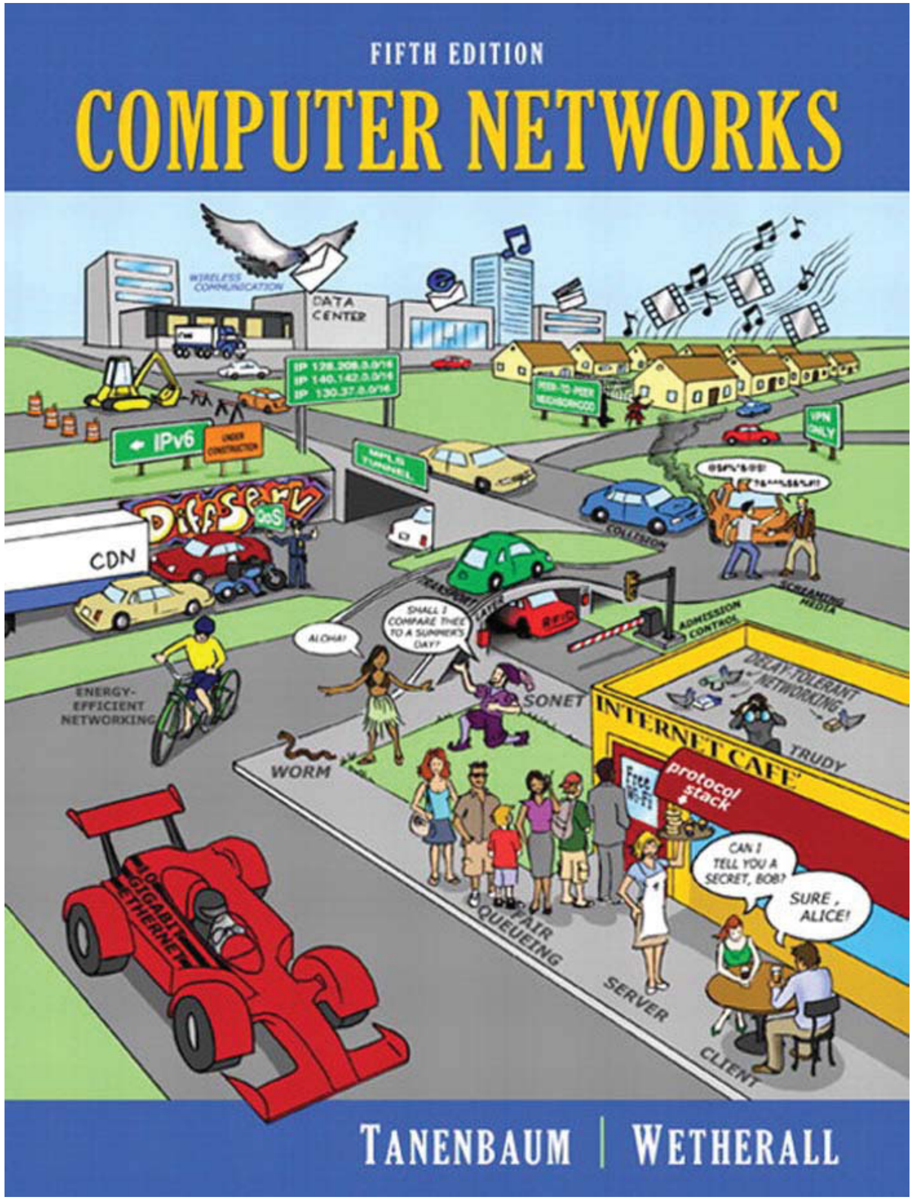
Text-book



Power modulation

- For mobile wireless communications
  - transmit power affects battery life
    - excessive transmit power also increases interference with other users
      - e.g. in cellular system with small cells
  - use the minimum power necessary
    - better error correction = lower power
      - reduce power until correctable errors occur?
    - trade-off of extra bits for higher redundancy...
      - better error correction
    - ...against lower energy/bit?

Summary

- Radio uses a shared broadcast medium...
  - normal broadcast network protocol issues apply
- ...but can have multiple channels...
  - using different frequency bands
- ...and has complex spatial properties.
  - transmissions have limited range
- There are many ways of using this resource
  - cellular telephony, Bluetooth, WiFi, car remotes, ...
- It is an unreliable medium
  - error detection and correction are important
- For mobile systems transmission power matters
  - it takes energy to send a bit of data a certain distance
  - power modulation, error correction, optimization