COS 140: Foundations of Computer Science

ALOHA Network Protocol Family

Fall 2018

Homework

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- Reading: Chapter 24 online
- Homework: end of Chapter 24, due 11/26

Introduction

Network Protocols

- *Protocol:* Set of rules that are followed to achieve some goal or to govern some interaction
- Network protocols: Followed by computers to allow intercommunication
- ALOHA protocols: one of the earliest network protocols
- Descendants include the Ethernet protocol

The Problem

- For local area networks (LANs), how do we connect the computers so that:
  - it is simple;
  - the communication channel is utilized efficiently;
  - necessary equipment is kept to a minimum; and
  - it is easy to add new computers without disrupting the LAN.

A solution: The Ethernet

- Most modern LANs use a bus architecture to solve the problem
- Benefits:
  - Little or no equipment other than the network cards themselves
  - Easy to add/delete computers
  - High speed
- Ethernet is the most commonly-used LAN protocol
  - Invented by Bob Metcalfe
  - Relatively simple
  - Capable of very high speeds (up to 100 Gbps)

ALOHA Protocols

- Ethernet is a descendant of one of the earliest LAN-like protocols, ALOHA
- One of the earliest, most successful *dynamic channel allocation methods*:
  - Addressed problem of allocating communication channel among set of transmitters/receivers
  - Also called *medium access control* (MAC) techniques
  - Also: multiple access (broadcast), rather than a point-to-point link
- Originally from packet radio; works well for satellite transmissions.
- Simpler than Ethernet – so a good place to start

ALOHA Basics

ALOHA station model

- *Stations* are independent computers (or terminals) used by users (now: *hosts* or *nodes*)
- Software on the stations generate *frames* (packets) for transmission
- The station sends the frame and blocks until it has been successfully transmitted

ALOHA channel model

- There is only one channel – all stations use this channel
- More than one frame is transmitted at the same time $\longrightarrow$ *collision*
- All stations can detect collisions (some variants of model)
  - In broadcast systems: listen to channel output – if not the same as sent $\Rightarrow$ collision
  - Also, if detect signal other than yours on the channel during frame transmission $\Rightarrow$ collision
- Assume no additional channel available for arbitration
- Assume the channel is error-free, except for collisions

ALOHA time models

- *Continuous time*: transmission can begin at any time
- *Slotted time*: time is divided into discrete slots, and transmissions begin at the start of a slot

Sensing the carrier

- In telecommunications, a basic waveform, the *carrier*, is *modulated* to encode the information
- *Carrier sense*: stations check to see if the channel is being used – don't attempt to use it until it becomes idle
- No carrier sense: stations do not check if the channel is busy before using it

Static vs. dynamic channel allocation

- *Static channel allocation*: make a decision on how to allocate the channel and stick with it
- *Dynamic channel allocation*: channel allocation can change as needed
- Static is simpler, but dynamic is more responsive to changing needs

Example: Static allocation methods

- *Frequency-division multiplexing (FDM)*:
  - Used (e.g.) for allocating telephone trunk lines
  - If have n nodes, give each its own $1/n$ section of the frequency bandwidth
- *Time-division multiplexing (TDM)*:
  - Also used for some telephone trunks, some network mechanisms (slotted ALOHA, e.g.)
  - Divide time into *frames*, divide frames into *slots*
  - Within each frame, a node has a slot it can use
  - Node has entire bandwidth during its slot
- Problems for computer networks: have *bursty* traffic and a changing number of users

ALOHA

The ALOHA System

- Created to link campuses of the University of Hawaii – on different islands
- Central computer also connected to ARPANET and PACNET
- Not truly a broadcast system – communication from a station to a central computer or from the central computer to a station – but shared spectrum, so same problems as broadcast
- Not truly a LAN (clearly not in the same building) – but used LAN technology to create a metropolitan area network (MAN)
- Computers connected by radio - two bands in UHF part of spectrum.

Collision detection in the ALOHA system

- ☐ One radio band used for communication from stations – there can be collisions on this band
- ☐ One band is used for communication from the central computer
- ☐ The central computer sends an ACK for messages it correctly receives
- ☐ If an ACK is not received by the station in some period of time, it assumes a collision has occurred
- ☐ Stations do not sense channel for communication to the central computer.
- ☐ Researchers later thought one channel would be better.

Pure Aloha

Pure ALOHA protocol

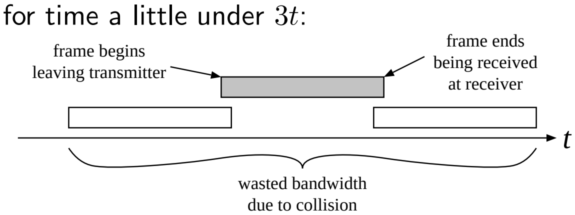
- ☐ A station sends a message whenever it has one to send
- ☐ If the transmission was successful, done
- ☐ If there is no ACK after some period of time, assume collision and retransmit
  - *Propagation delay*
  - How long to wait?
  - When to retransmit?

Random backoff

- *Backoff:* time to wait before retransmitting
- ALOHA used *random backoff* – why?
- Which probability distribution to use?
- *Binary exponential backoff:* retransmit, but each time there's a collision, double the average time of the delay

Efficiency of pure ALOHA

- If even one bit of overlap $\longrightarrow$ retransmit frame
- Assume frames are all the same size and take the same amount of time t to send.
- A frame can cause collisions for time a little under $3t$:



- If rate of sending is same for all users, the best channel utilization is about 18%.
- If users have different rates of use, throughput higher because communication can be bursty – all users not trying to send at the same time.

Slotted ALOHA

Slotted ALOHA

- □ Attempt to improve pure ALOHA.
- □ Divide channel into uniform *slots*, each of which is size of frame transmission time
- □ Frames can only be sent at the beginning of a slot – need clock sync
- □ Now, when there's a collision, frames completely overlap — wasted channel time $= t$, not $3t$
- □ Better throughput than pure ALOHA: ~37%

Carrier Sense Protocols

Carrier sense protocols

- □ Problem with pure ALOHA: poor channel utilization
- □ Can do better if can sense the medium to determine if busy
- □ *Carrier sense protocols*: like pure ALOHA, but can detect if carrier in use before transmitting
- □ E.g., carrier sense multiple access (CSMA)

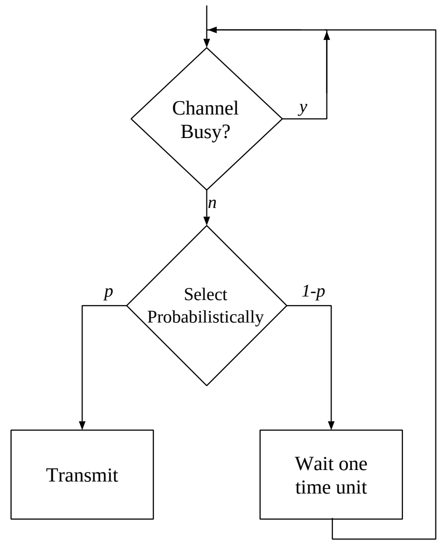
Propagation delay (again)

- Takes a finite amount of time to send signal from one place to another: the *propagation delay*
- Propagation in most media roughly the speed of light (approx. 3×10^8 m/s)
- Propagation delay roughly 1 ns/foot
  - Negligible for most LANs (order of 1 μs)
  - For WAN, can be considerable: ms to tenths of seconds
- Determines how long from time a station begins transmitting until another detects it
- Longer propagation delay $\rightarrow$ increased probability of collisions

1-Persistent CSMA

- The "1" refers to probability that station will transmit when channel is free, so:
  - If channel free, transmit
  - If channel busy, wait – transmit as soon as sense the channel free
- Collisions can occur:
  - due to propagation delays
  - when several stations, which are waiting, all transmit when channel becomes free

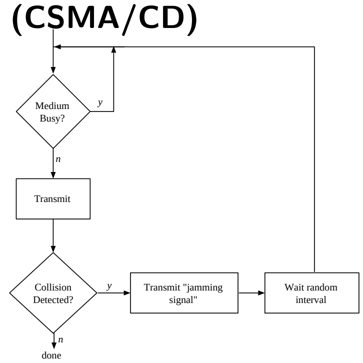
p-Persistent CSMA



Nonpersistent CSMA

- If channel is busy: wait a random time before trying again.
- Reduces collisions because reduce likelihood that waiting stations will collide when channel becomes idle.

CSMA with Collision Detection (CSMA/CD)



- Stop transmitting as soon collision detected
- Increases useful bandwidth by reducing the time wasted sending pieces of frames that have been ruined by collisions.
- Efficiency depends on propagation time (must wait for information about collision to propagate back to sender).

Ethernet

- CSMA/CD, IEEE 802.3
- Comprises bottom layers of OSI reference model:
  - Data link: MAC-client, Media Access (MAC) layers
  - Physical: Physical (media-specific)
- Many forms: 10Base-T 100Base-T2 (Fast Ethernet), 1000Base-LX (Gigabit Ethernet), ...
- Frame:

Preamble	Start-of-frame	Dest.	Source	Length/Type	Data+Pad	Check codes

- Clock synchronization via pattern of bits in frame's preamble
- Star topology (with switches) vs bus topology (with bridges)
- Full-duplex vs. half-duplex