TDMA

- TDMA (Time Division Multiple Access)
  - assign the fixed sending frequency to a transmission channel between a sender and a receiver for a certain amount of time
- No need to tune to a certain frequency.
- Simple transmitters and receivers.
- Almost all MAC schemes for wired network use TDMA, e.g., ethernet, Token ring, ATM.
- Fixed allocation v.s. dynamic allocation.
Fixed TDM

• Allocate time slots in a fixed pattern.
  – Fixed bandwidth for each user.
  – Simple, each mobile phone knows its turn, which is assigned by the base station.
  – Fixed delay.
  – Used in a number of phone systems.
  – Good for connections with a fixed rate, e.g., voice.
  – Inefficient for busty data or asymmetric transmissions.
TDD/TDMA - general scheme, example DECT

• DECT: each user is guaranteed access every 10 ms.
Aloha

- Time division multiple access without control.
- Invented by U. of Hawaii
- Used in ALOHANET between Hawaii islands.
- Random access scheme.
- Aloha does not coordinate nor resolve contention.
- If multiple stations access the medium at the same time, a collision happens, data is destroyed.
- Resolving packet loss is left to upper layers.
Aloha

- Random access, no central control.
- Very simple.
- Works fine for a light load.
- No delay guarantee

- Protocol:
  - Whenever a station has data, it transmits immediately
  - Receivers ACK all packets
  - No ACK = collision. Wait a random time and retransmit
Aloha and slotted aloha

- Slotted aloha: transmissions are synchronized and only start at the beginning of a time slot.
Fixed assignment v.s. random access

• Voice and data have different characteristics
  – Voice: continuous, steady rate.
  – Data: bursty, assymetric.

• Fixed assignment: resource is assigned at the beginning of the connection and is held throughout the lifetime.
  – Suitable for voice
  – Examples: TDMA, FDMA, CDMA
  – High throughput in high load, uniform traffic.
Fixed assignment v.s. random access

• Random access: resource is assigned per packet.
  – Contention: compete for resources.
  – Assignment is done in a distributed, random fashion.
  – Collision can happen, delay is not guaranteed.
  – Suitable for data – bursty traffic.
  – Throughput is low compared with fixed assignment, especially at high load. ➔ lots of collisions
  – Handles non-uniform data traffic much better.
Aloha

• How well does it work?
• What is the throughput?

• Throughput = \# packets transmitted/ total \# packets allowed.
• Throughput (Aloha) = 18%.
• Throughput (Slotted aloha) = 36%.
  – Packets either collide completely or do not collide at all.
Analysis of pure Aloha

- A packet will be in a collision if and only if another transmission begins in the vulnerable period.
- Vulnerable period has the length of 2 packet times.
Analysis of pure Aloha

• Assume that there are a large number (N) of users in the network
• All users transmit packets with a fixed (average) length of T seconds
• Each user transmits with a fixed probability (p) in the time period (T)
• Thus, the average number of packets transmitted in the system in the time period T will be R=NP.
Analysis of pure Aloha

- “Danger” period for a user’s transmission starts $T$ seconds before it initiates its transmission and ends $T$ seconds after it completes its packet.
- During this time period of $2T$, the average number of packets transmitted will be $E = 2Np = 2R$.
- A Poisson probability distribution indicates the probability of $k$ events occurring in a “unit time”.

$$p(k) = \frac{E^k e^{-E}}{k!}$$
Analysis of pure Aloha

• For transmission to be successful, no other user should transmit during the unit time of interest (2T). Thus the probability of a successful transmission will be

\[ p(k=0) = e^{-E} = e^{-2R} \]

• Therefore, the system throughput for the time period T will be

\[ S = \# \text{ transmission attempts in time period } T \times \text{ probability of successful transmission, or} \]

\[ S = R e^{-2R} \]
Analysis of pure Aloha

• Optimum Throughput occurs at R=0.5 or when

\[ N = \frac{1}{2p} \]

• Average number of attempts to ensure successful transmission is

\[ N_{av} = \sum_{i=1}^{\infty} n(1 - e^{-2G})^{n-1} e^{-2G} = e^{2G} \]

\[ N_{av}^{Optimum} = 2.72 \text{ attempts} \]
Pure Aloha

Ideal (no collisions): $R$

Pure ALOHA: $Re^{-2R}$
Slotted Aloha

- Enhancement of pure ALOHA in that users can only start to transmit so that it arrives at the beginning of defined time slots of duration $T$
- “Danger” period for this system is only the $T$ seconds prior to the start of the user’s frame and thus $E=Np$ and $S=Re^{-R}$
- For this system, optimum throughput occurs if $R=1$. 
Aloha, slotted aloha

Throughput (ALOHA)

Ideal (no collisions): $R$

Slotted ALOHA: $R^{-R}$

Pure ALOHA: $R^{-2R}$
Efficiency of slotted Aloha

- Successful throughput $S$ read from graph (e.g. $S_{\text{optimum}} = 0.368$ or 36.8% of timeslot contain successful transmissions)
- Number of frames with no transmissions can be found from Poisson distribution $p(k=0) = 0.368$ or 36.8% slots
- Remaining time slots must contain collisions
Summary

- Aloha and slotted aloha are simple schemes suitable for light traffic.
- What about heavy traffic?
- Next lecture
  - Reservation
  - Carrier sensing
  - 802.11