# COMP28411 Computer Networks
# Lecture 15

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Link Layer - 2

Some material from:

Kurose & Rose – Chapter 5 + Slides



## Overview

- More about Switches, Routing and Local Area Network (LAN) addresses.
- Multiple access – sharing a network.
- Collisions and channel partitioning.
- Random Access protocols:
  - Aloha
  - Slotted Aloha
  - Carrier Sense Multiple Access (CSMA) with Collision Detection (CD) – hence CSMA/CD
  - CSMA with Collision Avoidance (CA) – hence CSMA/CA
    - Used in wireless IEEE 802.11 (WiFi).



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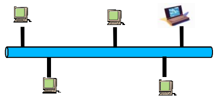
# Multiple Access

PPP extends the older HDLC. More later

**Two main types**:

- Point-to-Point (P2P)
  - Single sender + single receiver direct.
  - Point to Point (PPP) and High Level Data Link Control (HDLC) protocols over ADSL (PPPoA) or VDSL (PPPoE)
- Broadcast



  - Single shared broadcast channel.
  - Ethernet (up to 100Mbps) and Wireless
  - Everybody could speak or transmit at the same time – interference.
  - Analogies:

    - Party: Lots of people talk at the same time.
      - Rely on Signal to Noise and Interference ratio (SNIR) to listen and understand.

    - Classroom: Teacher and students (mostly) take it in turns to talk.
      - Mainly – Half Duplex.

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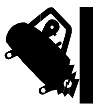
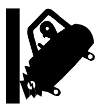
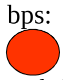


# Collision

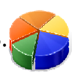


- On a broadcast channel: whenever more than 2 nodes transmit at the same time.

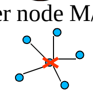
  - This is wasted resource. Will have to throw away or re-transmit.
  - More nodes + more traffic = more collisions = wasted bandwidth!
  - Therefore need coordination – Medium Access Control (MAC) protocol.
  - Three main categories of MAC:
    1. **Channel partitioning**
    2. **Random access**
    3. **Turn taking**
- Ideal Characteristics for channel with bandwidth B bps:
  - Only one node with data – uses total bandwidth B.



  - M nodes with data sharing – average throughput per node M/B.



  - Decentralized – no single point of failure.



  - Simple – inexpensive.

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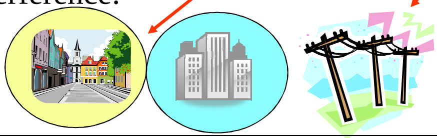
## Channel Partitioning

- Avoiding Interference:
  - Space:

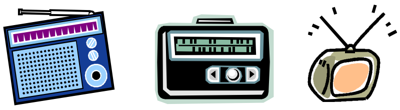


No Overlap

Separate wires, little or no crosstalk

Space Division Multiple Access (SDMA)

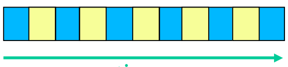
  - Frequency:



Frequency Division Multiple Access (FDMA)

  - Time:

Schedule – Assign slots



time

Time Division Multiple Access (TDMA)

  - Code:

Jim + Mary talk in French
Zuo and Chai talk in Chinese
They can hear each other over the background noise

3G phones use Code Division Multiple Access (CDMA)

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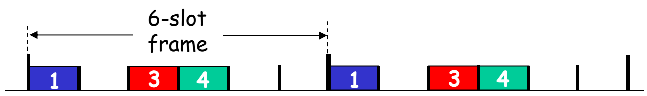
## Channel Partitioning MAC protocols: TDMA

### TDMA: Time Division Multiple Access

- Access to channel in "rounds“.
- Each station gets fixed length slot (length = packet TX time) in each round.
- Unused slots go idle.
- “2G” mobile phones, GSM uses TDMA with 8 slots per channel. But often several channels in a given space = cell.
- Example: 6-station LAN, 1,3,4 have pkt, slots 2,5,6 idle

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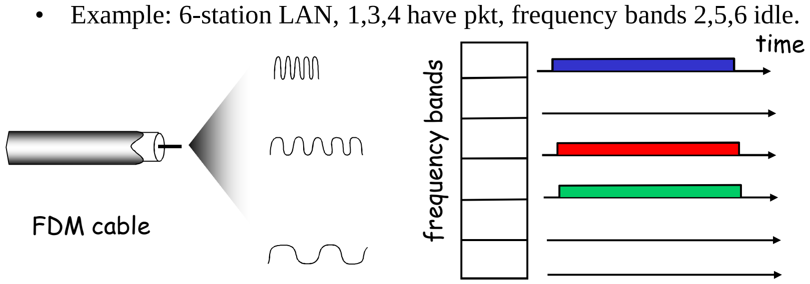
## Channel Partitioning MAC protocols: FDMA

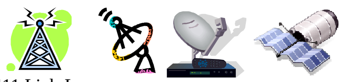
Remember: we use frequency in cables as well as for wireless.

### FDMA: Frequency Division Multiple Access

- Channel spectrum divided into frequency bands.
- Each station assigned fixed frequency band.
- Unused transmission time in frequency bands go idle.
- Example: 6-station LAN, 1,3,4 have pkt, frequency bands 2,5,6 idle.




- Same thing for wireless channels!



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## Random Access Protocols

Useful when:
- Must share
- Not much traffic.
- Collisions not very likely.
- Control difficult
- Cheap/simple

- **When node has packet to send**
  - **Transmit at full channel data rate R.**
  - **No *a priori* coordination among nodes**
- Two or more transmitting nodes = “collision”
- Random access MAC protocol specifies:
  - How to detect collisions
  - How to recover from collisions (e.g., via delayed retransmissions)
- Examples of random access MAC protocols:
  - **ALOHA**
  - Slotted ALOHA
  - CSMA, CSMA/CD (Old Ethernet), CSMA/CA (WiFi)

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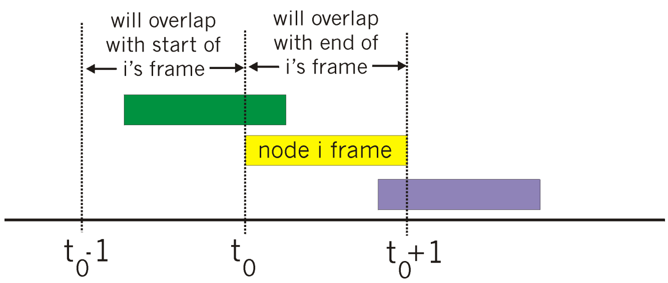
# Pure (unslotted) ALOHA

- Pure Aloha: no synchronization!
- When frame first arrives
  - Transmit immediately
- Collision probability:
  - Assuming fixed sized frames.
  - Frame sent at $t_0$ collides with other frames sent in $[t_0-1, t_0+1]$
  - Each frame is vulnerable to collision for twice its length!






# Pure Aloha Efficiency

$e \approx 2.71828 \approx \sum 1/n!$
Is Euler's number.

Few users or little traffic:

Very successful as few collisions. With more users and traffic…….

P(success by given node) = P(node transmits) **times**

P(no other node transmits it's in $[t_0-1, t_0]$ **times**

P(no other node transmits it's in $[t_0, t_0+1]$

$= p * (1-p)^{N-1} * (1-p)^{N-1}$

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

Probability series independent events is p(1) x p(2) x... x p(n) which is $p^n$.

Lots of nodes.

… choosing optimum p and then letting N ➔ infinity ...

= 1/(2e) = .18 or roughly 18% efficiency (= success rate!).

**1/e** is the answer to the secretary problem. See: http://en.wikipedia.org/wiki/Secretary_problem. Here we select 2 secretaries. For slotted Aloha only 1 secretary so the analogy is much easier to see.

*At best:* channel used for useful transmissions 18% of time! !



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# Slotted ALOHA

<u>Assumptions:</u>

- All frames same size
- Time divided into equal size slots (time to transmit 1 frame)
- Nodes start to transmit only at slot beginning
- Nodes are synchronized
- If 2 or more nodes transmit in the same slot, all nodes detect a collision.

<u>Operation:</u>

- When node obtains fresh frame, transmits in next slot
  - *If no collision:* node can send new frame in next slot
  - *If collision:* node retransmits frame in each subsequent slot with probability P until success

Implies shared or central clock to ensure synchronization.



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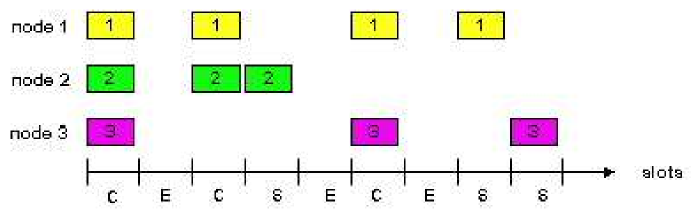
# Slotted ALOHA




<u>Pros</u>

- Single active node can continuously transmit at full rate of channel.
- Highly decentralized: only slots in nodes need to be in sync.
- Simple.

<u>Cons</u>

- Collisions, wasting slots
- Idle slots
- Nodes may be able to detect collision in less than time to transmit a packet.
- Clock synchronization



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## Slotted Aloha efficiency

**Efficiency** : Long-run fraction of successful slots (many nodes, all with many frames to send)

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

- Max efficiency: 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 ($\infty$), gives:

Max efficiency = 1/e = .37

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

!

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## CSMA (Carrier Sense Multiple Access)

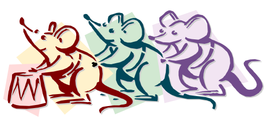
Instead of central control and synchronization.

**CSMA:** Listen before transmit:

If channel sensed idle: Transmit entire frame

- If channel sensed busy, defer transmission – queue.

- Human analogy: don't interrupt others!



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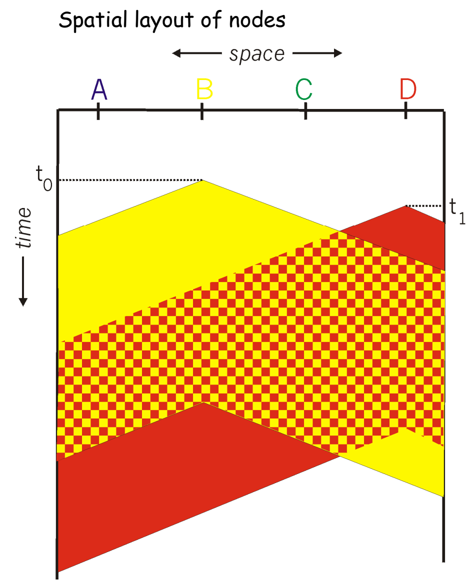
## CSMA collisions

Collisions *can* still occur:
Propagation delay means two nodes may not hear each other's transmission.

Collision:
Entire packet transmission time is wasted. Always?

Note:
Role of distance & propagation delay in determining collision probability.

Scenario:
B starts at $t_0$. D starts at $t_1$ before hearing B........

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## CSMA/CD (Collision Detection)

CSMA/CD: Carrier sensing, deferral as in CSMA.

- Used in Ethernet. Required at start so wire could be shared. 100Mbyte and above speeds do not share anymore!
- Collisions *detected* within short time. By listening
- Colliding transmissions aborted, reducing channel wastage.

- Collision Detection (CD):
  - Easy in wired LANs: Measure signal strengths, compare transmitted and received signals – Not much difference = OK
  - Difficult in wireless LANs: Received signal strength overwhelmed by local transmission strength – Due to inverse square law!
- On <u>wireless</u> use **CA** (Collision Avoidance)
  - **If listen to own transmission will destroy the transmitter due to too much power.**
  - Listen, random back-off after busy medium BUT **cannot detect collisions at the transmitter** until someone else tells you! e.g. No ACK

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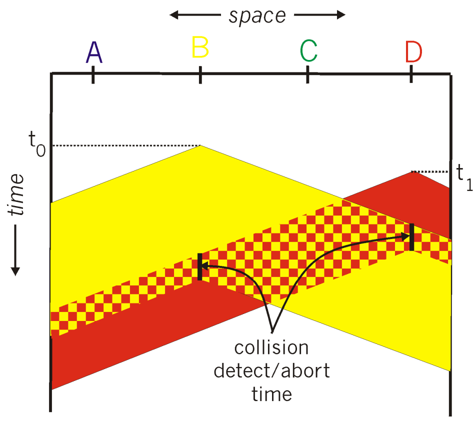
## CSMA/CD collision detection




- Both B and D are Idle.
- Both start to send leading to **collision**!
- CD detects overlap – 2 signals at same time – Change in signal strength.
- Can cut short the now useless transmission.
- How ensure others know a collision occurred?

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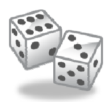
## "Taking Turns" MAC protocols - now mainly for wireless

Channel partitioning MAC protocols:

- Share channel *efficiently* and *fairly* at high load
- Inefficient at low load: Delay in channel access, 1/N bandwidth Allocated even if only 1 active node! Redundancy.

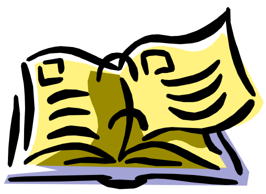
Random access MAC protocols



- Efficient at low load: single node can fully utilize channel
- High load: High collision probability and overhead – re-send.

"Taking turns" protocols

Look for best of both worlds!



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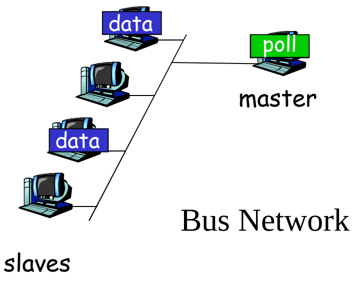
## "Taking Turns" MAC protocols

**Polling:**

- Master node "invites" slave nodes to transmit in turn.
- Typically used with "dumb" slave devices – not necessarily though.
- Concerns:
  - Polling overhead
  - Latency/delays
  - Single point of failure (master)



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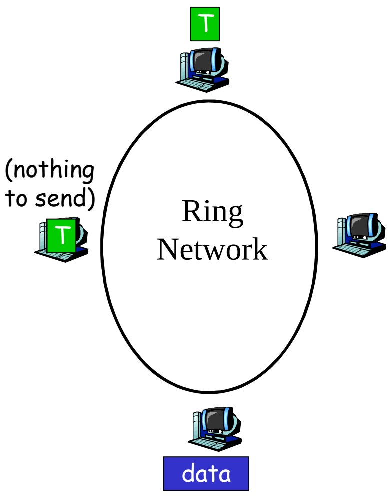
## "Taking Turns" MAC protocols

**Token passing:**

- Control **token** passed from one node to next sequentially.
- Token message
- Concerns:
  - Token overhead
  - Latency/delays
  - Single point of failure
    - Token
    - Broken ring



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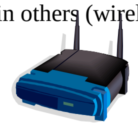
## Summary of MAC Protocols

- ***Started by*** ***looking at MAC addressees and the IP to/from MAC mapping called ARP.***
- ***Channel partitioning,*** by space, time, frequency or code
  - Space Division, Time Division, Frequency Division, Code Division - Multiple Access – SDMA. TDMA, FDMA, CDMA.
- ***Random access*** (dynamic),
  - ALOHA, Slotted-ALOHA, CSMA

  - Carrier sensing: easy in some technologies (wire), hard in others (wireless)
  - CSMA/CD used in Ethernet
  - CSMA/CA used in 802.11. CA = Collision Avoidance.
    - Why not CD?



- ***Taking turns***
  - Polling from central site, token passing
  - Bluetooth, FDDI, IBM Token Ring

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## Questions ?

- Why are collisions very unlikely when Gigabit Ethernet is used?
- What does CSMA stand for?
- What does CDMA stand for? **(Not “Collision”!)**
- Why is SDMA so useful for wireless systems?
- If random access protocols are so inefficient, why are they used?
- When does a mobile phone use:
  - TDMA?
    - What other multiplexing methods does it also use?
  - CDMA?
    - What other multiplexing methods does it also use?
  - Slotted Aloha?

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