CS4457 Lecture 4

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1 Problem

We want to be able to play two different signals at the same time. However, two possible scenarios can occur:

- Interference occurs to a signal when another signal is partially overlapped in the same frequency channel, which distorts the signal
- Jamming occurs when the second signal completely overlaps and overpowers the first signal in the frequency channel. In this case, only the audio from the second signal can be heard

Because of interference and jamming, we want an algorithm to determine how multiple signals can transmit at the same time.

2 Multiple Access Protocol

Multiple Access Protocol is a distributed algorithm that determines how nodes share a channel (determine when a node can transmit). Any communication about channel sharing must occur within the channel itself, which means that no out-of-band channel can be used for coordinating channel sharing.

For a given broadcast channel with rate R bits per second (bps), an ideal multiple access protocol would have the following attributes:

- When one node wants to transmit, it can send at rate R.
- When M nodes wants to transmit, each node can send at an average rate of R/M.
- The protocol would be decentralized such that no special node is required to coordinate transmissions and synchronization of clocks and slots are unnecessary.
- The protocol should be simple.

There are three broad classes of MAC protocols:

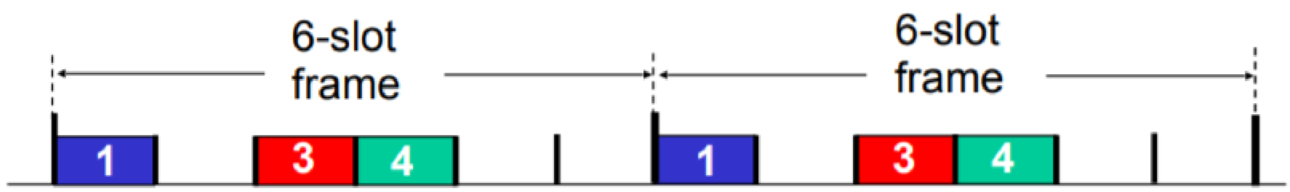
- Channel Partitioning
- Random Access
- "Taking Turns"

3 Channel Partitioning

The concept of channel partitioning is to divide the channel into smaller sections (by time or by frequency). Each section is given to a node for exclusive use.

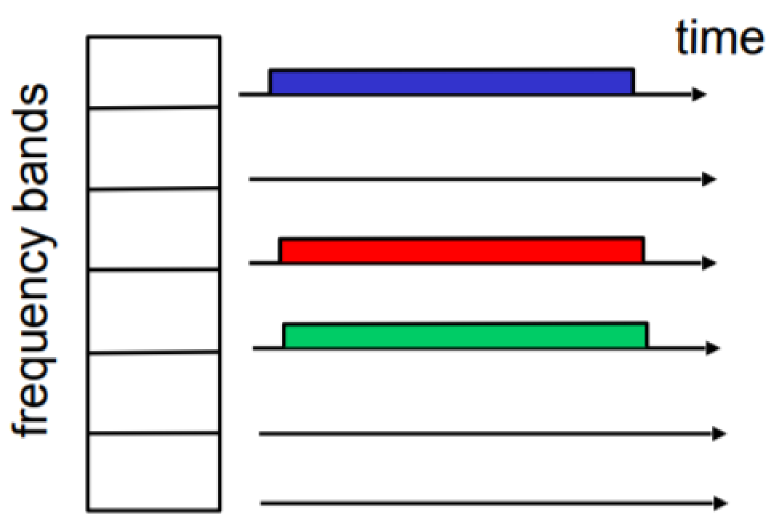
3.1 Time Division Multiple Access

In Time Division Multiple Access (TDMA), each station gets a fixed time slot to transmit. Unused slots are idle. For a phone call, 64kb/s is needed. In an example where TDMA is used for 6 nodes, an aggressive coding scheme is needed to encode the information in $1/6^{th}$ the amount of time. Telephone Networks uses the TDMA modulation scheme. The following figure shows a 6-station LAN where slots $1, 3, 4$ have packets and slots $2, 5, 6$ are idle



3.2 Frequency Division Multiple Access

In Frequency Division Multiple Access (FDMA), the frequency spectrum is divided for each station to transmit. The transmitting stations can transmit at the same time, but at different frequencies to prevent interference or jamming. Unused frequency channels will be idle. Radio Stations use the FDMA modulation scheme. In the following graphic, a 6-stations LAN is show where frequency bands $1, 3, 4$ have packets, and frequency bands $2, 5, 6$ are idle.



4 Random Access

With Random Access protocols, there is no coordination between nodes on when to send, so nodes transmit at the full channel rate when they need to. If there is a collision (two nodes transmitting at the same time), the nodes detect the collision and determine how to recover from the collision (through delayed re-transmissions). Examples of random access MAC protocols:

- Slotted ALOHA
- ALOHA
- CSMA, CSMA/CD, CSMA/CA

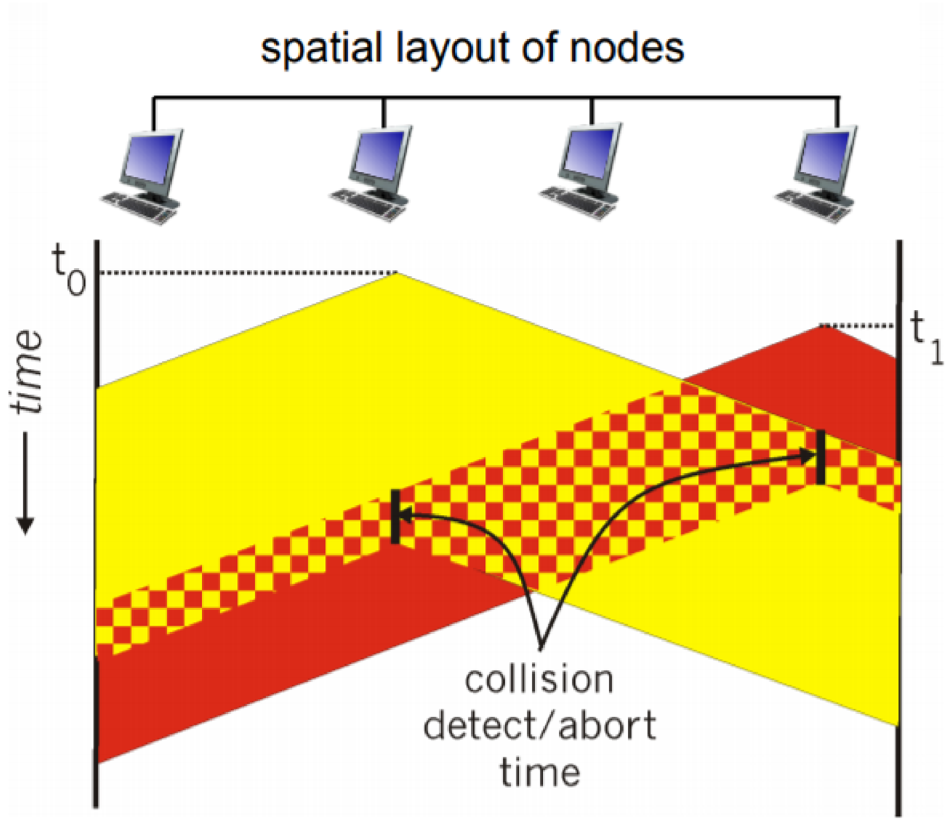
4.1 Carrier Sense Multiple Access (CSMA)

The concept with Carrier Sense Multiple Access (CSMA) is to not interrupt other nodes. A node should first check if the channel is idle or busy. If the channel is idle, the node can transmit. If the channel is sensed to busy, the transmission should be deferred. This is analogous to people not interrupting each other when one is speaking.

4.1.1 CSMA Collision Detection

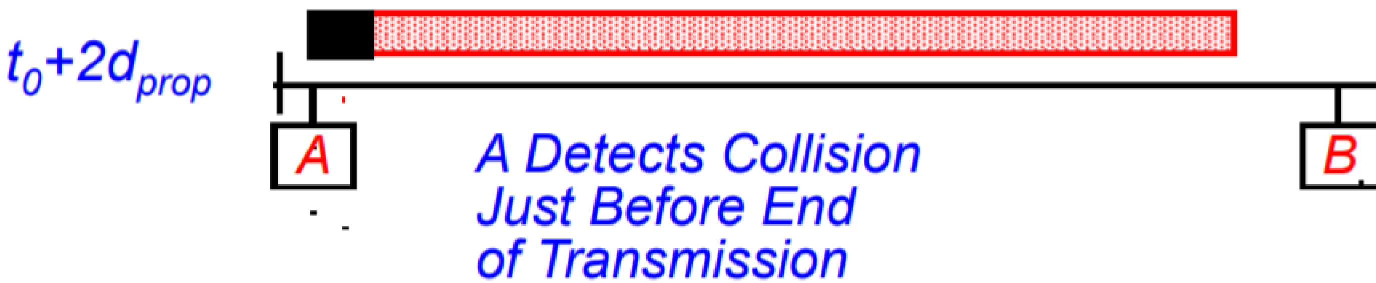
Even with CSMA, collisions can still occur. Due to propagation delay, a node may not hear another node's transmission before deciding to transmit. If a node senses another node's transmission while it is transmitting, it knows there is a collision and should stop transmitting. This collision detection is easier in wired LANs than wireless LANs because it is easier to compare the received signal with the transmitted signal to determine a collision.

As shown in the picture below, one node starts to transmit at t_0. This signal does not reach the node on the right in time. The node on the right starts to transmit at t_1. Eventually, the transmissions propagate and the nodes detect collisions. Once a collision is detected, the transmission is aborted.



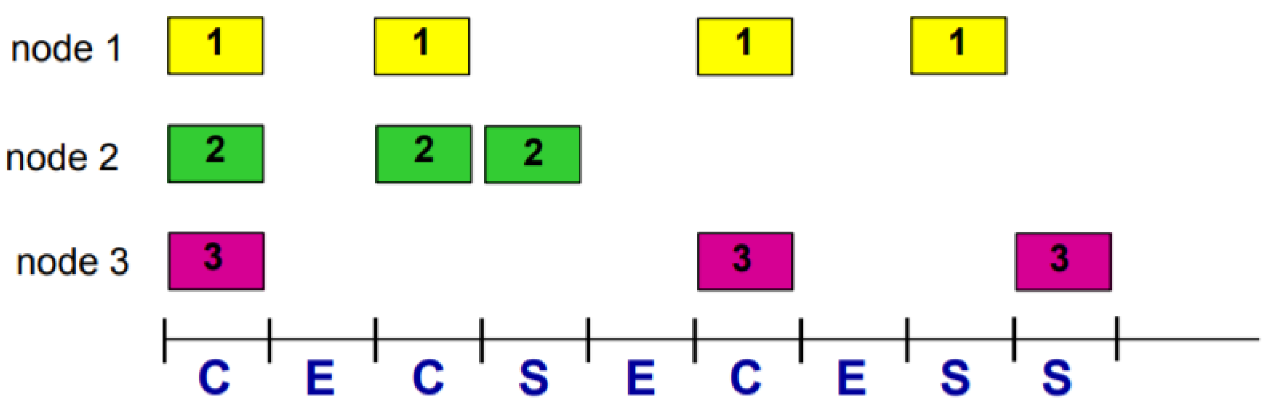
4.1.2 Ethernet CSMA/CD

Ethernet uses CSMA/CD algorithm. First the NIC card of a node receives a datagram from the network layer and creates a frame. The NIC card then senses the channel on the link layer. If it is idle, it transmits the frame. If the NIC card detects a collision while transmitting it aborts and sends a jamming signal. This jamming signal ensures that the other transmitting nodes also abort. After aborting, the NIC enters binary (exponential) backoff. After the m^{th} collision, the NIC card chooses a K at random from $1, 2, 3, ...2^m - 1$. The NIC waits K time slots before trying the transmit again. The length of the transmission frame needs to be at least twice the maximum propagation delay so that the NIC card can detect a collision.



4.2 Slotted ALOHA

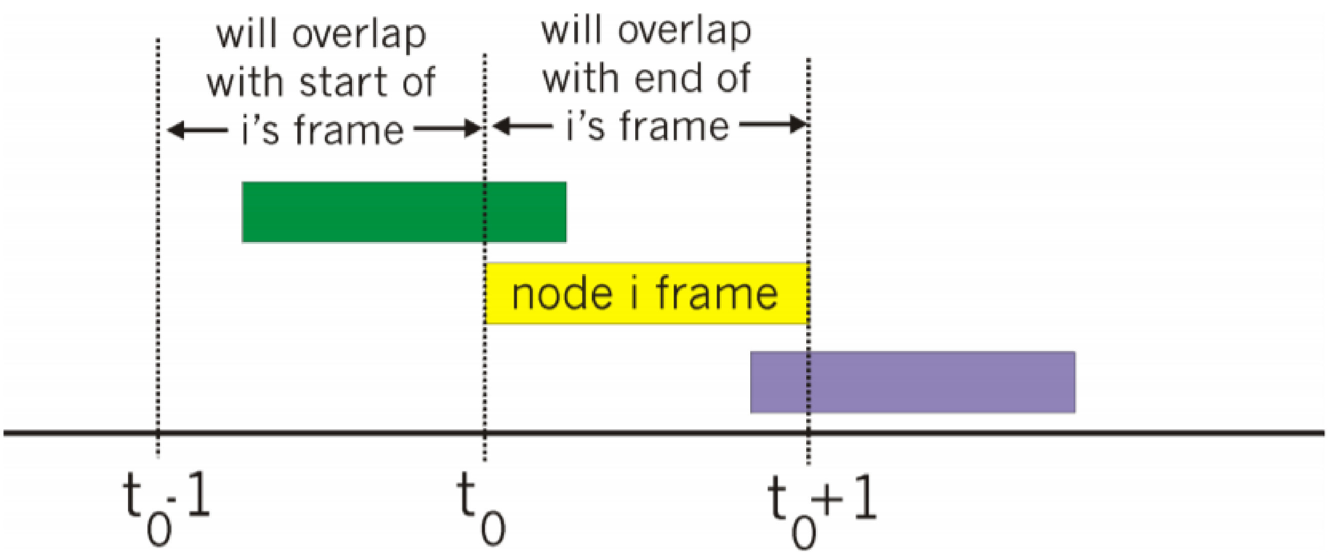
In Slotted ALOHA all of the frames are the same size and time is divided into equal slots. Nodes are synchronized to start their transmits at the start of slots. Whenever a node receives a new frame, it transmits at the next slot. If there is a collision, the node transmits again at subsequent slots with a probability of p.



With slotted ALOHA there are a lot of idle slots as well collisions(wasted slots). At best, the channel has useful transmissions 37 percent of the time.

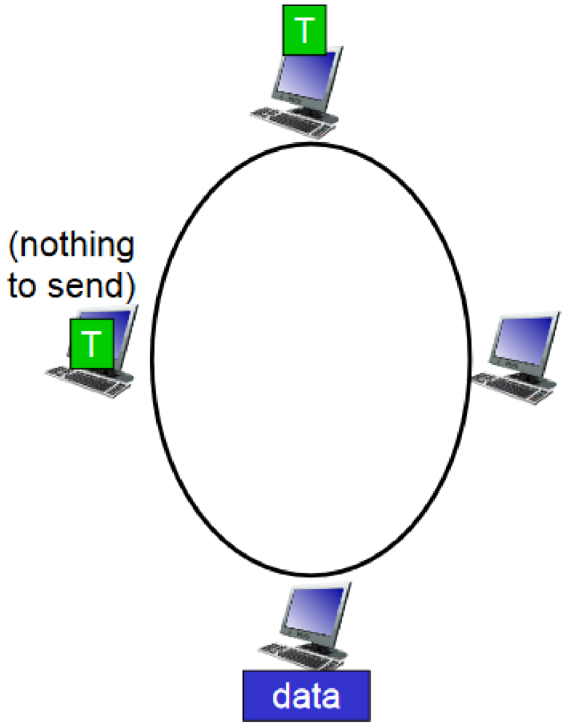
4.3 Pure ALOHA

Pure ALOHA is ALOHA without the synchronization of time slots. Nodes just transmit when they receive a frame and handle collision in a similar way to slotted ALOHA. This method has a higher collision probability than Slotted ALOHA and the channel has useful transmissions only 18 percent of the time.



5 Taking Turns

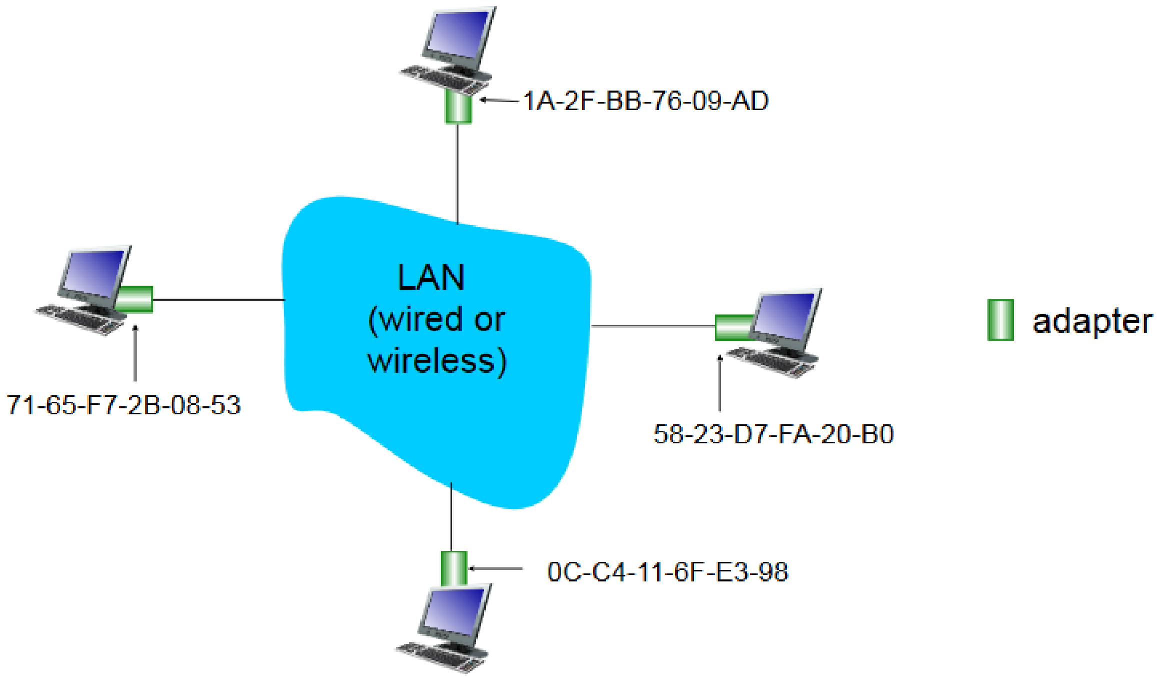
For "Taking Turns" MAC protocols, a control token is passed to a series of nodes in sequential order. This control token allows a node to transmit data throughout the network. If the node has nothing to send, then the control token is passed to the next node. The following figure is an example of this process:



An alternative strategy is to have a central node that polls the other nodes in the networks to see if they need to transmit any data. If so, the central node gives that node the control token to allow that node to transmit data. Examples of the "Taking Turns" protocol include Bluetooth, Token Ring, and FDDI. Both protocol strategies, however, have a disadvantage of having a single point of failure if the node that currently has the control token fails. This would render the entire network inoperable. Another disadvantage is the added latency in the network due to the control token being passed to each node before a node can transmit.

6 LANs

LAN Address also known as MAC/Physical/Ethernet Address is a unique identifier that is assigned to a network interface controller (NIC) for use as a network address when communicating with a network segment. A MAC address is also used to send and receive frames in the link layer. It is a 48 bit hexadecimal address embedded in hardware with MAC addresses being allocated by IEEE to ensure that MAC address are unique. This is analogous to a social security number with an IP address being analogous to a postal address. The following figure is an example of a LAN network.



7 Address Resolution Protocol (ARP)

Every IP node on a LAN has an Address Resolution Protocol (ARP) table. This table maps a device's IP address to its MAC address. The format of the table is ¡IP address; MAC address; Time to Live¿. The Time To Live (TTL) is the amount of time that the mapping will be remembered. Past the TTL, the mapping will be forgotten. Let's look at the scenario where Node A wants to send a datagram to Node B, but only has Node B's IP Address. First Node A can send a query containing B's IP address. all the nodes in the LAN will receive this query, but only Node B will respond. B will respond to A, and A will save the MAC address in the ARP table.