# ECE 333: Introduction to Communication Networks
# Fall 2002

## Lecture 13: Medium Access Control I

- **Introduction**
- **Static Allocations**



In Lecture 1, we classified links as either ***broadcast*** or ***point-to-point.*** With a broadcast link, more than two users share the same transmission media. At times an entire network, in particular a LAN, will consist of a single broadcast link connecting a group of users[1]. In this case we refer to the network itself as a ***broadcast network***. A broadcast link is also called a ***multiaccess channel.*** In such a channel,

1. A transmitter can be heard by multiple receivers
2. A receiver can hear multiple transmitters.

The first point implies that a technique is needed to decide which receiver(s) a transmitted packet was meant for. A direct way to accomplish this is through ***addressing***, i.e., each receiver is assigned an address in the form of a unique bit sequence, and this address is then added to the header field, before sending a packet. Regarding the second point, if two transmitters transmit at the same time, their signals may ***interfere*** or ***collide*** and not be recoverable at the receiver. A method is needed to share the broadcast link among the various transmitters and avoid such collisions; this is called the ***medium access control (MAC)*** problem. We will examine various solutions to this problem in the next several lectures. Before discussing these solutions in detail, we first describe several situations where broadcast links arise. We then look at where the medium access control problem is commonly addressed in a layered network architecture. Next we categorize the possible solution approaches, and begin discussing some specific approaches.

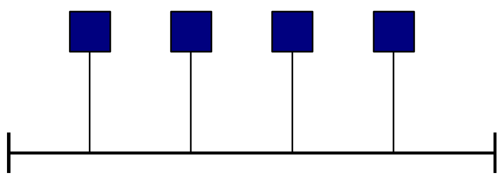
[1] The primary reason LANs have been designed this way is that it is a very cost effective approach for connecting together a group of users in a small geographical area.

## Examples of broadcast links:

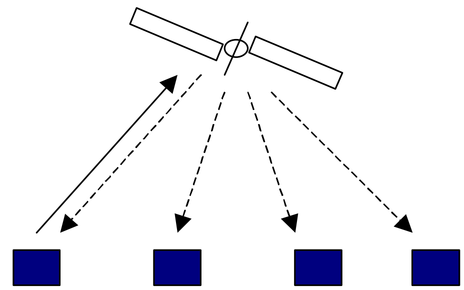
In the following we mention a few representative examples of broadcast links, several other examples will be provided in later lectures.

**Shared Bus:** A shared bus consists of a single cable (*e.g*. a coaxial cable) to which all users are connected. A signal transmitted by one user will propagate in both directions on the cable and can be received by any other user. Several versions of *Ethernet* use a shared bus, as does the *LocalTalk* LAN developed by *Apple Computer Corp*.

**"Bent-pipe" Satellite Link:** In a common form of satellite communication, users transmit messages to a satellite in one frequency band and the satellite simply relay's any received signal back down to all users in a second frequency band.



Shared bus



Satellite channel



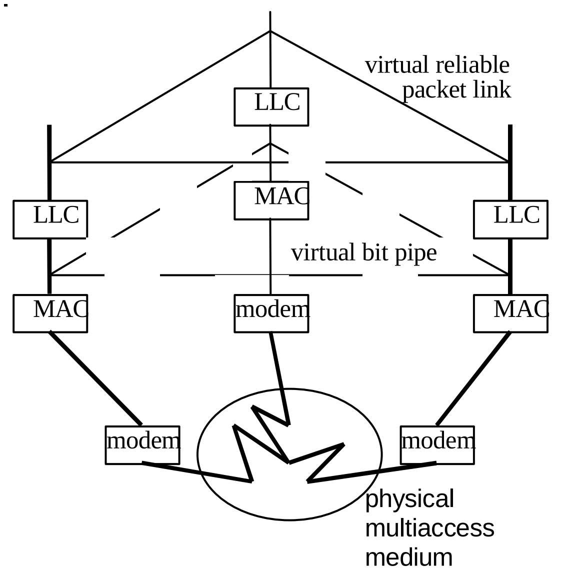
**Cable TV Networks**: In lecture 4, the cable TV distribution network is described. When this network is used for data communication, upstream communication from users to the head-end is over a shared link, which can also be viewed as a broadcast medium.

**(Terrestrial) Wireless Networks**: In wireless networks users communicate over a shared wireless channel, for example a given frequency band specified by the FCC. By nature a wireless channel is a broadcast medium. One of the most widespread types of wireless networks is a cellular telephone network. Another type of wireless network that is increasingly common is a wireless LAN. A number of different wireless LAN standards have been defined including the *IEEE 802.11* (*Wi-Fi*) wireless LAN standard and the *Bluetooth* standard.

# MAC Sublayer

In the OSI protocol stack, channel allocation is addressed in the ***Medium access control (MAC)*** sublayer. This is a sublayer of the Data Link Layer - considered to be below the Logical Link Control (LLC) sub-layer. Many LAN technologies, such as Ethernet are based on this type of architecture. The MAC layer provides an unreliable connectionless service; if required, the LLC layer can convert this into a reliable service by using an ARQ protocol.

| |
|---|
| Network Layer |
| Logical Link Control Sublayer |
| Medium Access Control Sublayer |
| Physical layer |






## Channel Allocation

**Basic problem:** How to allocate a multiaccess channel among competing users.

In other words, we need a set of rules (i.e. a protocol) to allow each user to communicate and avoid interference. There are a variety of solutions to this problem that are used in practice. These solutions can be classified as either ***static*** or ***dynamic***. With a static approach, the channel's capacity is essentially divided into fixed portions; each user is then allocated a portion for all time. If the user has no traffic to use in its portion, then it goes unused. With a dynamic approach the allocation of the channel changes based on the traffic generated by the users. Generally, a static allocation performs better when the traffic is predictable. A dynamic channel allocation tries to get **better utilization and lower delay** on a channel **when the traffic is unpredictable**.

## Static Channel Allocation Techniques

Two common static channel allocation techniques are TDMA and FDMA.

**Time Division Multiple Access (TDMA)** – With TDMA the time axis is divided into time slots of a fixed length. Each user is allocated a fixed set of time slots at which it can transmit. TDMA requires that users be synchronized to a common clock. Typically extra overhead bits are required for synchronization.

**Frequency Division Multiple Access (FDMA)** – With FDMA the available frequency bandwidth is divided into disjoint frequency bands. A fixed band is allocated to each user. FDMA requires a ***guard band*** between user frequency bands to avoid ***cross-talk.***

Another static allocation technique is ***Code Division Multiple Access (CDMA),*** this technique is used in many wireless networks (you can learn more about CDMA in ECE 380).

To a first approximation, if a channel has a capacity of $R$ bps, and either FDMA or TDMA is used, then each user will get an effective rate of $R/N$ bps, where $N$ is the number of users. (This is an approximation, because we have neglected the overhead required for timing or guard bands as discussed above.)



The performance of static channel allocation depends on:

- The variation in the number of users over time
- The nature of the traffic sent by the user

If the traffic on a shared medium is from a fixed number of sources each transmitting at a fixed rate, static channel allocation can be very efficient.

Voice and Video (in their fixed rate forms) have this property and commonly are placed in a shared channel using a static channel allocation.

The variation in the number of users over time impacts the performance of a static allocation because some method is needed to allocate the slot to users as they come and go.

When the traffic sent by a user is bursty, then, under a static allocation, a user's portion of the channel may be empty when another user could use it. This leads one to think that a dynamic allocation will perform better in such cases. This idea is made precise in the following example (this is related to problem 6 from Problem Set 4).

**Example:**

Consider ***K*** users transmitting over a common shared link with capacity ***C***.

Assume by TDMA, or FDMA each user is statically allocated a portion of the link with capacity ***C/K***.

Packets for each user arrive according to a Poisson process with rate $\lambda$ and are placed into a buffer until they are transmitted.

Assume that packets for each user have lengths that are exponentially distributed with mean **1/μ,** and thus have an average transmission time of $K/\mu C$. In this case each user's packets wait in a separate M/M/1 queue.

The average delay in such a system is

$$T_{TDMA} = \frac{1}{\mu C / K - \lambda}$$

Suppose that instead the packets from all ***K*** users could be placed into a single buffer and served FCFS.

Then the total arriving traffic stream would be a Poisson process with rate $K\lambda$. The average transmission time of a packet would now be **1/μC.**



Thus the average delay in the systems is now

$$T = \frac{1}{\mu C - K\lambda} = \left(\frac{1}{K}\right)\cdot\frac{1}{\mu C / K - \lambda} = (1/K)T_{TDMA}$$

⇒ By serving the packets FCFS, the average delay is reduced by a factor of 1/*K*.

(When used to combine packets from various sessions on a point-to-point link serving packets FCFS in the this way is called *statistical multiplexing.*)

The above suggests that to minimize delay with bursty traffic, the channel should be allocated FCFS to the various users. However, there is a problem in doing this in a multiaccess channel. Specifically, the packets of the various users are not placed into a single buffer, but are buffered at each source. The various users are unaware of the arrivals at the other users. The fact that this information is distributed among the users is the main challenge to be overcome by a dynamic channel allocation strategy.