

3rd Unit, MCC

Methodist College of Engineering and Technology, Hyderabad

Dr. John William Carey

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# Multiple Access Techniques for Wireless Communications

Multiple access schemes are used to allow many mobile users to share simultaneously a finite amount of radio spectrum. The sharing of spectrum is required to achieve high capacity by simultaneously allocating the available bandwidth (or the available amount of channels) to multiple users. For high quality communications, this must be done without severe degradation in the performance of the system.

## 1. Introduction

In wireless communications systems, it is often desirable to allow the subscriber to send simultaneously information to the base station while receiving information from the base station. For example, in conventional telephone systems, it is possible to talk and listen simultaneously, and this effect, called duplexing, is generally required in wireless telephone systems.

Duplexing may be done using frequency or time domain techniques. Frequency division duplexing (FDD) provides two distinct bands of frequencies for every user. The forward band provides traffic from the base station to the mobile, and the reverse band provides traffic from the mobile to the base station. In FDD, any duplex channel actually consists of two simplex channels (a forward and reverse), and a device called a duplexer is used inside each subscriber unit and base station to allow simultaneous bidirectional radio transmission and reception for both the subscriber unit and the base station on the duplex channel pair. The frequency separation between each forward and reverse channel is constant throughout the system, regardless of the particular channel being used.

Time division duplexing (TDD) uses time instead of frequency to provide both a forward and reverse link. In TDD, multiple users share a single radio channel by taking turns in the time domain. Individual users are allowed to access the channel in assigned time slots, and each duplex channel has both a forward time slot and a reverse time slot to facilitate bidirectional communication. If the time separation between the forward and reverse time slot is small, then the transmission and reception of data appears simultaneous to the users

at both the subscriber unit and on the base station side. Figure -1- illustrates FDD and TDD techniques. TDD allows communication on a single channel (as opposed to requiring two separate simplex or dedicated channels) and simplifies the subscriber equipment since a duplexer is not required.

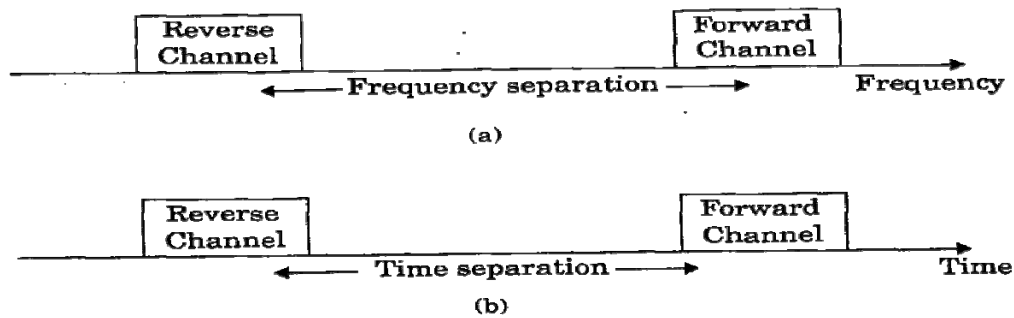


Figure-1- (a) FDD provides two simplex channels at the same time; (b) TDD provides two simplex time slots on the same frequency.

There are several tradeoffs between FDD and TDD approaches. FDD is geared toward radio communications systems that allocate individual radio frequencies for each user. Because each transceiver simultaneously transmits and receives radio signals which can vary by more than 100 dB, the frequency allocation used for the forward and reverse channels must be carefully coordinated within its own system and with out-of-band users that occupy spectrum between these two bands. Furthermore, the frequency separation must be coordinated to permit the use of inexpensive RF and oscillator technology. TDD enables each transceiver to operate as either a transmitter or receiver on the same frequency, and eliminates the need for separate forward and reverse frequency bands. However, there is a time latency created by TDD due to the fact that communications is not full duplex in the truest sense, and this latency creates inherent sensitivities to propagation delays of individual users. Because of the rigid timing required for time slotting, TDD generally is limited to cordless phone or short range portable access. TDD is effective for fixed wireless access when all users are stationary so that propagation delays do not vary in time among the users.

## Introduction to Multiple Access

Frequency division multiple access (FDMA), time division multiple access (TDMA), and code division multiple access (CDMA) are the three major access techniques used to share the available bandwidth in a wireless communication system. These techniques can be grouped as narrowband and wideband systems, depending upon how the available bandwidth is allocated to the users. The duplexing technique of a multiple access system is usually described along with the particular multiple access scheme, as shown in the examples that follow.

**Narrowband Systems** — The term narrowband is used to relate the bandwidth of a single channel to the expected coherence bandwidth of the channel. In a narrowband multiple access system, the available radio spectrum is divided into a large number of narrowband channels. The channels are usually operated using FDD. To minimize interference between forward and reverse links on each channel, the frequency separation is made as great as possible within the frequency spectrum, while still allowing inexpensive duplexers and a common transceiver antenna to be used in each subscriber unit. In narrowband FDMA, a user is assigned a particular channel which is not shared by other users in the vicinity, and if FDD is used (that is, each duplex channel has a forward and reverse simplex channel), then the system is called FDMA/FDD. Narrowband TDMA, on the other hand, allows users to share the same radio channel but allocates a unique time slot to each user in a cyclical fashion on the channel, thus separating a small number of users in time on a single channel. For narrowband TDMA systems, there generally are a large number of radio channels allocated using either FDD or TDD, and each channel is shared using TDMA. Such systems are called TDMA/FDD or TDMA/TDD access systems.

**Wideband systems** — In wideband systems, the transmission bandwidth of a single channel is much larger than the coherence bandwidth of the channel. Thus, multipath fading does not greatly vary the received signal power within a wideband channel, and frequency selective fades occur in only a small fraction of the signal bandwidth at any instance of time. In wideband multiple access systems a large number of transmitters are allowed to transmit on the same channel. TDMA allocates time slots to the many transmitters on the same

channel and allows only one transmitter to access the channel at any instant of time, whereas spread spectrum CDMA allows all of the transmitters to access the channel at the same time. TDMA and CDMA systems may use either FDD or TDD multiplexing techniques.

In addition to FDMA, TDMA, and CDMA, two other multiple access schemes will soon be used for wireless communications. These are packet radio (PR) and space division multiple access (SDMA). In this chapter, the above mentioned multiple access techniques, their performance, and their capacity in digital wireless systems are discussed.

## 2. Spread Spectrum Multiple Access

Spread spectrum multiple access (SSMA) uses signals which have a transmission bandwidth that is several orders of magnitude greater than the minimum required RF bandwidth. A pseudo-noise (PN) sequence converts a narrowband signal to a wideband noise-like signal before transmission. SSMA also provides immunity to multipath interference and robust multiple access capability. SSMA is not very bandwidth efficient when used by a single user. However, since many users can share the same spread spectrum bandwidth without interfering with one another, spread spectrum systems become bandwidth efficient in a multiple user environment. It is exactly this situation that is of interest to wireless system designers. There are two main types of spread spectrum multiple access techniques; frequency hopped multiple access (FH) and direct sequence multiple access (DS). Direct sequence multiple access is also called code division multiple access (CDMA).

### 2.1 Frequency Hopped Multiple Access (FHMA)

Frequency hopped multiple access (FHMA) is a digital multiple access system in which the carrier frequencies of the individual users are varied in a pseudorandom fashion within a wideband channel. Figure - 2- illustrates how FHMA allows multiple users to simultaneously occupy the same spectrum at the same, time, where each user dwells at a specific narrowband channel at a particular instance of time, based on the particular PN code of the user. The digital data of each' user is broken into uniform sized bursts which are transmitted on different channels within the allocated

spectrum band. The instantaneous bandwidth of any one transmission burst is much smaller than the total spread bandwidth. The pseudorandom change of the channel frequencies of the user randomizes the occupancy of a specific channel at any given time, thereby allowing for multiple access over a wide range of frequencies. In the FH receiver, a locally generated PN code is used to synchronize the receiver's instantaneous frequency with that of the transmitter. At any given point in time, a frequency hopped signal only occupies a single, relatively narrow channel since narrowband FM or FSK is used. The difference between FHMA and a traditional FDMA system is that the frequency hopped signal changes channels at rapid intervals. If the rate of change of the carrier frequency is greater than the symbol rate, then the system is referred to as a fast frequency hopping system. If the channel changes at a rate less than or equal to the symbol rate, it is called slow frequency hopping. A fast frequency hopper may thus be thought of as an FDMA system which employs frequency diversity. FHMA systems often employ energy efficient constant envelope modulation. Inexpensive receivers may be built to provide noncoherent detection of FHMA. This implies that linearity, is not an issue, and the power of multiple users at the receiver does not degrade FHMA performance.

A frequency hopped system provides a level of security, especially when a large number of channels are used, since an unintended (or an intercepting) receiver that does not know the pseudo-random sequence of frequency slots must retune rapidly to search for the signal it wishes to intercept. In addition, the FH signal is somewhat immune to fading, since error control coding and interleaving can be used to protect the frequency hopped signal against deep fades which may occasionally occur during the hopping sequence. Error control coding and interleaving can also be combined to guard against erasures which can occur when two or more users transmit on the same channel at the same time. Bluetooth and HomeRF wireless technologies have adopted FHMA for power efficiency and low cost implementation.

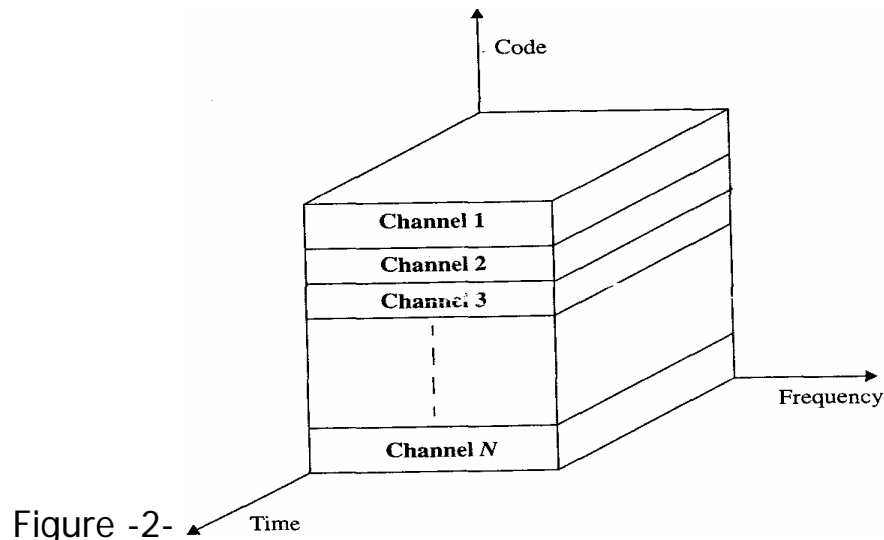


Figure -2- spread spectrum multiple access in which each channel is assigned a unique PN code which is orthogonal or approximately orthogonal to PN codes used by other users.

## 2.2 Code Division Multiple Access (CDMA)

In Code Division Multiple Access systems, the narrowband message signal is multiplied by a very large bandwidth signal called the spreading signal. The spreading signal is a pseudo-noise code sequence that has a chip rate which is orders of magnitudes greater than the data rate of the message. All users in a CDMA system, as seen from Figure -2- use the same carrier frequency and may transmit simultaneously. Each user has its own pseudorandom codeword which is approximately orthogonal to all other codewords. The receiver performs a time correlation operation to detect only the specific desired codeword. All other codewords appear as noise due to decorrelation. For detection of the message signal, the receiver needs to know the codeword used by the transmitter. Each user operates independently with no knowledge of the other users.

In CDMA, the power of multiple users at a receiver determines the noise floor after decorrelation. If the power of each user within a cell is not controlled such that they do not appear equal at the base station receiver, then the near—far problem occurs.

The near—far problem occurs when many mobile users share the same channel. In general<sup>4</sup> the strongest received mobile signal will capture the demodulator at a base station. In CDMA, stronger received signal levels raise the noise floor at the base station demodulators for the weaker signals, thereby decreasing the probability that weaker signals will be received. To combat the near—far problem, power control is used in most CDMA implementations. Power control is provided by each base station in a cellular system and assures that each mobile



within the base station coverage area provides the same signal level to the base station receiver. This solves the problem of a nearby subscriber overpowering the base station receiver and drowning out the signals of far away subscribers. Power control is implemented at the base station by rapidly sampling the radio signal strength indicator (RSSI) levels of each mobile and then sending a power change command over the forward radio link. Despite the use of power control within each cell, out-of-cell mobiles provide interference which is not under the control of the receiving base station.

The features of CDMA including the following:

- Many users of a CDMA system share the same frequency. Either TDD or FDD may be used.
- Unlike TDMA or FDMA, CDMA has a soft capacity limit. Increasing the number of users in a CDMA system raises the noise floor in a linear manner. Thus, there is no absolute limit on the number of users in CDMA. Rather, the system performance gradually degrades for all users as the number of users is increased, and improves as the number of users is decreased.
- Multipath fading may be substantially reduced because the signal is spread over a large spectrum. If the spread spectrum bandwidth is greater than the coherence bandwidth of the channel, the inherent frequency diversity will mitigate the effects of small-scale fading.

Channel data rates are very high in CDMA systems. Consequently, the symbol (chip) duration is very short and usually much less than the channel delay spread. Since PN sequences have low autocorrelation, multipath which is delayed by more than a chip will appear as noise. A RAKE receiver can be used to improve reception by collecting time delayed versions of the required signal.

- Since CDMA uses co-channel cells, it can use macroscopic, spatial diversity to provide soft handoff. Soft handoff is performed by the MSC, which can simultaneously monitor a particular user from two or more base stations. The MSC may chose the best version of the signal at any time without switching frequencies.

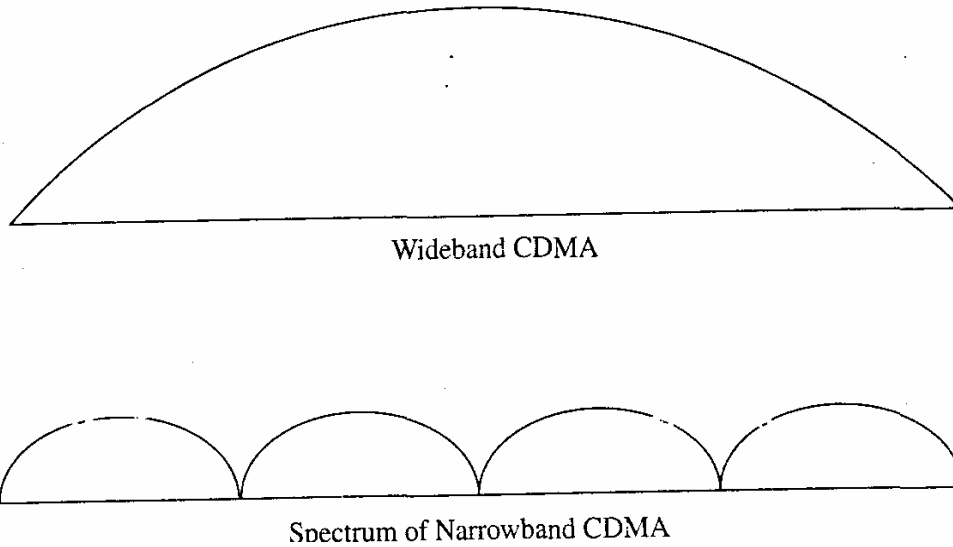
- Self-jamming is a problem in CDMA system. Self-jamming arises from the fact that the spreading sequences of different users are not exactly orthogonal, hence in the despreading of a particular PN code, non-zero contributions to the receiver decision statistic for a desired user arise from the transmissions of other users in the system.

- The near—far problem occurs at a CDMA receiver if an undesired user has a high detected power as compared to the desired user.

## 2.3 Hybrid Spread Spectrum Techniques

In addition to the frequency hopped and direct sequence, spread spectrum multiple access techniques, there are certain other hybrid combinations that provide certain advantages. These hybrid techniques are described below.

**Hybrid FDM/CDMA (FCDMA)** — This technique can be used as an alternative to the DS-SS-CDMA techniques discussed above. Figure -3- shows the spectrum of this hybrid scheme. The available wideband spectrum is divided into a number of subspectras with smaller bandwidths.



Fig

Figure-3-

Spectrum of wideband CDMA compared to the a hybrid, frequency division, direct sequence multiple access.

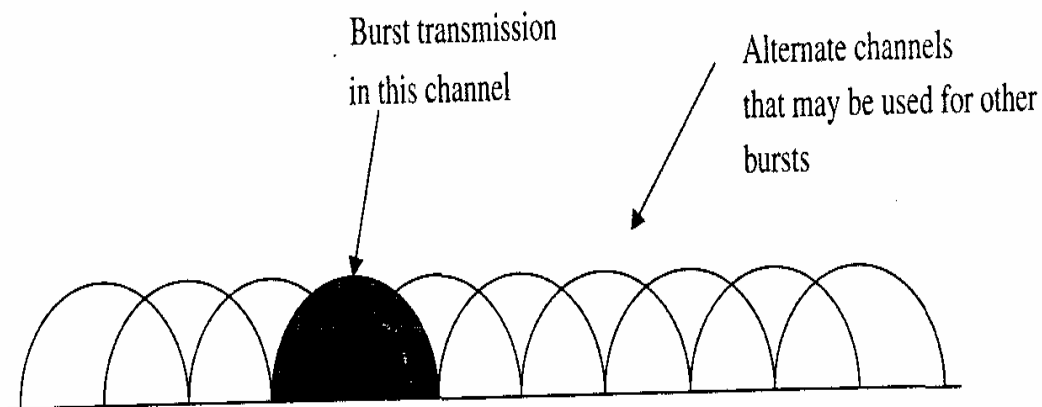


Figure-4- Frequency spectrum of a hybrid FH/DS system.

Each of these smaller subchannels becomes a narrowband CDMA system having processing gain lower than the original CDMA system. This hybrid system has an advantage in that the required bandwidth need not be contiguous and different users can be allotted different subspectrum bandwidths depending on their requirements. The capacity of this FDMA/CDMA technique is calculated as the sum of the capacities of a system operating in the subspectra .

**Hybrid Direct Sequence/Frequency Hopped Multiple Access (DSFHMA)** — This technique consists of a direct sequence modulated signal whose center frequency is made to hop periodically in a pseudorandom fashion. Figure-4-shows the frequency spectrum of such a signal [Dix941]. Direct sequence, frequency hopped systems have an advantage in that they avoid the near—far effect. However, frequency hopped CDMA systems are not adaptable to the soft handoff process since it is difficult to synchronize the frequency hopped base station receiver to the multiple hopped signals.

**Time Division CDMA (TCDMA)** — In a TCDMA (also called TDMA/CDMA) system, different spreading codes are assigned to different cells. Within each cell, only one user per cell is allotted a particular time slot. Thus at any time, only one CDMA user is transmitting in each cell.

When a handoff takes place, the spreading code of the user is changed to that of the new cell. Using TCDMA has an advantage in that it avoids the near—far effect since only one user transmits at a time within a cell.

**Time Division Frequency Hopping (TDFH)** This multiple access technique has an advantage in severe multipath or when severe co-channel interference occurs. The subscriber can hop to a new frequency at the start of a new TDMA frame, thus avoiding a severe fade or erasure event on a particular channel. This technique has been adopted for the GSM standard, where the hopping sequence is predefined and the subscriber is allowed to hop only on certain frequencies which are assigned to a cell. This scheme also avoids co-channel interference problems between neighboring cells if two interfering base station transmitters are made to transmit on different frequencies at different times. The use of TDFH can increase the capacity of GSM by several fold [Gud92].

### 3. Space Division Multiple Access (SDMA)

Space division multiple access (SDMA) controls the radiated energy for each user in space. It can be seen from Figure 9.8 that SDMA serves different users by using spot beam antennas. These different areas covered by the antenna beam may be served by the same frequency (in a TDMA or CDMA system) or different frequencies (in an FDMA system). Sectorized antennas may be thought of as a primitive application of SDMA. In the future, adaptive antennas will likely be

used to simultaneously steer energy in the direction of many users at once and appear to be best suited for TDMA and CDMA base station architectures.

The reverse link presents the most difficulty in cellular systems for several reasons [Lib94b}. First, the base station has complete control over the power of all the transmitted signals on the forward link. However, because of different radio propagation paths between each

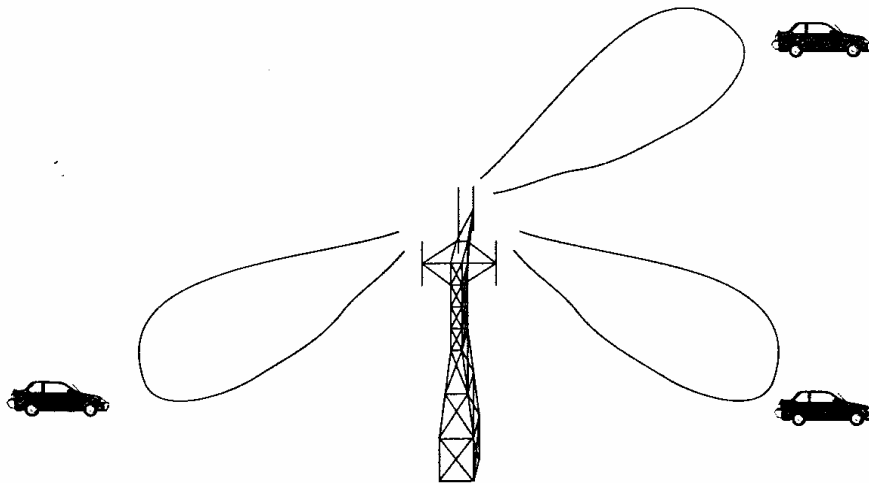


Figure-5- A spatially filtered base station antenna serving different users by using spot beams.

user and the base station, the transmitted power from each subscriber unit must be dynamically controlled to prevent any single user from driving up the interference level for all other users. Second, transmit power is limited by battery consumption at the subscriber unit, therefore there are limits on the degree to which power may be controlled on the reverse link. If the base station antenna is made to spatially filter each desired user so that more energy is detected from each subscriber, then the reverse link for each user is improved and less power is required.

Adaptive antennas used at the base station (and eventually at the subscriber units) promise to mitigate some of the problems on the reverse link. In the limiting case of infinitesimal beamwidth and infinitely far tracking ability, adaptive antennas implement optimal SDMA, thereby providing a unique channel that is free from the interference of all other users in the cell. With SDMA, all users within the system would be able to communicate at the same time using the same channel. In addition, a perfect adaptive antenna system would

be able to track individual multipath components for each user and combine them in an optimal manner to collect all of the available signal energy from each user. The perfect adaptive antenna system is not feasible since it requires infinitely large antennas. However, illustrates what gains might be achieved using reasonably sized arrays with moderate directivities.

## 4. Packet Radio

In packet radio (PR) access techniques, many subscribers attempt to access a single channel in an uncoordinated (or minimally coordinated) manner. Transmission is done by using bursts of data. Collisions from the simultaneous transmissions of multiple transmitters are detected at the base station receiver, in which case an ACK or NACK signal is broadcast by the base station to alert the desired user (and all other users) of received transmission. The ACK signal indicates an acknowledgment of a received burst from a particular user by the base station, and a NACK (negative acknowledgment) indicates that the previous burst was not received correctly by the base station. By using ACK and NACK signals, a PR system employs perfect feedback, even though traffic delay due to collisions may be high.

Packet radio multiple access is very easy to implement, but has low spectral efficiency and may induce delays. The subscribers use a contention technique to transmit on a common channel. ALOHA protocols, developed for early satellite systems, are the best examples of contention techniques. ALOHA allows each subscriber to transmit whenever they have data to send. The transmitting subscribers listen to the acknowledgment feedback to determine if transmission has been successful or not. If a collision occurs, the subscriber waits a random amount of time, and then retransmits the packet. The advantage of packet contention techniques is the ability to serve a large number of subscribers with virtually no overhead. The performance of contention techniques can be evaluated by the throughput (T), which is defined as the average number of messages successfully transmitted per unit time, and the average delay (D) experienced by a typical message burst.

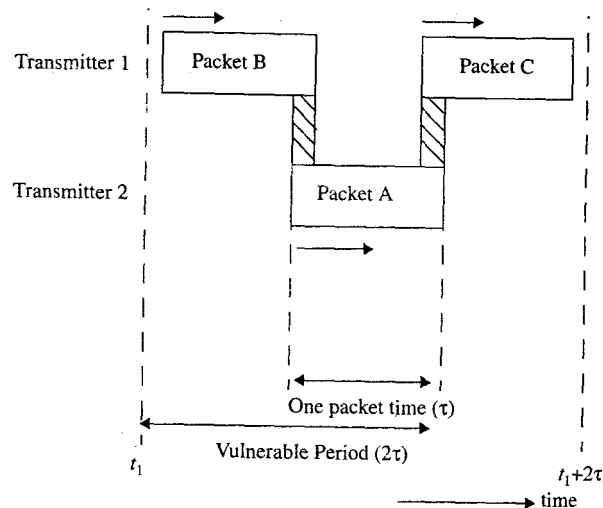


Figure-6-

Packet A will collide with packet B and C because of overlap in transmission time.  
Vulnerable period for a packet using the ALOHA protocol.

## 4.1 Packet Radio Protocols

In order to determine the throughput, it is important to determine the vulnerable period, VP, which is defined as the time interval during which the packets are susceptible to collisions with transmissions from other users. Figure -6-shows the vulnerable period for a packet using ALOHA [Tan8 1]. The Packet A will suffer a collision if other terminals transmit packets during the period  $t_1$  to  $t_1 + 2t$ . Even if only a small portion of packet A sustains a collision, the interference may render the message useless.

To study packet radio protocols, it is assumed that all packets sent by all users have a constant packet length and fixed, channel data rate, and all other users may generate new packets at random time intervals. Furthermore, it is assumed that packet transmissions occur with a Poisson distribution having a mean arrival rate of 1. packets per second. If  $t$  is the packet duration in seconds, then the traffic occupancy or throughput  $R$  of a packet radio network is given by

$$R = \lambda \tau$$

In Equation,  $R$  is the normalized channel traffic (measured in Erlangs) due to arriving and buffered packets, and is a relative measure of the channel utilization. If  $R > 1$ , then the packets generated by the users exceed the maximum transmission rate of the channel [Tan8]. Thus, to obtain a reasonable throughput, the rate at which new packets are generated must lie within  $0 < R < 1$ . Under conditions of normal loading, the, throughput  $T$  is the same as the total offered load,  $L$ . The

load  $L$  is the sum of the newly generated packets and the retransmitted packets that suffered collisions in previous transmissions. The normalized throughput is always less than or equal to unity and may be thought of as the fraction of time (fraction of an Erlang) a channel is utilized. The normalized throughput is given as the total offered load times the probability of successful transmission, i.e.,

$$T = R \cdot \text{Pr}[\text{no collision}] = \text{Pr}[\text{no collision}]$$

where  $\text{Pr}[\text{no collision}]$  is the probability of a user making a successful packet transmission. The probability that  $n$  packets are generated by the user population during a given packet duration interval is assumed to be Poisson distributed and is given as

$$\text{Pr}(n) = \frac{R^n e^{-R}}{n!}$$

A packet is assumed successfully transmitted if there are no other packets transmitted during the given packet time interval. The probability that zero packets are generated (i.e., no collision) during this interval is given by

$$\text{Pr}(0) = e^{-R}$$

Based on the type of access, contention protocols are categorized as random access, scheduled access, and hybrid access. In random access, there is no coordination among the users and the messages are transmitted from the users as they arrive at the transmitter. Scheduled access is based on a coordinated access of users on the channel, and the users transmit messages within allotted slots or time intervals. Hybrid access is a combination of random access and scheduled access.



### 4.1.1 Pure ALOHA

The pure ALOHA protocol is a random access protocol used for data transfer. A user accesses a channel as soon as a message is ready to be transmitted. After a transmission, the user waits for an acknowledgment on either the same channel or a separate feedback channel. In case of collisions, (i.e., when a NACK is received), the terminal waits for a random period of time and retransmits the message. As the number of users increase, a greater delay occurs because the probability of collision increases.

For the ALOHA protocol, the vulnerable period is double the packet duration (see Figure 9.9). Thus, the probability of no collision during the interval of  $2t$  is found by evaluating  $Pr(n)$  given as

$$Pr(n) = \frac{(2R)^n e^{-2R}}{n!} \quad \text{at } n = 0$$

One may evaluate the mean of Equation to determine the average number of packets sent during  $2\tau$ . (This is useful in determining the average offered traffic.) The probability of no collision is The throughput of the ALOHA protocol is found by using Equation as

$$T = R e^{-2R}$$

### 4.1.2 slotted ALOHA

In slotted ALOHA time is divided into equal time slots of length greater than the packet duration  $\tau$ . The subscribers each have synchronized clocks and transmit a message only at the beginning of a new time slot, thus resulting in a discrete distribution of packets. This prevents partial collisions, where one packet collides with a portion of another. As the number of users increase, a greater delay will occur due to complete collisions and the resulting repeated transmissions of those packets originally lost. The number of slots which a transmitter waits prior to retransmitting also determines the delay characteristics of the traffic. The vulnerable period for slotted ALOHA is only one packet duration, since partial collisions are prevented through synchronization.

The probability that no other packets will be generated during the vulnerable period is  $S = e^{-R}$ . The throughput for the case of slotted ALOHA is thus given by

$$T = R e^{-R}$$

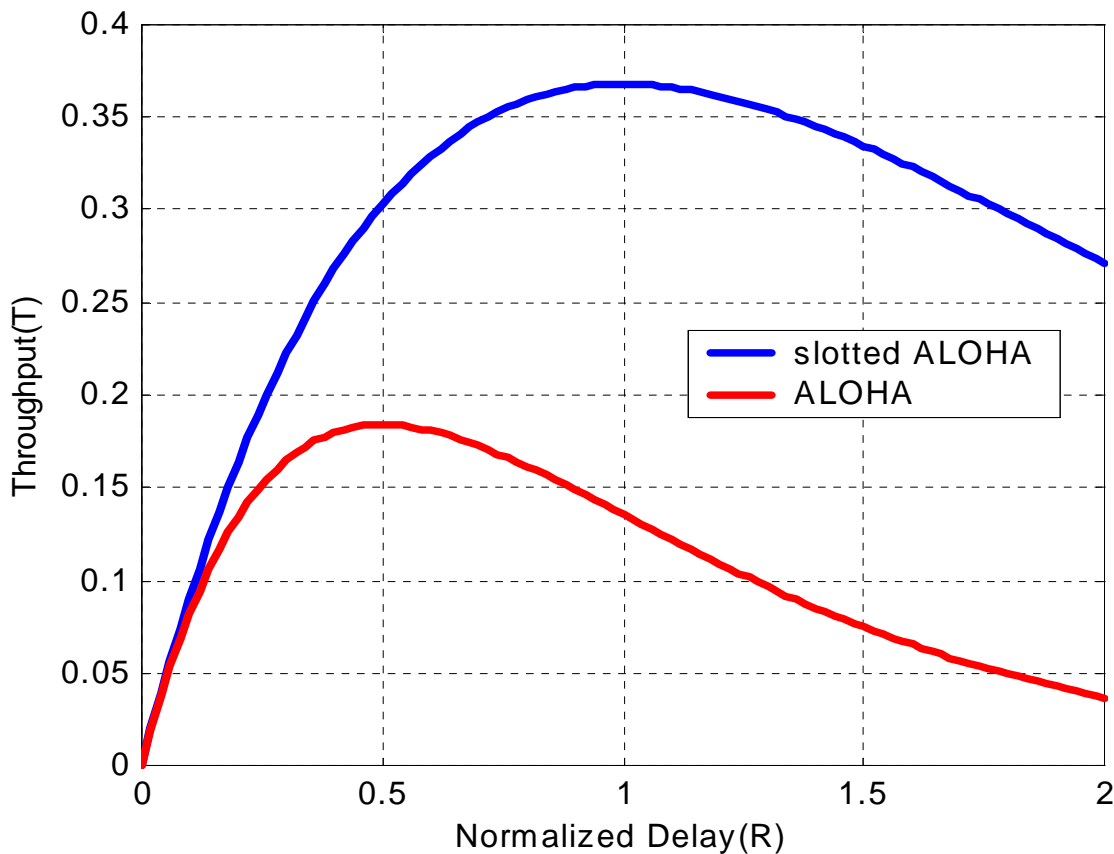


Figure -7- illustrates how ALOHA and slotted ALOHA systems tradeoff throughput for delay. Tradeoff between throughput and delay for ALOHA and slotted ALOHA packet radio protocol.

## 4.2 Carrier Sense Multiple Access (CSMA) Protocols

ALOHA protocols do not listen to the channel before transmission, and therefore do not exploit information about the other users. By listening to the channel before engaging in transmission, greater efficiencies may be achieved. CSMA protocols are based on the fact that each

terminal on the network is able to monitor the status of the channel before transmitting information. If the channel is idle (i.e., no carrier is detected), then the user is allowed to transmit a packet based on a particular algorithm which is common to all transmitters on the network.

In CSMA protocols, detection delay and propagation delay are two important parameters. Detection delay is a function of the receiver hardware and is the time required for a terminal to sense whether or not the channel is idle. Propagation delay is a relative measure of how fast it takes for a packet to travel from a base station to a mobile terminal. With a small detection time, a terminal detects a free channel quite rapidly, and small propagation delay means that a packet is transmitted through the channel in a small interval of time relative to the packet duration.

Propagation delay is important, since just after a user begins sending a packet, another user may be ready to send and may be sensing the channel at the same time. If the transmitting packet has not reached the user who is poised to send, the latter user will sense an idle channel and will also send its packet, resulting in a collision between the two packets. Propagation delay impacts the performance of CSMA protocols. If  $t_p$  is the propagation time in seconds,  $R_b$  is the channel bit rate, and  $m$  is the expected number of bits in a data packet [Tan81] , [Ber92], then the propagation delay  $t_d$  (in packet transmission units) can be expressed as

$$t_d = \frac{t_p R_b}{m}$$

### 4.3 Reservation Protocols

Reservation ALOHA is a packet access scheme based on time division multiplexing. In this protocol, certain packet slots are assigned with priority, and it is possible for users to reserve slots for the transmission of packets. Slots can be permanently reserved or can be reserved on request.

For high traffic conditions, reservations on request offers better throughput. In one type of reservation ALOHA, the terminal making a

successful transmission reserves a slot permanently until its transmission is complete, although very large duration transmissions may be interrupted. Another scheme allows a user to transmit a request on a subslot which is reserved in each frame. If the transmission is successful (i.e., no collisions are detected), the terminal is allocated the next regular slot in the frame for data transmission [Tan8 1].

### Packet Reservation Multiple Access (PRMA)

PRMA uses a discrete packet time technique similar to reservation ALOHA and combines the cyclical frame structure of TDMA in a manner that allows each TFMA time slot to carry either voice or data, where voice is given priority. PRMA was proposed in [Goo89] as a means of integrating bursty data and human speech. PRMA defines a frame structure, much like is used in TDMA systems. Within each frame, there are a fixed number of time slots which may be designated as either "reserved" or "available", depending on the traffic as determined by the controlling base station.

## 4.4 Capture Effect in Packet Radio

Packet radio multiple access techniques are based on contention within a channel. When used with FM or spread spectrum modulation, it is possible for the strongest user to successfully capture the intended receiver, even when many other users are also transmitting. Often, the closest transmitter is able to capture a receiver because of the small propagation path loss. This is called the near—far effect. The capture effect offers both advantages and disadvantages in practical systems. Because a particular transmitter may capture an intended receiver, many packets may survive despite collision on the channel. However, a strong transmitter may make it impossible for the receiver to detect a much weaker transmitter which is attempting to communicate to the same receiver. This problem is known as the hidden transmitter problem.

A useful parameter in analyzing the capture effects in packet radio protocols is the minimum power ratio of an arriving packet, relative to the other colliding packets, such that it is received. This ratio is called the capture ratio, and is dependent upon the receiver and the modulation used.

In summary, packet radio techniques support mobile transmitters sending bursty traffic in the form of data packets using random access. Ideal channel throughput can be increased if terminals synchronize their packet transmissions into common time slots, such that the risk of partial packet overlap is avoided. With high traffic loads, both unslotted and slotted ALOHA protocols become inefficient, since the contention between all transmitted packets exposes most of the offered traffic to collisions, and thus results in multiple retransmissions and increased delays. To reduce this situation, CSMA can be used where the transmitter first listens either to the common radio channel or to a separate dedicated acknowledgment control channel from the base station. In a real world mobile system, the CSMA protocols may fail to detect ongoing radio transmissions of packets subject to deep fading on the reverse channel path. Utilization of an ALOHA channel can be improved by deliberately introducing differences between the transmit powers of multiple users competing for the base station receiver.

## 5. Conclusion

Different Multiple access Techniques were presented. These include FDMA, TDMA, CDMA, SSMA, SDMA, and Packet Radio. Applications that use multiple access techniques such as GSM and others were also discussed. Multiple access techniques solved many of the problems such as channel capacity and security that face the users sharing a channel.

## 6. Referenc

- Wireless Communications—Theodore S.Rappaport.