UNIT II CELLULAR ARCHITECTURE

2.1 MULTIPLE ACCESS TECHNIQUES

Multiple access schemes are used to allow many mobile users to share simultaneously a finite amount of radio spectrum.

High capacity is required.

Must be done without severe degradation in the performance.

Duplexing is needed to allow subscribers send and receive information simultaneously.

Example- Telephone systems

Frequency division duplexing (FDD)

Provides two distinct bands of frequencies for every user.

Forward band - from the base station to the mobile.(Referred in figure 2.1.1.)

Reverse band - from the mobile to the base station.

Consists of two simplex channels . The frequency split between the forward and reverse channel is constant.

Time division duplexing (TDD)

Uses time to provide both a forward and reverse link. (Referred in figure 2.1.1.)

If the time split between the forward and reverse time slot is small, then the transmission and reception of data appears simultaneous.

Allows communication on a single channel and simplifies the subscriber equipment since a duplexer is not required.

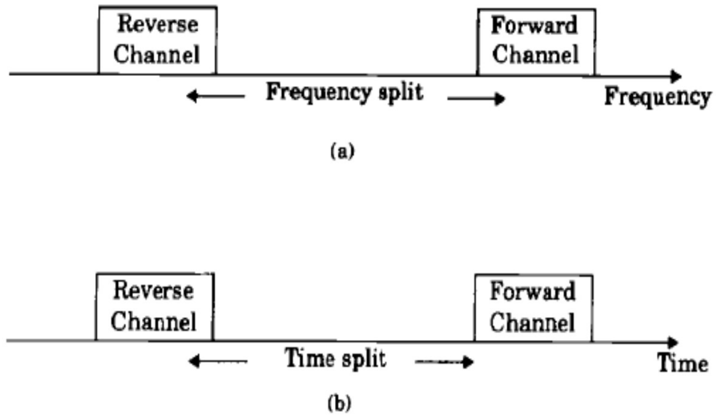

Fig 2.1.1 : Duplexing

[Source:" Wireless Communications "by Theodore S. Rappaport,Page-396]

Trade-offs between FDD and TDD:

FDD

Each transceiver simultaneously transmits and receives radio signals which vary by more than **100 dB**, the frequency allocation used for the forward and reverse channels must be carefully coordinated with out-of-band users that occupy spectrum between these two bands. The frequency separation must be coordinated to permit the use of inexpensive RF technology.

TDD

Eliminate the need for separate forward and reverse frequency bands.

There is a time latency due to the fact that communications is not full duplex in the truest sense.

Three major techniques:

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.

Narrowband Systems

The available radio spectrum is divided into a large number of narrowband channels.

Each channel is relatively narrow compared with the coherence bandwidth. The channels are usually operated using FDD.

To minimize interference between forward and reverse links, the frequency split is made as great as possible allowing inexpensive duplexers.

Narrowband FDMA-- a user is assigned a particular channel which is not shared by other users in the vicinity.

If FDD is used, the system is called FDMA/FDD.

Narrowband TDMA -- allows users to share the same channel but allocates a unique time slot to each user.

For narrowband TDMA, generally a large number of channels allocated using either FDD or TDD, and each channel is shared using TDMA.

Wideband systems

The transmission bandwidth of a single channel is much larger than the coherence bandwidth.

Multipath fading does not greatly affect the received signal, frequency selective fades occur in only a small fraction of the bandwidth.

A large number of transmitters are allowed to transmit on the same channel.

Wideband TDMA - allocates time slots to many transmitters on the same channel and allows only one transmitter to access the channel at any instant of time,

TDMA/FDD, TDMA/TDD

Wideband CDMA- allows all of the transmitters to access the channel at the same time.

Frequency Division Multiple Access (FDMA)

Each user is allocated a unique frequency band or channel. These channels are assigned on demand, and cannot be shared a shown in figure 2.1.2.

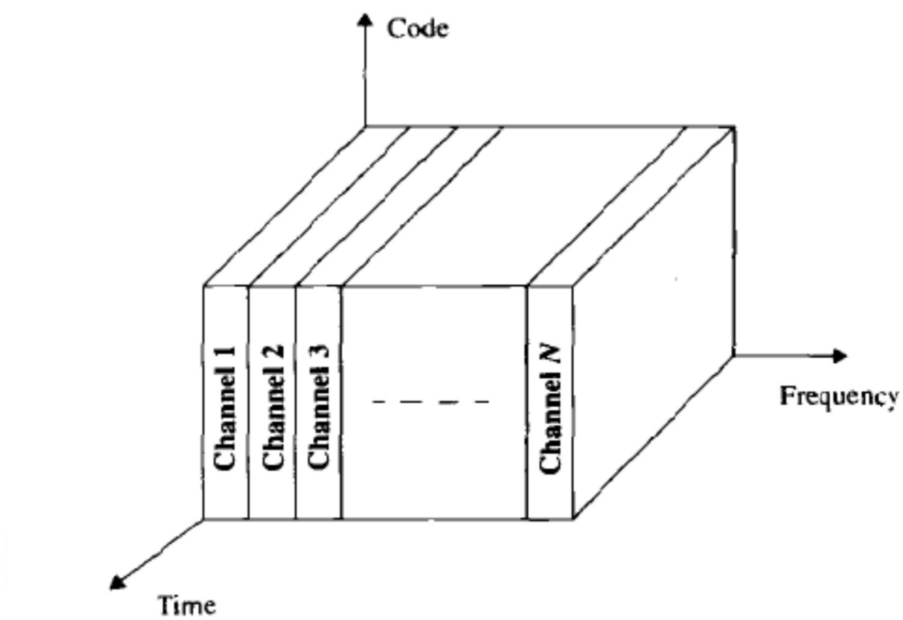

Fig 2.1.2 : FDMA

[Source: "Wireless Communications" by Theodore S. Rappaport,Page-400]

The Features of FDMA:

The FDMA channel carries only one phone circuit at a time.

If an FDMA channel is not in use, then it is idle and cannot be used by other users to increase or share capacity.It is essentially a wasted resource.

After the assignment of a voice channel, the base station and the mobile transmit simultaneously and continuously.

The bandwidths of FDMA channels are relatively narrow (30 kHz) as each channel supports only one circuit per carrier.

That is, FDMA is usually implemented in narrowband systems. The symbol time is large as compared to the average delay spread.This implies that the amount of inter symbol interference is low and, thus, little or no equalization is required in FDMA narrowband systems.

Since FDMA is a continuous transmission scheme, fewer bits are needed for overhead purposes (such as synchronization and framing bits) as compared to TDMA.

FDMA systems have higher cell site system costs as compared to TDMA systems, because of the single channel per carrier design, and the need to use costly bandpass filters to eliminate spurious radiation at the base station.

The FDMA mobile unit uses duplexers since both the transmitter and receiver operate at the same time.

This results in an increase in the cost of FDMA subscriber units and base stations.

FDMA requires tight RF filtering to minimize adjacent channel interference.

Nonlinear Effects in FDMA:

In FDMA, Many channels share the same antenna at the base station.

The power amplifiers or the power combiners, when operated at or near saturation for maximum power efficiency, are nonlinear.

The nonlinearities cause signal spreading in the frequency domain and generate inter modulation (IM) frequencies. ie, interfere adjacent-channels, or adjacent services.

The first U.S. analog cellular system, the Advanced Mobile Phone System (AMPS), is based on FDMA/ FDD. A single user occupies a single channel while the call is in progress, and the single channel is actually two simplex channels which are frequency duplexed with a 45 MHz split.

When a call is completed, or when a handoff occurs, the channel is vacated so that another mobile subscriber may use it.

The number of channels that can be simultaneously supported in a FDMA system is given by

$$N = \frac{B_t - 2B_{guard}}{B_c}$$

Where B_t is the total spectrum allocation. Bguard is the guard band allocated at the edge of the allocated spectrum, and B_c is the channel bandwidth.

Time Division Multiple Access (TDMA)

Time Division Multiple Access (TDMA) systems divide the radio spectrum into time slots, and in each slot only one user is allowed to either transmit or receive as shown in figure 2.1.3.

Each user occupies a cyclically repeating time slot.

A channel may be thought of as particular time slot that re occurs every frame, where N time slots comprise a frame.

TDMA systems transmit data in a buffer-and-burst method, the transmission for any user is non continuous.

Digital data and digital modulation must be used with TDMA.

Frame consists of a number of slots (information message), together with a preamble, and tail bits as shown in figure 2.1.4.

Preamble contains the address and synchronization information that both the base station and the subscribers use to identify each other.

Guard times allow synchronization of the receivers between different slots and frames.

In TDMA/ TDD, half of the time slots in the frame information message would be used for the forward link channels and half would be used for reverse link channels.

In TDMA/ FDD systems, an identical or similar frame structure would be used solely for either forward or reverse transmission, but the carrier frequencies would be different for the forward and reverse links.

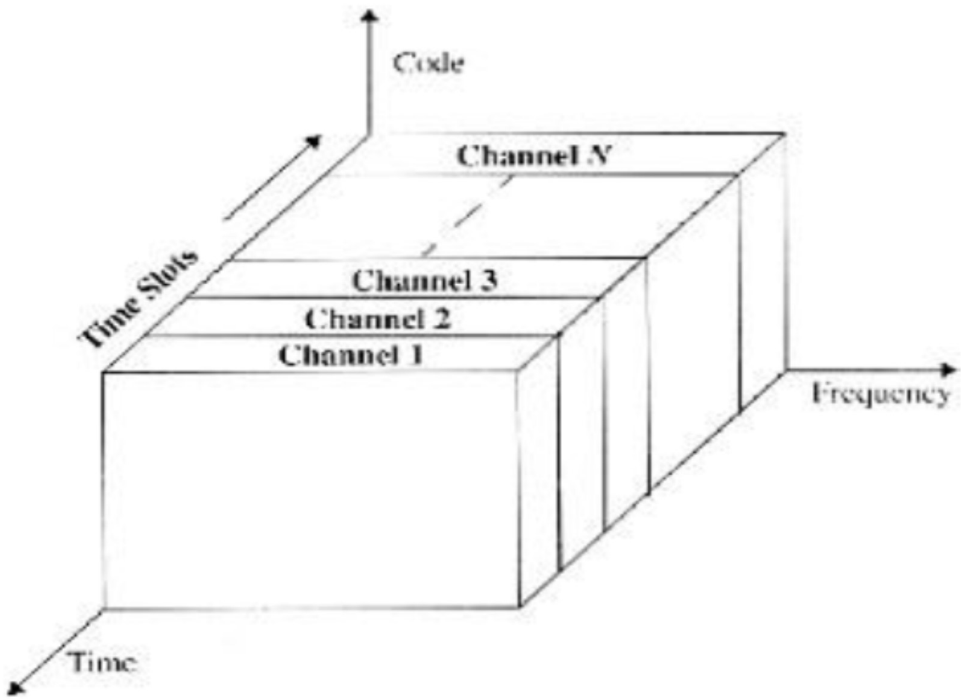

Fig 2.1.3: TDMA

[Source : "Wireless communications" by Theodore S. Rappaport,Page-401]

Features of TDMA:

TDMA shares a single carrier frequency with several users, where each user makes use of non overlapping time slots.

The number of time slots per frame depends on several factors, such as modulation technique, available bandwidth, etc.

Data transmission for users of a TDMA system is not continuous, but occurs in bursts. This results in low battery consumption, since the subscriber transmitter can be turned off when not in use (which is most of the time).

Because of discontinuous transmissions in TDMA, the handoff process is much simpler for a subscriber unit, since it is able to listen for other base stations during idle time slots.

An enhanced link control, such as that provided by mobile assisted handoff (MAHO) can be carried out by a subscriber by listening on an idle slot n the TDMA frame.

TDMA uses different time slots for transmission and reception, thus duplexers are not required.

Even if FDD is used, a switch rather than a duplexer inside the subscriber unit is all that is required to switch between transmitter and receiver using TDMA.

Adaptive equalization is usually necessary in TDMA systems, since the transmission rates are generally very high as compared to FDMA channels.

In TDMA, the guard time should be minimized. If the transmitted signal at the edges of a time slot are suppressed sharply in order to shorten the guard time, the transmitted spectrum will expand and cause interference to adjacent channels.

TDMA has an advantage in that it is possible to allocate different numbers of time slots per frame to different users.

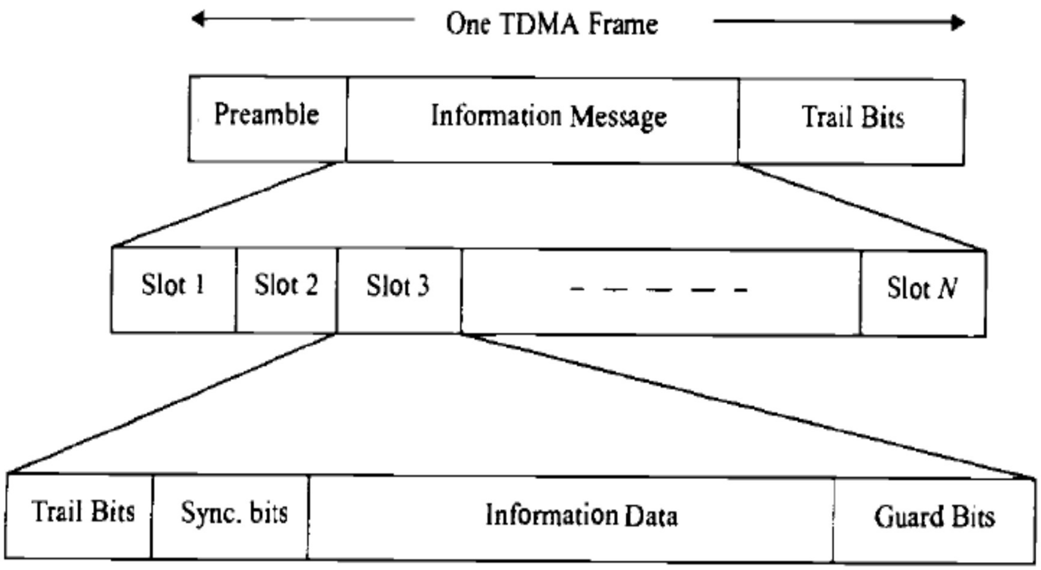

Fig 2.1.4: TDMA Frame structure

[Source : "Wireless communications" by Theodore S. Rappaport,Page-402]

Efficiency of TDMA:

The frame efficiency, is the percentage of bits per frame which contain transmitted data.

$$\eta_f = \left(1 - \frac{b_{OH}}{b_T}\right) \times 100\%$$

The number of overhead bits per frame is

$$b_{OH} = N_r b_r + N_t b_p + N_t b_g + N_r b_g$$

The total number of bits per frame, b_t, is $\boldsymbol{b_t = T_f R}$

It is a measure of the percentage of transmitted data that contains information as opposed to providing overhead for the access scheme.

The transmitted data may include source and channel coding bits, so the raw end- user efficiency of a system is generally less than frame efficiency.

Number of channels in TDMA system:

Can be found by multiplying the number of TDMA slots per channel by the number of channels available. m is the maximum number of TDMA users supported on each radio channel.

$$N = \frac{m\,(B_{tot} - 2B_{guard})}{B_c}$$