WIRELESS MULTIPLE ACCESS TECHNIQUES

Multiple access techniques are used to allow a large number of mobile users to share the allocated spectrum in the most efficient manner.
As the spectrum is limited, so the sharing is required to increase the capacity of cell or over a geographical area by allowing the available bandwidth to be used at the same time by different users.
And this must be done in a way such that the quality of service doesn't degrade within the existing users.
In wireless communications, it is necessary to utilize limited frequency bands at the same time, allowing multiple users (MSs) to share radio channels simultaneously. The scheme that is used for this purpose is called multiple access.
To provide simultaneous two-way communications (duplex communications), a forward channel (downlink) from the BS to the MS and a reverse channel (uplink) from the MS to the BS are necessary.
Two types of duplex systems are utilized: frequency division duplexing (FDD) divides the frequency used, and time division duplexing (TDD) divides the same frequency by time.
FDMA mainly uses FDD, while TDMA and CDMA systems use either FDD or TDD.

Multiple Access Techniques for Wireless Communication

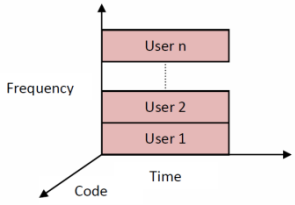
In wireless communication systems it is often desirable to allow the subscriber to send simultaneously information to the base station while receiving information from the base station.
A cellular system divides any given area into cells where a mobile unit in each cell communicates with a base station.
The main aim in the cellular system design is to be able to increase the capacity of the channel i.e. to handle as many calls as possible in a given bandwidth with a sufficient level of quality of service.
There are several different ways to allow access to the channel. These include mainly the following:
1) Frequency division multiple-access (FDMA)
2) Time division multiple-access (TDMA)
3) Code division multiple-access (CDMA)

Table 1: MA techniques in different wireless communication systems

Advanced Mobile Phone Systems:	FDMA/FDD
Global System for Mobile:	TDMA/FDD
U.S. Digital Cellular:	TDMA/FDD
Japanese Digital Cellular:	TDMA/FDD
CT2 Cordless Telephone:	FDMA/TDD
Digital European Cordless Telephone:	FDMA/TDD
U.S. Narrowband Spread Spectrum (IS-95):	CDMA/FDD

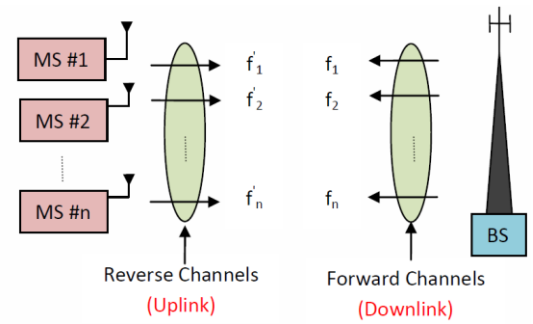
FDMA, TDMA and CDMA are the three major multiple access techniques that are used to share the available bandwidth in a wireless communication system.

Frequency Division Multiple Access



FDMA is a multiple-access system that has been widely adopted in existing analog systems for portable and automobile wireless telephones. The BS dynamically assigns a different carrier frequency to each active user (MS).
A frequency synthesizer is used to adjust and maintain the transmission and reception frequencies.
Basic structure of a FDMA system, consisting of a BS and many MSs.

FDMA Structure

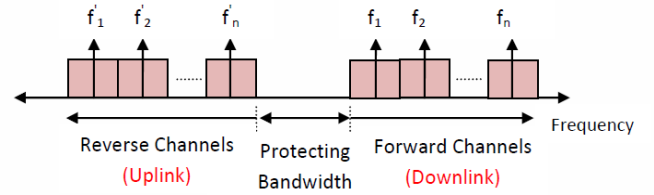


There is a pair of channels for the communication between the BS and the MS.
The paired channels are called forward channel (downlink) and reverse channel (uplink).
Different frequency bandwidths are assigned to different users. This implies that there is no frequency overlapping between the forward and reverse channels.
For example, the forward and reverse channels for MS #1 are *f*1 and *f* [1]1, respectively. The radio antenna is at a much higher elevation and the MSs are shown at the same level.

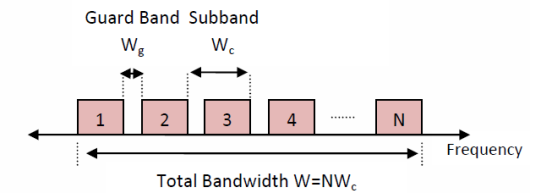
FDMA – Forward and Reverse Channels

A protecting bandwidth is used between the forward and reverse channels, and a guard band *Wg* between two adjacent channels is used to minimize adjacent channel interference between them.

The frequency bandwidth for each user is called subband *Wc*. If there are *N* channels in a FDMA system, the total bandwidth is equal to $N \cdot Wc$.



Structure of forward and reverse channels in FDMA



Guard Band in FDMA

The features of FDMA are as follows:

1. The FDMA channel carries only one phone circuit at a time. If an FDMA channel is not in use, then it sits idle and it cannot be used by other users to increase share capacity. After the assignment of the voice channel the BS and the MS transmit simultaneously and continuously.
2. The bandwidths of FDMA systems are generally narrow
3. The data rate is very less.
4. The complexity of the FDMA mobile systems is lower than that of TDMA mobile systems.
5. FDMA requires tight filtering to minimize the adjacent channel interference.

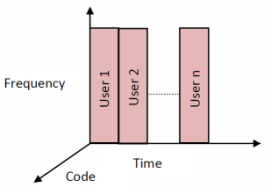
Advantages:

1. If the channel is not in use, its sits idle.
2. Channel Bandwidth is narrow (30KHz)
3. Fairly efficient when the number of stations is small and the traffic is uniformly constant
4. Uses existing hardware and hence this technology is cost efficient
5. Network timing is not required, hence making the system less complex.

Disadvantages

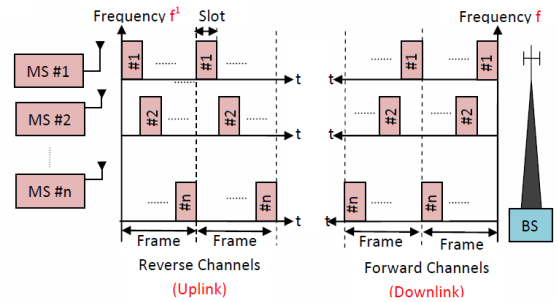
1. The presence of guard bands.
2. Requires right RF filtering to minimize adjacent channel interference
3. Maximum bit rate per channel is fixed.
4. Small inhibiting flexibility in bit rate capability.
5. Flexibility in channel allocation is less.
6. Uplink power control is required to maintain the link quality.

Time Division Multiple Access



TDMA splits a single carrier wave into several time slots and distributes the slots among multiple users.

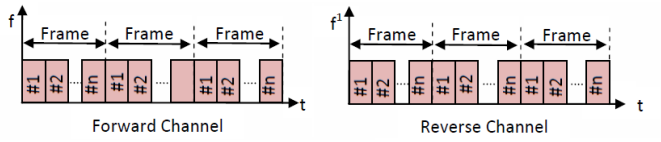
TDMA System: Basic Structure



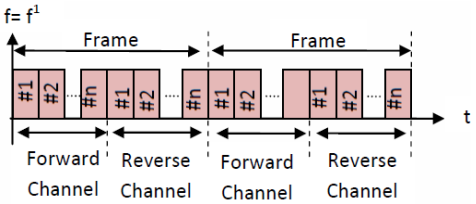
The communication channels essentially consist of many units, i.e., time slots, over a time cycle, which makes it possible for one frequency to be efficiently utilized by multiple users, given that each utilizes a different time slot.

This system is widely used in the field of digital portable and automobile telephones and mobile satellite communication systems. A TDMA system may be in either of two modes: FDD (in which the forward/ reverse or uplink/downlink communication frequencies differ) and TDD (in which the forward/reverse communication frequencies are the same). For a TDMA system, there is guard time between the slots so that interference due to propagation delays along different paths can be minimized.

TDMA – Forward and Reverse Channels



Structure of forward and reverse Channels in TDMA/FDD system



Structure of forward and reverse Channels in TDMA/TDD system

The features of TDMA includes the following:

1. TDMA shares a single carrier frequency with several users where each user makes use of non overlapping time slots.
2. The number of time slots per frame depends on several factors such as modulation technique, available bandwidth.
3. Data transmission in TDMA 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. Because of a discontinuous transmission in TDMA the handoff process is much simpler for a subscriber unit, since it is able to listen to other base stations during idle time slots.
4. TDMA uses different time slots for transmission and reception thus duplexers are not required.
5. TDMA has an advantage that is possible to allocate different numbers of time slots per frame to different users. Thus bandwidth can be supplied on demand to different users by concatenating or reassigning time slot based on priority.

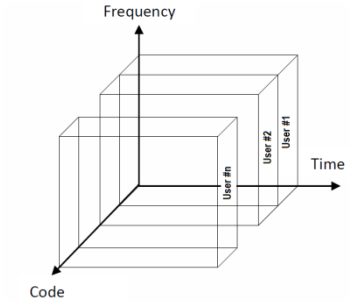
Advantages:

1. It carries data rates of 64kbps to 120 Mbps
2. It provides the user with extended battery life and talk time.
3. TDMA technology separates users according to time; it ensures that there will be no interference.
4. TDMA allows the operator to do services like fax, voice bad data and SMS as well bandwidth intensive application such as multimedia and video conferencing.
5. Uplink power control is not required.
6. Transmission plans and capacity management is done by the satellite are very flexible.

Disadvantages

1. Each user has predefined time slot. When moving from one cell to other, if all the time slots in this cell are full the user might be disconnected.
2. It is subjected to multipath distortion. A signal coming from a tower to a handset might come from any one of several directions. It might have bounced off several different buildings before arriving.
3. It requires a network wide time synchronization which makes the entire system very complex.
4. Analog of digital conversions are required.

Code Division Multiple Access



In a CDMA system, different spread-spectrum codes are selected and assigned to each user, and multiple users share the same frequency. A CDMA system is based on spectrum-spread technology, which makes it less susceptible to the noise and interference by substantially spreading over the bandwidth range of the modulated signal. However, high efficiency of frequency usage has been demonstrated by using CDMA, since the introduction of power control enables us to adjust the antenna emitting power so that the near-far problem could be solved.

CDMA uses a modulation technique called spread spectrum. Here all the users transmit signals simultaneously on the multiple access schemes.(Spread Spectrum: It refers to a modulation technique that converts the baseband signal to a modulated signal with a spectrum bandwidth that covers or is spread over the band orders of magnitude larger than that normally necessary to transmit the baseband signal itself.)

It could be used as a multiple access system by giving each user a unique pseudo random code rather than a unique carrier frequency or time slot.

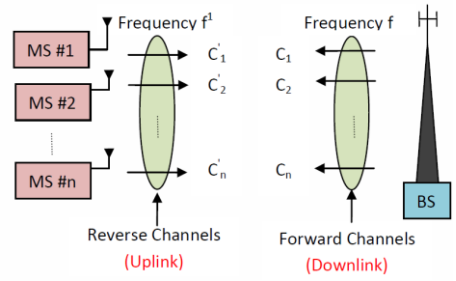
All the users contribute to the noise background.

To detect the desired signal in the presence of all the interferences, the composite signal is cross-correlated with the known pseudo random number spreading sequence.

The net performance is improved essentially by the ration of the un-spread signal bandwidth.

Highly resistant to interferences and thus satellite spacing could be reduced considerably without causing unacceptable degradation in the received signal quality.
Spread spectrum sequences are resistant to multiple noises present in the mobile terminals.
Small antennas can be used without any interference issues from the neighboring satellites.
CDMA is a very secure form of communication.

Structure of a CDMA



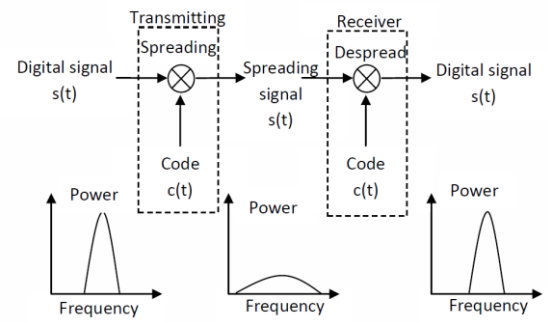
There are two basic types of CDMA implementation methodologies: direct sequence (DS) and frequency hopping (FH).
Since it is difficult to use FH on a practical basis unless a super-fast synthesizer is employed, DS is considered the most feasible generic method when the code is selected and assigned dynamically to each MS.

Spread Spectrum

Spread spectrum is a transmission technique wherein data occupy a larger bandwidth than necessary. Bandwidth spreading is accomplished before transmission through the use of a code that is independent of the transmitted data. The same code is used to demodulate the data at the receiving end. Figure 7.12 illustrates the spreading done on the data signal *s(t)* by the code signal *c(t)* resulting in the message signal to be transmitted, *m(t)*. That is,
$m(t) = s(t) \times c(t)$.
Designed for military use to avoid jamming (interference created intentionally to make a communication channel unusable).
Used in personal communication systems due to its superior performance in an interference dominated environment.

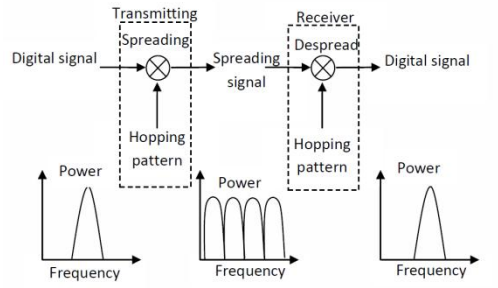
Direct Sequence Spread Spectrum (DSSS)

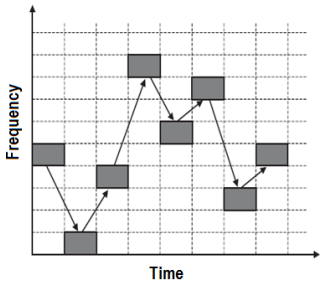
In a DSSS method, the radio signal is multiplied by a pseudorandom sequence whose bandwidth is much greater than that of the signal itself, thereby spreading its bandwidth.



This is a modulation technique wherein a pseudorandom sequence directly phase modulates a (data-modulated) carrier, thereby increasing the bandwidth of the transmission and lowering the spectral power density (i.e., the power level at any given frequency).
The resulting RF signal has a noise like spectrum and in fact can be intentionally made to look like noise to all but the intended radio receiver.
The received signal is despread by correlating it with a local pseudorandom sequence identical to and in synchronization with the sequence used to spread the carrier at the radio transmitting end.

Frequency Hopping Spread Spectrum (FHSS)





In a FH method, a pseudorandom sequence is used to change the radio signal frequency across a broad frequency band in a random fashion.
A spread spectrum modulation technique implies that the radio transmitter frequency hops from channel to channel in a predetermined but pseudorandom manner.
The RF signal is dehopped at the receiver end using a frequency synthesizer controlled by a pseudorandom sequence generator synchronized to the transmitter's pseudorandom sequence generator.
Multiple simultaneous transmission from several users is possible using FH, as long as each uses different frequency hopping sequences and none of them "collides" (no more than one unit using the same band) at any given instant of time.

Advantage of CDMA

1. It gives good protection against interference and tapping.
2. Potentially larger capacity (more users can communicate simultaneously)
3. The transition from one Base station to another (handoff) is not abrupt as in TDMA and provides better quality.
4. Easy addition of more users.
5. Impossible for hackers to decipher the code sent.
6. Better signal quality.

Disadvantages:

1. As the number of users increases, the overall quality of services decreases.
2. Self jamming
3. Near-Far problem arises.
4. Relatively high complexity of the receiver. (A receiver has to know the code and must separate the channel with user data from the background noise composed of other signals and environmental noise. Additionally, a receiver must be precisely synchronized with the transmitter the decoding correctly.)
5. All signals should reach a receiver with almost equal strength; otherwise some signals could drain others. If some people close to a receiver talk very loudly the language does not matter. The receiver cannot listen to any other person. To apply CDM, precise power control is required.

Comparison of Various Multiple Division Techniques

Technique	FDMA	TDMA	CDMA
Concept	Divide the frequency band into several subbands	Divide the time into non-overlapping time slots	Spread the signal with orthogonal codes
Active terminals	All terminals active on their specified frequencies	Terminals active on in their specified slot on same frequency	All terminals active on same frequency
Signal separation	Filtering in Frequency	Synchronization in time	Code separation
Handoff	Hard handoff	Hard handoff	Soft handoff
Advantages	Simple and robust	Flexible	Flexible
Disadvantages	Inflexible, available frequencies are fixed, requires guard bands	Requires guard space, synchronization problem.	Complex receivers, requires power control to avoid near-far problem