UNIT 2

WIRELESS MEDIUM ACCESS CONTROL AND CDMA-BASED COMMUNICATION

Unit 2: SYLLABUS

Wireless Medium Access Control and CDMA-based Communication: Medium Access Control, Introduction to CDMA-based Systems, OFDM. **(6 Hours)**

2.1 Medium access control (MAC)

When a number of signal sources attempt to access a wireless medium simultaneously, networks encounter the problem of receiving signals from each radio carrier distinctly. This is because the signals tend to interfere with each other when they are simultaneously transmitted through a medium. Also we come across the problem of hidden and exposed terminal, near and far terminal. To overcome these problems we use some of the protocols as shown below.

- **SDMA:** Wireless stations (WSs), which are distantly located, access the medium by transmitting at the same f_{c0} as well as in the same time-slot SL in different spaces only. Wireless stations located at suitable distances from each other are then said to transmit using SDMA.
- **TDMA:** When WSs are located in the same space, then WSs can access the medium in m different time-slots, SL_0 to SL_{m-1}, when there are m slots in a TDMA. DECT systems use TDMA for controlling medium access. Half of the TDMA slots are used for uplink and half for downlink.
- **FDMA:** This is the another scheme of operation is that the uplink and downlink access of the WSs in the medium are in different time-slots or in the same slots,SL_0 to SL_{m-1}, but the uplink and downlink frequencies of the radio carrier, f_c, are distinct for FDD access. Also different uplink-downlink frequency pairs are assigned distinct f_cs in a cell. This is called FDMA.

- **ALOHA:** Simple method for reducing the collisions is to employ the basic ALOHAnet protocol for a point-to-point or broadcast network. Whenever a WS has any voice-data or data to transmit, it just transmits the data. In case there is interference or collision, the WS retransmits the data at a later instant.
- **Slotted ALOHA:** In which a WS retransmits in a discrete time-slot instead of transmitting at a random time. A WS cannot transmit at any time, but just at the beginning of that time-slot. Thus the chances of collisions are reduced.
- **Reservation ALOHA:** In which the slots of the WSs are reserved as per the current demand of the WSs.
- **CSMA:** Each WS first listens whether the carrier f_c is already present in the channel to be used and transmits only when there is no carrier present because only then will there be a negligible chance of interference or collision. This method is called CSMA.
- **CSMA/CA [CSMA/collision avoidance]:** Each node wits for certain period of time after sensing the carrier after which the carrier is sensed again.
- **CSMA/CD [CSMA/collision detection]:** Is a protocol in which it is checked whether a collision is detected at the transceiver before transmitting.

2.1.1 Exposed terminal problem

When ch_2 is active, then ch_0 cannot be used by WS_3 for transmitting to WS_0 even though there is no interference between ch_0 and ch_2. This is because WS_3 senses that the radio carrier frequency f_c is being used by WS_2 and backs off. Ws_3 is thus exposed to the WS_2 carrier

2.1.2 Hidden terminal problem

There could also be a case where WS_3 cannot sense the ch_0 signals from WS_0. This is because the signal strength decreases as the inverse of the square of the distance between the two terminals. When WS_0 transmits to WS_1 or WS_2, since WS_3 does not sense that the radio carrier f_c is being used by WS_0, WS_3 also starts transmitting to WS_1 or WS_2. The radio carriers from WS_0 and WS_3 interfere in the region near WS_1 and WS_2. The collisions of the signals from WS_0 are not detected by WS_0 in CSMA. This is because WS_0 is hidden to the WS_3 carrier.

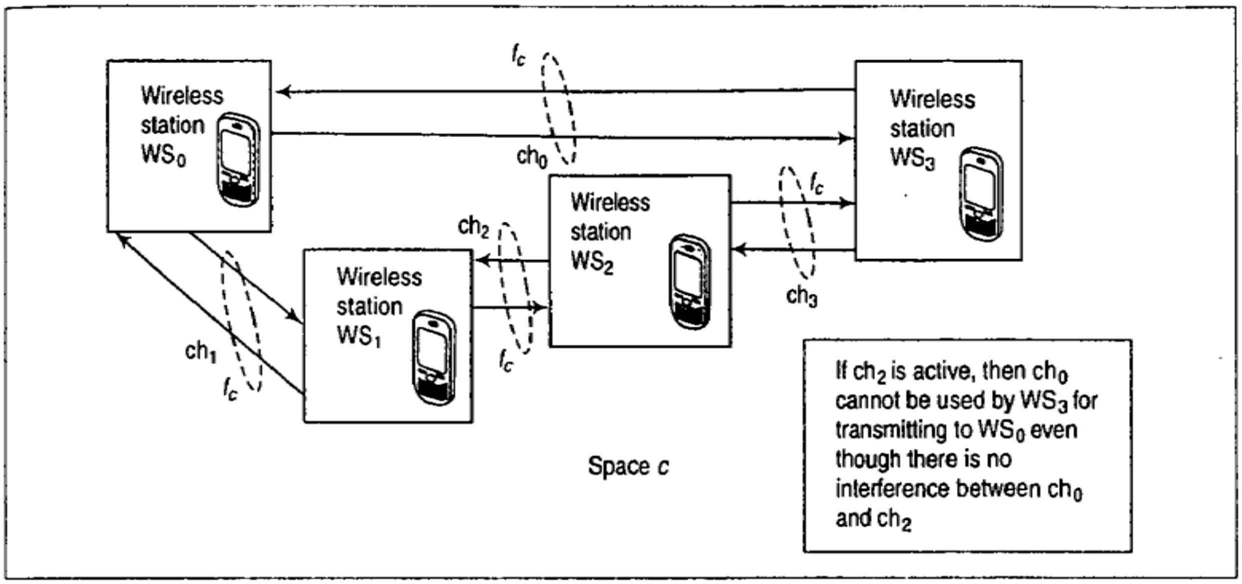

Fig. 4.1 Exposed terminal problem: space *c* with four radio-carrier channels, ch_0, ch_1, ch_2, and ch_3, of four wireless stations, WS_0 to WS_3, using the same radio-carrier frequency f_c and using CSMA for medium access control

2.1.3 Media Access Control for Near and Far Terminals

Assume that WS_3 sends signals via ch_0 for WS_0. The signal strength is weak along the ch_0 region near WS_0. This is because the signal strength decreases as inverse of the square of the distance between the two terminals. When WS_0 is transmitting to WS_1 or WS_2, the WS_3 signal, being weak because of its proximity to WS_0, is not listened by WS_0. This is because the ch_1 signal strengths are higher near WS_0 as compared to the ch_0 signal strength. The strong ch_1 signals superimpose on the weak ch_0 signals at WS_0. WS_3 is the far terminal and WS_1 or WS_2 are the near terminal.

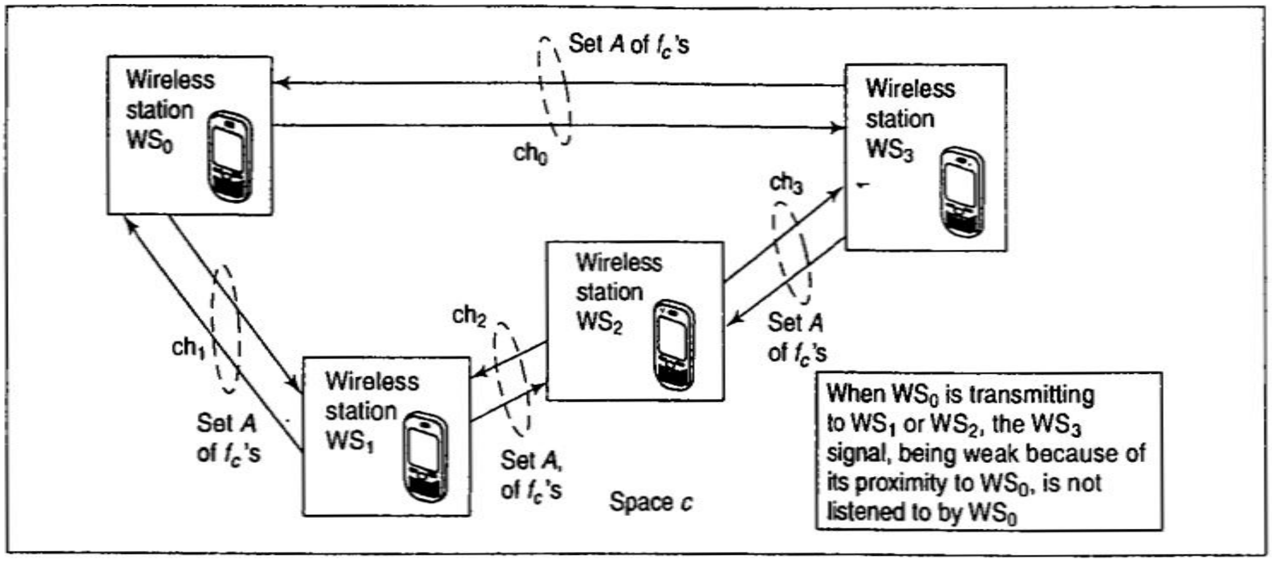

Fig. 4.2 Near and far terminal problem: space c with four radio-carrier channels, ch_0, ch_1, ch_2, and ch_3, of four wireless stations, WS_0 to WS_3, using the same set A of radio-carrier frequencies (f_c's) and using CSMA for medium access control

2.2 Introduction to CDMA-based systems

Code division multiple access (CDMA) is used as a multiplexing method in many mobile telephony systems. Such systems are called CMDA systems.

FEATURES OF CDMA SYSTEMS:

- CDMA is more robust for multi-path delay and provides higher immunity towards frequency selective fading.
- CDMA systems use a good set of codes. A good set of CDMA code is one in which all the codes are orthogonal to each other and which results in autocorrelation at the receiver.
- A set of n equally spaced frequencies, known as chipping or hopping frequencies, is used for transmission either in direct sequence or by frequency hopping. The n chipping or hopping frequency signals are given as.

$$S_{(n-1)}(t)=s_{(n-1)}*(s_0/\sqrt{n})\ \sin\{2\pi*(f_{c0}+(n-1)f_s)*\ t + \varphi_{r0}\}$$

- A CDMA DSSS receiver (fig. 4.6) XORs the received signal with the chipping code, which was used for transmission, thus giving back the original symbol in user data.
- A CDMA FHSS receiver (fig. 4.7) demodulates the signals of that channel frequency which corresponds to the code symbol for the hop.

- CDMA systems give signals of higher voice and data quality and small bit error rate.
- CDMA systems have soft handover.
- CDMA systems perform power control by open loop or closed loop methods to solve the problem of drowning of signals from far mobile terminals by those from the near terminal.

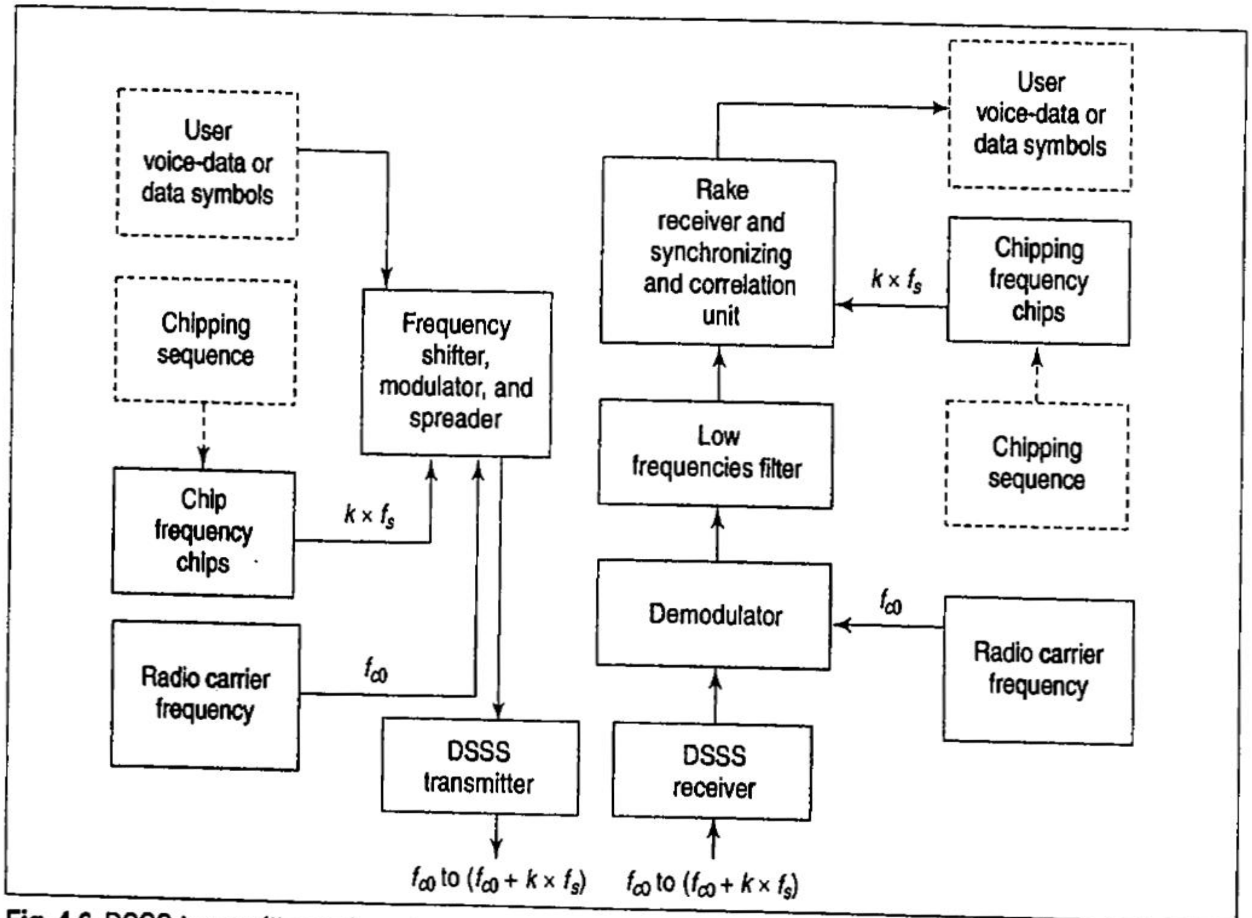

Fig. 4.6 DSSS tra nsmitter and receiver

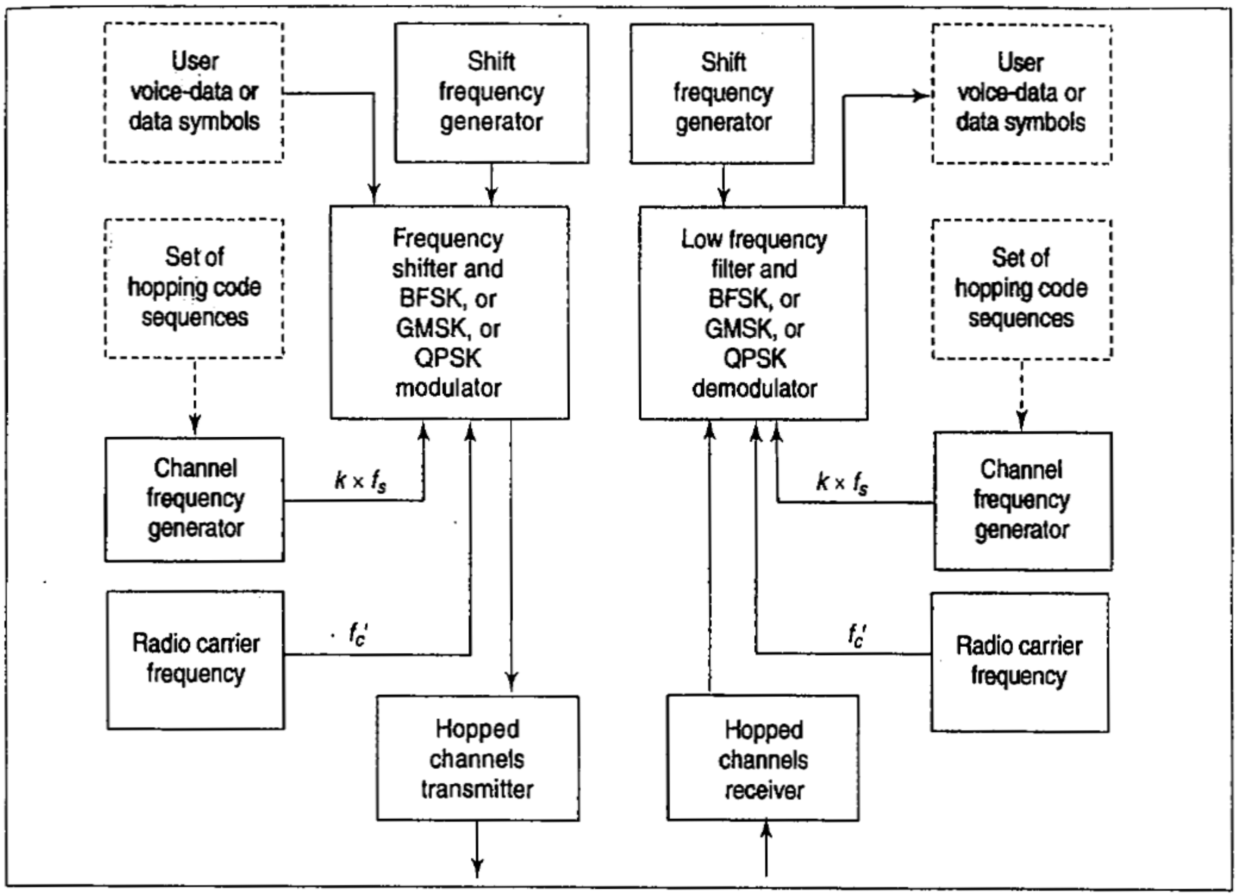

Fig. 4.7 FHSS transmitter and receiver

2.2.1 Spread spectrum in CDMA systems

CDMA systems employ spread spectrum techniques for medium access control, CDMA can work in two different ways.

1. Direct Sequence Spread Spectrum (DSSS).
2. Frequency Hopping Spread Spectrum (FHSS).

Spread spectrum is a transmission technique that provides a novel solution to the interference problem.

FEATURES OF SPREAD SPECTRUM:

- Reduced co-channel interference.
- Greatly reduced narrow-band interference.

2.2.2 Direct sequence spread spectrum (DSSS)

If a sequence of data needs to be transmitted by the sender, data is XORed with a pseudorandom code. The result looks like a random set of numbers. This random set of numbers is transmitted.

The receiver receives the random number, the random number is XORed with the same pseudorandom code to retrieve back the data that user intended to send.

The block diagram for DSSS transmitter and receiver is fig: 4.6 in page 144.

2.2.3 Frequency hopping spread spectrum (FHSS):

FHSS is a method of transmitting user data using one of the carrier-frequency channels in a given interval of time from among multiple channels and then hop the channel frequency to another channel in the next interval of time.

If a sequence of data needs to be transmitted, then it will be transmitted at different frequencies based on pseudorandom code.

The receiver should know the random code. The receiver should read the frequencies in the order of the random code to obtain the data back.

Slow FHSS: FHSS spectrum in which the interval during a hop, $t_h >> t_s$, is called FHSS. A number of symbols transmitted during a channel hop period.

Advantage:

- Even if a channel frequency signal is faded at the receiver due to narrow band interface, the other symbols are received correctly.

Fast FHSS: FHSS in which the interval during a hop, t_h >> ts. During a symbol period, a large number of frequency hops take place.

Advantage:

- Even if a few channel frequencies are faded at the receiver due to narrow band interference, the symbol is received correctly.

The block diagram for FHSS transmitter and receiver is fig: 4.7 in page 145.

2.3 OFDM:

OFDM is a spread-spectrum-based technique for distribution of data over a larger of sub-carriers that are spaced at precise frequency intervals with a coding scheme.

OFDM is also called COFDM (code orthogonal frequency division multiplexing), it is also called spread-spectrum based multi-carrier or discrete multi-tone modulation. The term COFDM is used in order to distinguish the modulation method from quadrature modulation QPSK.

Characteristics:

- High spectral efficiency.
- Strong resiliency to RF inter-symbol interferences.
- Lower multi-path distortion.

Applications:

- Used in Wireless LANs for point-to-point transmission and for multicasting.
- Used in digital audio broadcasting (DAB), digital video broadcasting (DVB).
- Also used in asymmetric digital subscriber line (ADSL).

2.3.1 Techniques in OFDM:

Wideband OFDM (WOFDM): Is a technique in which spacing between multi-carrier channels is made large. Therefore, any frequency error between the transmitter and the receiver do not affect system performance.

Flash OFDM: Is another technique based on the FHSS spectrum. It is also called fast-hopped OFDM.

MIMO-OFDM (multiple input, multiple output OFDM): Is a technique in which multiple antennae are used for inputs and outputs. It provides broadband wireless access (BWA) and performs well in multiple non-line-of-sight multiple-path environments.

VOFDM (vector OFDM): Is another technique based on MIMO-OFDM.