Department of Computing

**Hong Kong Polytechnic University**

**Comp 5527 Mobile Computing and Data Management**

**Tutorial Two Sample Solutions**

Q1. Sample Solution:

Yes, data can be transmitted without being modulated with a carrier signal (called *baseband transmission*).

* + First, the digital data stream is encoded to facilitate synchronization at the receiver, e.g., by using Manchester Encoding. Then the encoded data is signaled through the amplitude, location, or duration of a basic pulse shape.
  + Each user occupies the entire available bandwidth of the medium. In wired networking, this might be ok because we can always use different channels for different transmissions (e.g., we have telephone wiring, TV cables, and LAN wiring).

In wireless networking, we have only one medium (air) that must be shared among a variety of applications To arrange a multiple transmission environment, the message signal is mixed with a carrier signal at a higher frequency (called *broadband transmission*).

* + In broadband signaling, carrier modulation shifts the spectrum of the transmitted signal to the location of the carrier in the spectrum, so each transmission occupies a different channel separated by its carrier frequency, allowing orderly coexistence of a number of transmissions via FDM.
  + Carrier modulation also shifts the frequency operation to higher values providing better coverage and reducing the length of the antenna to a practical size (the lower the signal’s frequency, the larger the size of the antenna).

However, with increasing carrier frequency, the design of RF circuits becomes more challenging, and also in-building penetration of the signal becomes smaller.

Note:

1. The wired computer communication community is dominated by baseband systems, and the term “broadband” is used for all carrier-modulated systems. In the wireless community, however, the dominant technique is carrier modulation, and the term “broadband” is used when the transmission rate approaches a very high value.
2. “Modulation” is also used to mean changing the form of a signal to carry information. The carrier signal is continuous wave with constant amplitude and frequency, so on receiver site you can indicate only if carrier is present or not but nothing more. If you also want to transmit any data, information or audio signal, for example, you must modulate this carrier signal, in different type or kind from simple AM, FM, SSB to QPSK and other digital types.

Q1: Sample Solutions:

In the *Frequency Hopping Spread Spectrum* (FHSS) modulation scheme, signal is broadcast over seemingly random series of radio frequencies. A number of channels are allocated for the FH signal. Width of each channel corresponds to bandwidth of input signal. Signal hops from frequency to frequency at fixed intervals.

The Transmitter operates in one channel at a time. Bits are transmitted using some encoding scheme. At each successive interval, a new carrier frequency is selected.

Receiver hops between frequencies in synchronization with transmitter and picks up message.

The following is an example:



Q3. Sample Solutions:

In the *Direct Sequence Spread Spectrum* (DSSS) modulation scheme, each bit in the original stream is encoded by a *chip code* of *m* bits.

DSSS works as follows:

* Both the sending and receiving stations agree on a sequence of random chip-codes, one code for each data bit.
* The sending station generates the chip code sequence; Then, the data stream is represented and/or combined with the chip code sequence in some way and then transmitted.
* The receiver generates the same pseudo random sequence in synchronization with the sending station, and then recovers the original bit stream.
  + Synchronization is needed between sender and receiver. In order to intercept the signal, a receiver must know the “frequency-versus-time” function employed by the transmitter, and must know the starting time point at which the function begins.

The following is an example using XOR:

0 1 1 0 0 1 1 0 0 1 1 0 1 0 1 1 1 0 1 0 0 0 1 1 1 0 1 1 0 1 1 0

0 1 1 0 0 1 1 0 0 1 1 0 1 0 1 1 1 0 1 0 0 0 1 1 1 0 1 1 0 1 1 0

1 0 0 1 0 1 1 0 1 0 0 1 0 1 0 0 1 0 1 0 1 1 0 0 1 0 1 1 0 1 1 0

1 0 1 1 0 1 0 0

Data input A

Locally generated

pseudorandom bit

stream B

Transmitted signal

C = A ⊕ B

T

r

a

n

s

m

I

t

t

e

r

Data output

A = C ⊕ B

Locally generated

pseudorandom bit

stream identical

to B above

Received signal

R

e

c

e

I

v

e

r

1 0 0 1 0 1 1 0 1 0 0 1 0 1 0 0 1 0 1 0 1 1 0 0 1 0 1 1 0 1 1 0

1 0 1 1 0 1 0 0

In CDMA schema,

* The chip code is used to encode the binary 1 and its complement is used for binary 0.
* The chip codes assigned to stations are not truly random, but carefully designed to cancel each other out. Let station S have chip code ***S***, and ***S’*** be negation of ***S***. we say chip codes are *pair-wise orthogonal* if, for any two chip codes ***S*** and ***T*** their normalized inner product is 0, that is

***S* • *T*** = (1/*m*) ∑i=1 .. m *Si × Ti = 0*

The following properties also hold for pair-wise orthogonal codes:

* ***S* • *S*** = 1 and ***S* • *S*’** = -1 for any ***S***;
* If ***S* • *T*** = 0 then ***S* • *T***’= 0.
* Using the property, if a station knows the chip code of the sending station, it can extract its transmission information from the “mixed” transmission by calculating the inner product of the mixed transmission and the chip code.

e.g., *A* transmits a 1, *B* a 0 and *C* a 1 (concurrently). *D* wants to receive only *C*’s transmission; it uses *C*’s chip code:

(**A** + **B’**+ **C**) **•** **C** = **A • C** + **B’ • C** + **C • C** = 0 + 0 + 1 = 1

The result is 1, it means C sent a 1. If the result is -1, C sent a 0. If the result is 0, C sent nothing.

Now, for the question, just compute the four normalized inner products:

(−1 +1 −3 +1 −1 −3 +1 +1) (−1 −1 −1 +1 +1 −1 +1 +1)/8 = 1

(−1 +1 −3 +1 −1 −3 +1 +1) (−1 −1 +1 −1 +1 +1 +1 −1)/8 = −1

(−1 +1 −3 +1 −1 −3 +1 +1) (−1 +1 −1 +1 +1 +1 −1 −1)/8 = 0

(−1 +1 −3 +1 −1 −3 +1 +1) (−1 +1 −1 −1 −1 −1 +1 −1)/8 = 1

The result is that A and D sent 1 bit, B sent a 0 bit, and C was silent.

Why using CDMA (spread spectrum) allows nodes to communicate with each other concurrently?

* + - It allows each station to transmit over the entire frequency spectrum all the time, because it is no more the case that colliding frames are totally garbled; instead, multiple signals add linearly - multiple simultaneous transmissions are separated using coding theory.
  + Therefore, different sets of transmitters and receivers using different chip sequences will not interfere with each other.
  + Each receiver is provided by the corresponding code so that it can decode the data it is expected to receive. Any variation of the code interprets the received information simply as noise.
    - The number of users being serviced simultaneously is determined by the number of possible orthogonal codes that could be generated.

CDMA can be potentially very efficient.

Suppose a 1 MHz channel is given. Using FDM, the channel divides into 100 sub-bands, each of 10 KHz and each is used to carry 10 Kbps. The total channel capacity is 1 Mbps.

With CDMA, each of 100 stations transmits at 1 Mbps (106 chips/sec). If the chip code length is 50, then the 100 stations can transmit effectively at 106 / 50 = 20 Kbps, and the total channel capacity is of 2 Mbps.