CS8601- MOBILE COMPUTING
UNIT I
INTRODUCTION

Introduction to Mobile Computing – Applications of Mobile Computing- Generations of Mobile Communication Technologies- Multiplexing – Spread spectrum -MAC Protocols – SDMA- TDMA- FDMA- CDMA

INTRODUCTION TO MOBILE COMPUTING

What is the mobile or nomadic computing? - someone /something can move or be moved easily and quickly from place to place
What is computing? - Operation of computers
What is mobile computing? - Users with portable computers still have network connections while they move
Mobile Computing to describe technologies ,it enable people to access network services anyplace, anytime, and anywhere

Introduction to Mobile Computing

- It collecting information and computational services in mobile environment
- It is based on the wireless networking environment and enable to accessing data in mobile status.

Function of Mobile Computing

- User mobility
- Bearer mobility
- Host mobility
- Service mobility

Characteristics of mobile computing

- Adaptation
- Personalization
- Ubiquity
- Location Awareness
- Broadcast

A communication device can exhibit any one of the following characteristics:
1.Fixed **and wired-** This configuration describes the typical desktop computer in an office. the devices allow for mobile usage. The devices use fixed networks for performance reasons.
2. Mobile **and wired-** users carry the laptop from one hotel to the next, reconnecting to the company's network via the telephone network and a modem.
3. Fixed **and wireless -** used for installing networks, e.g., in historical buildings to avoid damage by installing wires, or at trade shows to ensure fast network setup.
4. Mobile **and wireless -** is the most interesting case. No cable restricts the user, who can roam between different wireless networks.

APPLICATIONS OF MOBILE COMPUTING

1. Vehicles: transmission of news, road condition, weather, music via DAB (digital audio broadcasting)

- personal communication using GSM
- position via GPS(global positioning system)
- local ad-hoc network with vehicles close-by to prevent accidents, guidance system, redundancy
- vehicle data (e.g., from busses, high-speed trains) can be transmitted in advance for maintenance

- Buses, trucks, and trains are already transmitting maintenance and logistic information to their home base, which helps to improve organization (fleet management), and saves time and money.

2. Emergencies - early transmission of patient data to the hospital, current status, first diagnosis

- Replacement of a fixed infrastructure in case of earthquakes, hurricanes, fire etc.
- crisis, war, ...

3. Travelling salesmen(Business) - direct access to customer files stored in a central location

- consistent databases for all agents
- mobile office

4. Replacement of fixed networks - remote sensors, e.g., weather, earth activities

- flexibility for trade shows
- LANs in historic buildings

5. Entertainment, education - outdoor Internet access

- intelligent travel guide with up-to-date location dependent information
- ad-hoc networks for multi user games

6. Credit Card Verification- Supermarkets, when customers use credit cards for transactions, the intercommunication required between the bank central computer

7. Replacement of Wired Networks- wireless networks can also be used to replace wired networks, e.g., remote sensors, for tradeshows, or in historic buildings

8. Infotainment: wireless networks can provide up-to-date information at any appropriate location.

9. For Estate Agents - With mobile computers they can be more productive.

- They can obtain current real estate information by accessing multiple Listing services, which they can do from home, office or car when out with clients.

<u>10. Location dependent services</u>

Location aware services - what services, e.g., printer, fax, phone, server etc. exist in the local environment

Follow-on services- automatic call-forwarding, transmission of the actual workspace to the current location

Information services - „push“: e.g., current special offers in the supermarket

- „pull“: e.g., where is the Black Forrest Cherry Cake?

Support services -caches, intermediate results, state information etc. „follow“ the mobile device through the fixed network

Privacy -who should gain knowledge about the location

GENERATIONS OF MOBILE COMMUNICATION TECHNOLOGIES

- This innovation consists of a number of generations
- mobile wireless communication began with 1G followed by 2G,3G,4G,and under research upcoming generations 5G.
- The <u>mobile wireless Generation</u> (G) - to a change in the nature of the system, speed, technology, frequency, data capacity, latency etc.
- Each generation have some standards, different capacities, new techniques and new features which differentiate it from the previous one.
- The <u>first generation</u> (1G) mobile wireless communication network was analog used for voice calls only.
- The <u>second generation</u> (2G) is a digital technology and supports text messaging.
- The third generation (3G) mobile technology provided higher data transmission rate, increased capacity and provide multimedia support.
- The <u>fourth generation</u> (4G) integrates 3G with fixed internet to support wireless mobile internet, which is an evolution to mobile technology and it overcome the limitations of 3G. It also increases the bandwidth and reduces the cost of resources.
- <u>5th Generation</u> Mobile technology and is going to be a new revolution in mobile market which has changed the means to use cell phones within very high bandwidth.

First Generation (1G)

- This was introduced in 1982 and completed in early 1990.
- It was used for voice services and was based on technology called as Advanced Mobile Phone System (AMPS).
- The AMPS system was frequency modulated and used frequency division multiple access (FDMA) with a channel capacity of 30 KHz and frequency band of 824-894MHz.
- Such as Mobile Telephone System (MTS), Advanced Mobile Telephone System (AMTS), Improved Mobile Telephone Service (IMTS), and Push to Talk (PTT).

Features are:

- Speed-2.4 kbps
- Allows voice calls in 1 country
- Use analog signal.
- Poor voice quality
- Poor battery life
- Large phone size
- Limited capacity
- Poor handoff reliability
- Poor security
- Offered very low level of spectrum efficiency

Second Generation (2G)

- second generation based on GSM, 1980.
- It uses digital signals for voice transmission.
- provides services to deliver text and picture message at low speed (in kbps).
- It use the bandwidth of 30 to 200 KHz. Next to 2G, 2.5G system uses packet switched and circuit switched domain and provide data rate up to 144 kbps. e.g. GPRS, CDMA and EDGE

Features of 2G are

- Data speed was upto 64kbps
- Use digital signals
- Enables services such as text messages, picture messages and MMS(Multimedia message)
- Provides better quality and capacity
- Unable to handle complex data such as videos.
- Required strong digital signals to help mobile phones work. If there is no network coverage in any specific area, digital signals would weak.

Features of 2.5G are

- Provides phone calls
- Send/receive e-mail messages
- Web browsing
- Speed : 64-144 kbps
- Camera phones
- Take a time of 6-9 mins. to download a 3 mins. MP3 song.

Third Generation (3G)

- To offer high speed data(launched in 2000)
- The original technology was improved to allow data up to 14 Mbps and more using packet switching.
- It uses Wide Band Wireless Network with which clarity is increased.
- It also offers data services, access to television/video, new services like Global Roaming.
- It operates at a range of 2100MHz and has a bandwidth of 15-20MHz used for High-

speed internet service, video chatting.

Features of 3G are:

- Speed 2 Mbps
- typically called smart phones
- Increased bandwidth and data transfer rates to accommodate web-based applications and audio and video files.
- Provides faster communication
- Send/receive large email messages
- High speed web/more security/video conferencing/3D gaming
- large capacities and broadband capabilities
- TV streaming/mobile TV/Phone calls
- to download a 3 minute MP3 song only 11 sec-1.5 mins time required.
- High bandwidth requirement
- Expensive 3G phones
- Large cell phones

Fourth Generation (4G)

- 4G offers a downloading speed of 100Mbps.
- services like Multi-Media Newspapers, to watch T.V programs with more clarity and send Data much faster
- Applications like wireless broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV, HDTV content, Digital Video Broadcasting (DVB), minimal services like voice and data, and other services that utilize bandwidth, LTE (Long Term Evolution).

Features of 4G are :

- Capable of provide 10Mbps-1Gbps speed
- High quality streaming video
- Combination of Wi-Fi and Wi-Max
- High security
- Provide any kind of service at any time as per user requirements anywhere
- Expanded multimedia services
- Low cost per-bit
- Battery uses is more
- Hard to implement
- Need complicated hardware

Fifth Generation (5G)

- started from late 2010s,includes far better levels of connectivity and coverage.
- 5G will be on world-Wireless World Wide Web (WWWW).
- It is a complete wireless communication with no limitations.

features of 5G are :

- It is highly supportable to WWWW (wireless World Wide Web)
- High speed, high capacity
- Provides large broadcasting of data in Gbps.
- Multi-media newspapers, watch TV programs with the clarity(HD Clarity)
- Faster data transmission that of the previous generation
- Large phone memory, dialing speed, clarity in audio/video
    - Support interactive multimedia, voice, streaming video, internet and other
    - More effective and attractive

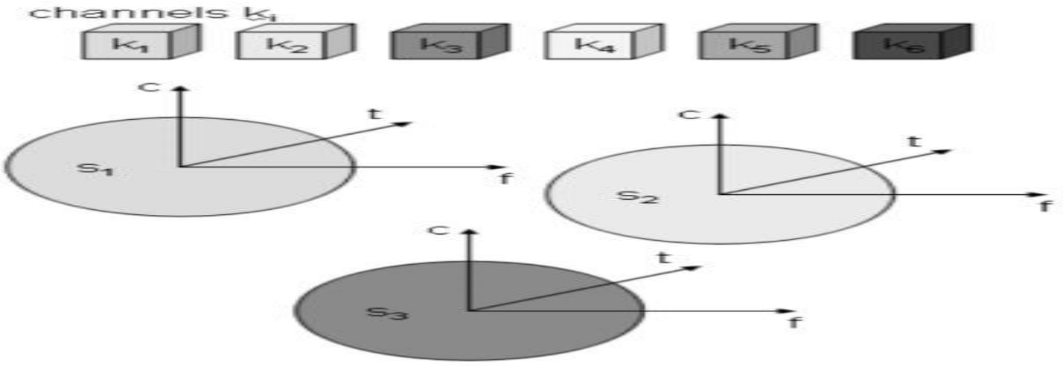
MULTIPLEXING - How several users can share a medium with minimum (or) no interference

Types :

1. Space division multiplexing (SDM)
2. Frequence division multiplexing (FDM)
3. Time division multiplexing (TDM)
4. Code division multiplexing (CDM)

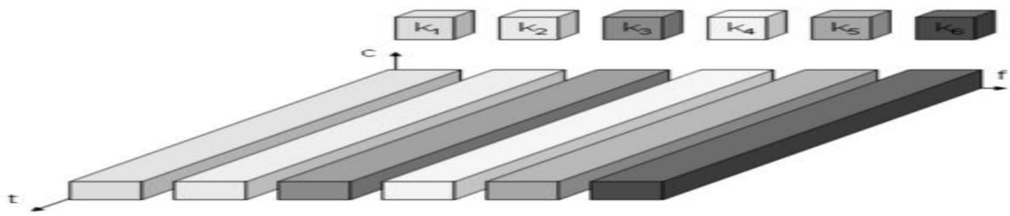
1. Space Division Multiplexing

- Six channels ki introduces a three dimensional coordinate system. It shows the dimensions of code c, time t and frequency t. Space division multiplexing (SDM) the (three dimensional) space si
- The channels k1 to k3 can be mapped onto the three spaces s1 to s3 which clearly separate the channels and prevent the interference ranges from overlapping.
- The space between the interference ranges is sometimes called **guard space**. Such a guard space is needed in all 4 multiplexing schemes presented. The remaining channels (k4 to k6) three additional spaces would be needed.
- In wireless transmission SDM implies a separate sender for each communication channel with a wide enough distance between senders.



2. Frequency Division Multiplexing (FDM)

- Schemes to subdivide the frequency dimension into several non-overlapping frequency bands.
- Each channel k1 is now allotted its frequency band as indicated. Senders using a certain frequency band can use this band continuously.
- Guard spaces are needed to avoid frequency band overlapping called adjacent channel interference.



This is used in radio stations within the same region where each radio station has its own frequency.

Significance:

- No dynamic coordination necessary
- Works also or analog signals

Disadvantages - Waste of bandwidth if the traffic is distributed unevenly

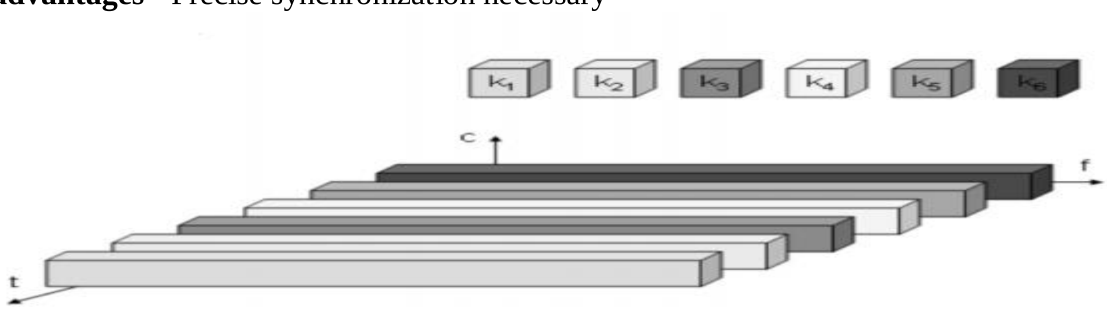
3. Time Division Multiplexing (TDM)

- Here channels k1 is given the whole bandwidth for a certain amount of time i.e all senders use the same frequency but at different point of time Guard spaces
- which represent time gaps have to separate the different periods when the senders use the medium. If two transmissions overlap in time this is called co-interference.
- To avoid this type of interference precise synchronization between different senders is necessary.

Significance:

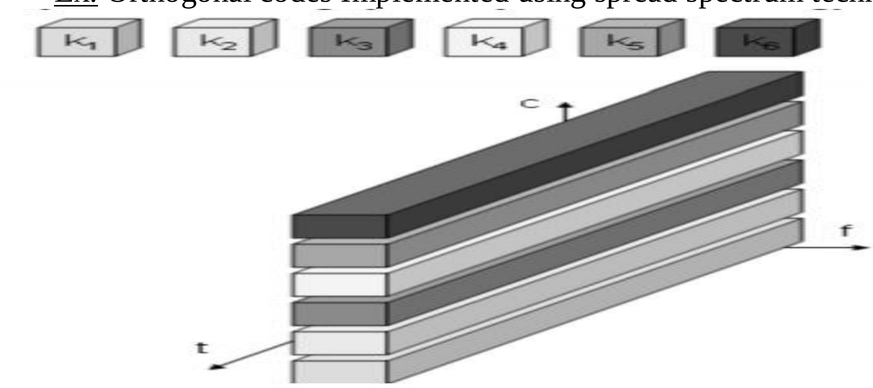
- Only one carrier in the medium at any time
- Throughput high even for many users

Disadvantages - Precise synchronization necessary



4. Code Division Multiplexing

- Each channel has a unique code
- All channels use the same spectrum at the same time
- Guard spaces are raises by using codes with the necessary distance in code space
- Ex. Orthogonal codes Implemented using spread spectrum technology



Significance:

- Bandwidth efficient
- No coordination and synchronization necessary
- Good protection against interference and tapping

Disadvantages

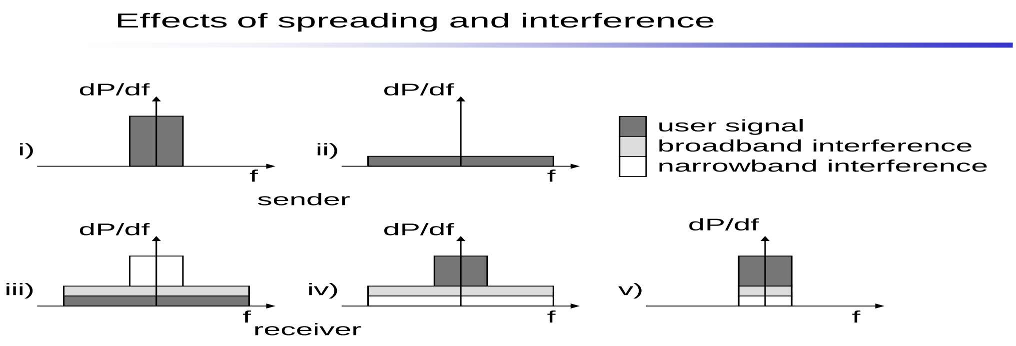
- Varying user data rates
- More complex signal regeneration

SPREAD SPECTRUM

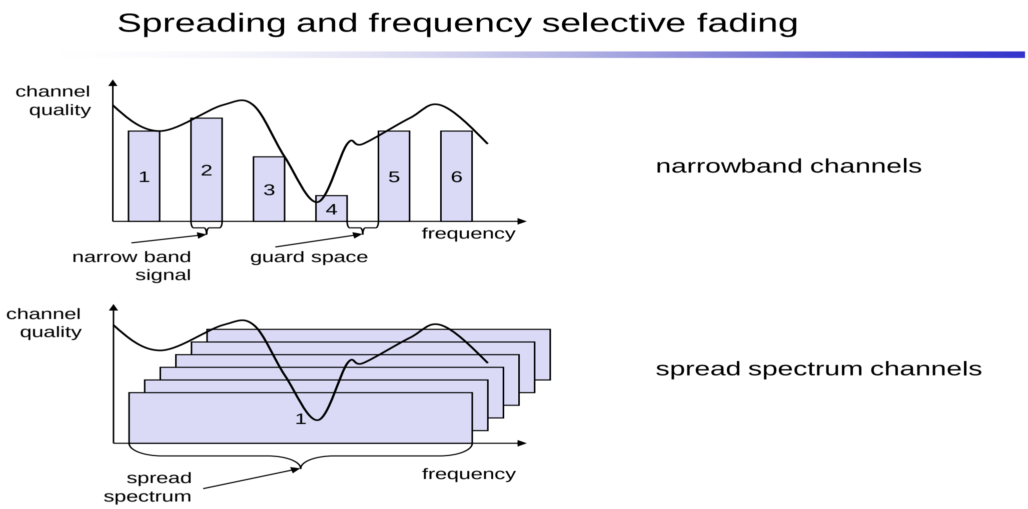
- Techniques involve spreading the bandwidth needed to transmit data.
- The main advantage is the resistance to narrowband interference.

Problem of radio transmission: frequency dependent fading can wipe out narrow band signals for duration of the interference

Solution: spread the narrow band signal into a broad band signal using a special code Protection against narrow band interference



- i) shows an idealized narrowband signal from a sender of user data (here power density dP/df versus frequency f). The sender now spreads the signal in step.
- ii) Converts the narrowband signal into a broadband signal. The energy needed to transmit the signal is the same, but it is now spread over a larger frequency range, the power level of the user signal can even be as low as the background noise.
- iii)The sum of interference and user signal is received. The receiver now knows how to desperado the signal, converting the spread user signal into a narrowband signal again, while spreading the narrowband interference and leaving the broadband interference.
- v) the receiver applies a band pass filter to cut off frequencies left and right of the narrowband signal. Finally, the receiver can reconstruct the original data because the power level of the user signal is high enough,



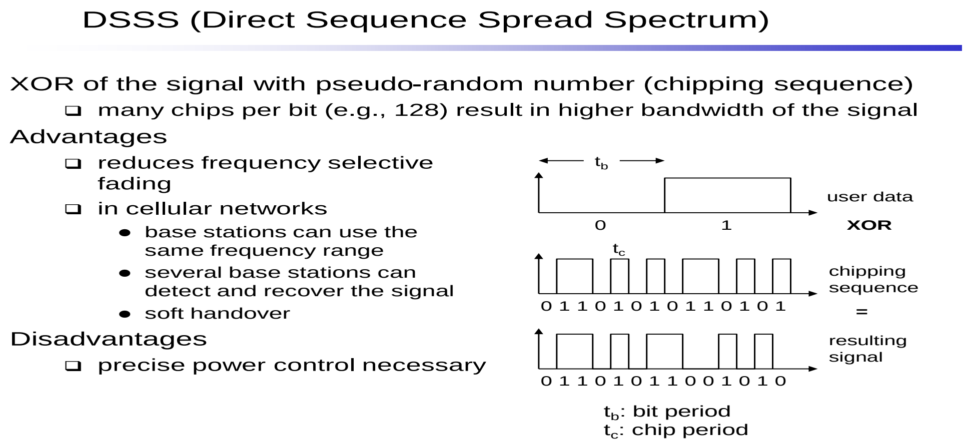
Narrowband channels

- Six different channels use FDM for multiplexing, which means that each channel has its own narrow frequency band for transmission. Between each frequency band a guard space is needed to avoid adjacent channel interference
- Channel quality also changes over time
- Depending on receiver characteristics, channels 1, 2, 5, and 6 could be received while the quality of channels 3 and 4 is too bad to reconstruct transmitted data. Narrowband interference destroys the transmission of channels 3 and 4.

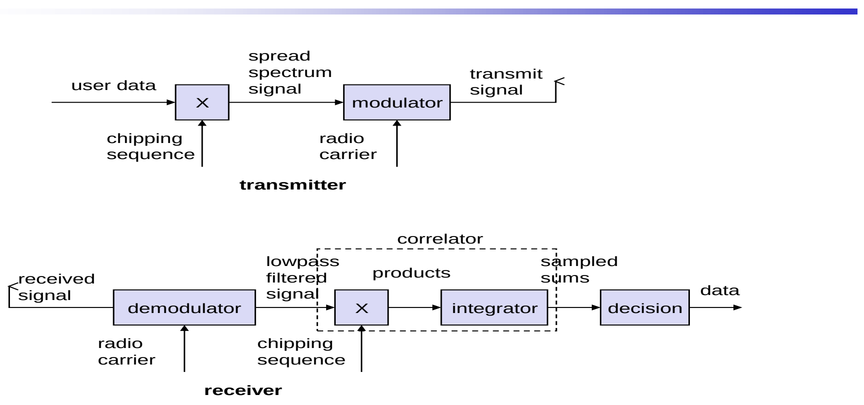
Spread spectrum channels

- Narrowband signals are now spread into broadband signals using the same frequency range.
- No more frequency planning is needed
- and all senders use the same frequency band.

1. DSSS (Direct Sequence Spread Spectrum)



- While each user bit has a duration tb, the chipping sequence consists of smaller pulses, called **chips,** with a duration tc.
- If the chipping sequence is generated properly it appears as random noise: this sequence is also sometimes called pseudo-noise sequence. The spreading factor **s = tb/tc**
- first step in a DSSS transmitter is the spreading of the user data with the chipping sequence (digital modulation). The spread signal is then modulated with a radio carrier as explained in (radio modulation).



- A DSSS transmitter is the spreading of the user data with the chipping sequence (digital modulation). The spread signal is then modulated with a radio carrier as explained in (radio modulation).
- The receiver involves demodulating the received signal.
- This is achieved using the same carrier as the transmitter reversing the modulation and results in a signal with approximately the same bandwidth as the original spread spectrum signal. Additional filtering can be applied to generate this signal.

2. FHSS (Frequency Hopping Spread Spectrum)

- The total available bandwidth is split into many channels of smaller bandwidth plus guard spaces between the channels.
- Transmitter and receiver stay on one of these channels for a certain time and then hop to another channel. This system implements FDM and TDM.
- The pattern of channel usage is called the **hopping sequence**, the time spend on a channel with a certain frequency is called the **dwell time**.

Discrete changes of carrier frequency - sequence of frequency changes determined via pseudo random number sequence

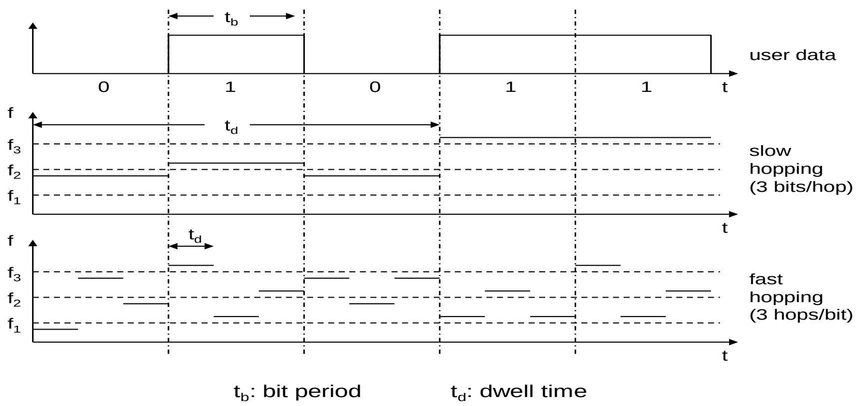
Two versions: Fast Hopping- several frequencies per user bit

Slow Hopping - several user bits per frequency

Advantages

- frequency selective fading and interference limited to short period
- simple implementation
- uses only small portion of spectrum at any time

Disadvantages - not as robust as DSSS simpler to detect, Example - Bluetooth

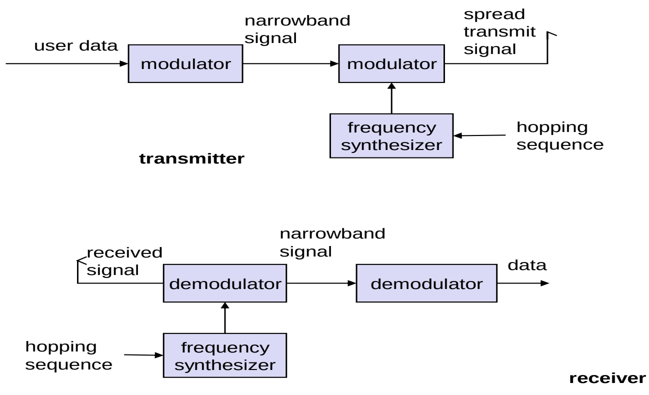


Performing slow hopping

- Five user bits with a bit period tb. the transmitter uses the frequency f2 for transmitting the first three bits during the dwell time td.
- the transmitter hops to the next frequency f3.
- Slow hopping systems are typically cheaper and have relaxed tolerances, but they are not as immune to narrowband interference as fast hopping systems.
- Slow frequency hopping is an option for GSM.

fast hopping systems,

- the transmitter changes the frequency several times during the transmission of a single bit.
- the transmitter hops three times during a bit period.
- Fast hopping systems are more complex to implement because the transmitter and receiver have to stay synchronized within smaller tolerances to perform hopping at more or less the same points in time.



FHSS transmitters and receivers

1) FHSS transmitter is the modulation of user data according to one of the digital-to-analog modulation schemes, e.g., FSK or BPSK, .

- This results in a narrowband signal, if FSK is used with a frequency f0 for a binary 0 and f1 for a binary 1.
- In the next step, frequency hopping is performed, based on a hopping sequence. The hopping sequence is fed into a frequency synthesizer generating the carrier frequencies fi.

2) A second modulation uses the modulated narrowband signal and the carrier frequency to generate a new spread signal with frequency of fi+f0 for a 0 and fi+f1 for a 1 respectively.

- If different FHSS transmitters use hopping sequences that never overlap, i.e., if two transmitters never use the same frequency fi at the same time, then these two transmissions do not interfere

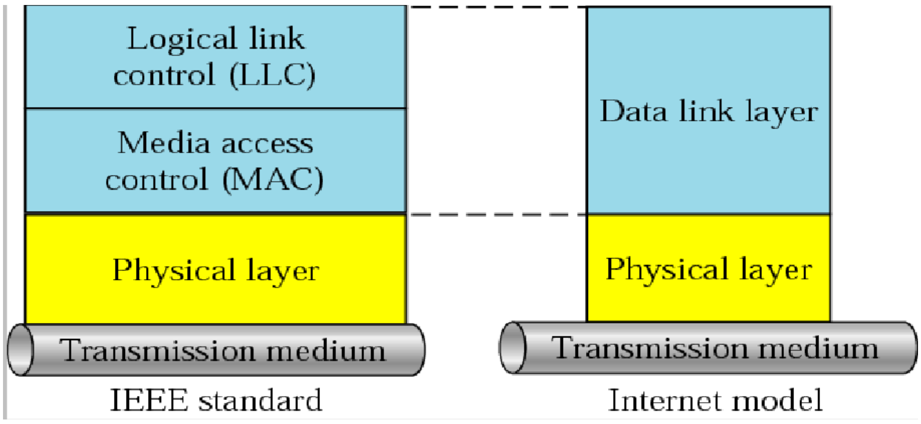
The receiver of an FHSS system has to know the hopping sequence and must stay synchronized.

- It then performs the inverse operations of the modulation to reconstruct user data

MAC PROTOCOLS

- The **Media Access Control** (**MAC**) data communication protocol sub-layer, also known as the **Medium Access Control**, is a sub-layer of the Data Link Layer specified in the seven-layer OSI model (layer 2).
- The hardware that implements the MAC
- The MAC sub-layer acts as an interface between the Logical Link Control (LLC) sub-layer and the network's physical layer.

LLC and MAC sublayers



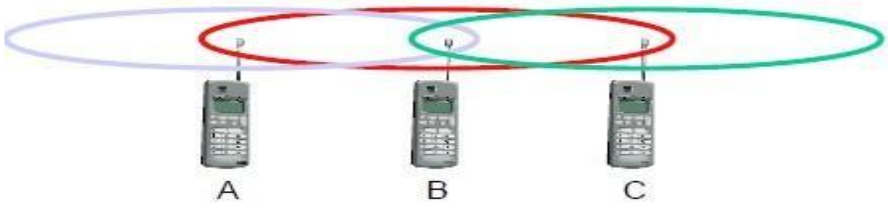
Motivation for a specialized MAC

- wired networks is carrier sense multiple access with collision detection (CSMA/CD).
- a sender senses the medium (a wire or coaxial cable) if it is free.
- If the medium is busy, the sender waits until it is free.
- If the medium is free, the sender starts transmitting data and continues to listen into the medium.
- If the sender detects a collision while sending, it stops at once and sends a jamming signal.

But this scheme doest work well with wireless networks. The problems are:

- Signal strength decreases proportional to the square of the distance
- The sender would apply CS and CD, but the collisions happen at the receiver
- It might be a case that a sender cannot "hear" the collision, i.e., CD does not work
- Furthermore, CS might not work, if for e.g., a terminal is "hidden"

Consider the scenario with three mobile phones as shown below. The transmission range of A reaches B, but not C (the detection range does not reach C either). The transmission range of C reaches B, but not A. Finally, the transmission range of B reaches A and C, i.e., A cannot detect C and vice versa.



Hidden terminals

- A sends to B, C cannot hear A
- C wants to send to B, C senses a "free" medium (CS fails) and starts transmitting
- Collision at B occurs, A cannot detect this collision (CD fails) and continues with its transmission to B
- A is "hidden" from C and vice versa

Exposed terminals

- B sends to A, C wants to send to another terminal (not A or B) outside the range
- C senses the carrier and detects that the carrier is busy.
- C postpones its transmission until it detects the medium as being idle again
- but A is outside radio range of C, waiting is **not** necessary
- C is "exposed" to B

Hidden terminals cause collisions, where as Exposed terminals causes unnecessary delay.

Near and far terminals

Consider the situation shown below. A and B are both sending with the same transmission power.

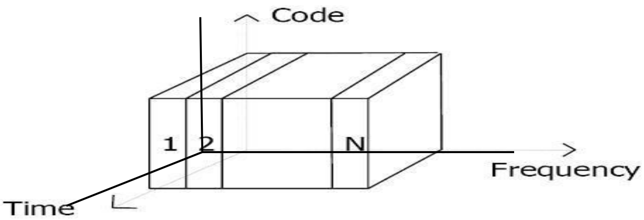
- Signal strength decreases proportional to the square of the distance
- So, B's signal drowns out A's signal making C unable to receive A's transmission
- If C is an arbiter for sending rights, B drown out A's signal on the physical layer making C unable to hear out A.

SDMA

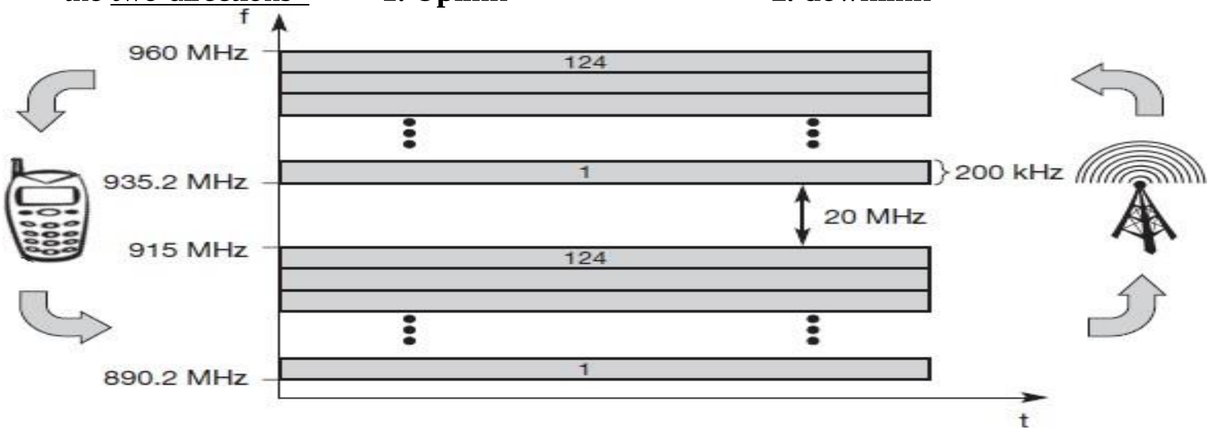
- **Space Division Multiple Access (SDMA)** is used allocating a separated space to users in wireless networks.
- assigning base station to a mobile phone user.
- The mobile phone may receive several base stations with different quality.
- A MAC algorithm -which base station is best,which frequencies (FDM), time slots (TDM) or code (CDM) are still available.
- SDMA algorithm is formed by cells and sectorized antennas which constitute the infrastructure implementing **space division multiplexing (SDM).** SDM has the unique ,advantage of not requiring any multiplexing equipment.
- It is usually combined with other multiplexing techniques
- to better utilize the individual physical channels.

FDMA

Frequency division multiplexing (FDM) describes schemes to subdivide the frequency dimension into several non-overlapping frequency bands.



- schemes to subdivide the frequency dimension into several non-overlapping frequency bands.
- to permit several users to transmit simultaneously
- Such as one satellite transponder by assigning a specific frequency within the channel to each user.
- Each conversation gets its own, unique, radio channel.
- The channels are relatively narrow, usually 30 KHz or less and either transmit or receive channels.
- A full duplex conversation - it requires a transmit & receive channel pair. It is called **frequency division duplexing (FDD)**
- the two directions **1. Uplink** **2. downlink**



FDM formultipleaccess and duplex

Uplink- from mobile station to base station or from ground control to satellite
downlink- from base station to mobile station or from satellite to ground control.

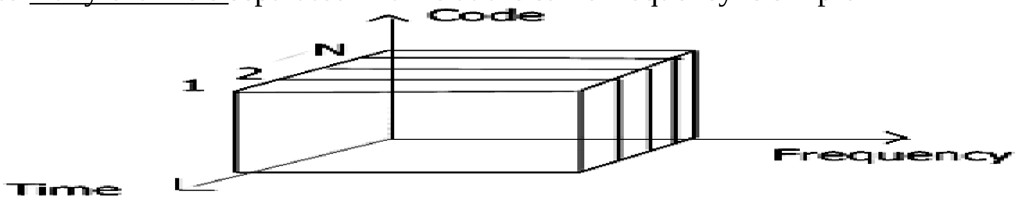
- basic frequency allocation scheme for GSM is fixed .

- All uplinks use the band between 890.2 and 915 MHz,
- all downlinks use 935.2 to 960 MHz.
- allocates a certain frequency for up- and downlink to establish a duplex channel with a mobile phone.
- Up- and downlink have a fixed relation.
- If the uplink frequency is $f_u = 890$ MHz + $n \cdot 0.2$ MHz,
- the downlink frequency is $f_d = f_u + 45$ MHz
- Each channel (uplink and downlink) has a bandwidth of 200 kHz.

TDMA

- A more flexible multiplexing scheme
- typical mobile communications(time slots)is time division multiplexing (TDM) ,Compared to FDMA,
- Synchronization between sender and receiver has to be achieved
- using a dynamic allocation scheme

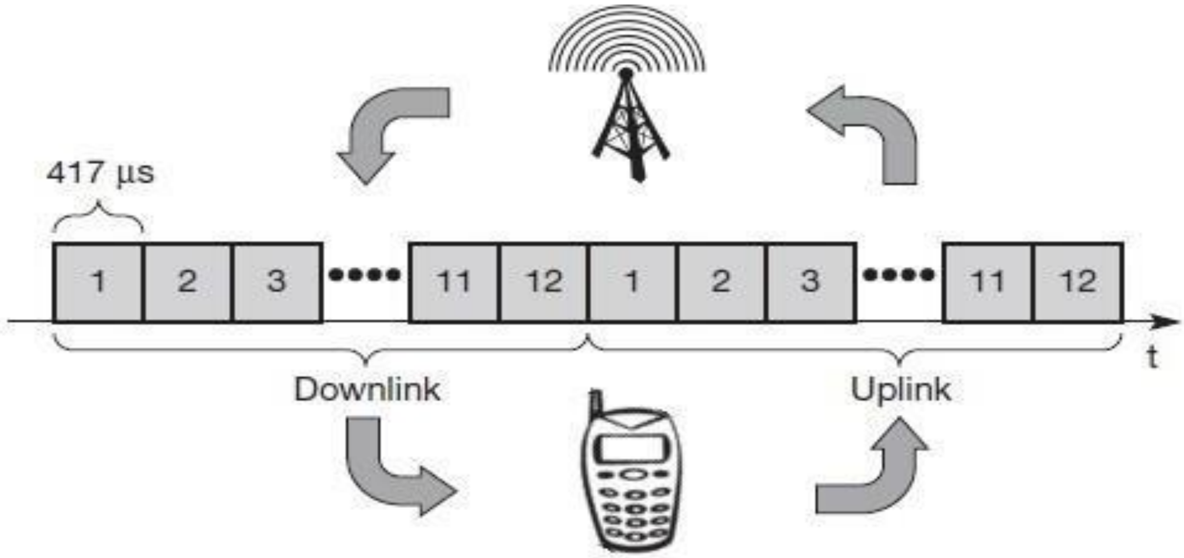
to many channels separated in time at the same frequency is simple



Fixed TDM

- TDM is allocating time slots for channels in a fixed pattern
  - The fixed pattern - assigned by the base station,

  where competition between different mobile stations that want to access the medium is solved.
  - This results in a fixed bandwidth and is the typical solution for wireless phone systems
  - MAC is simple, as accessing the reserved time slot at the right moment.
  - each mobile station knows its turn and no interference

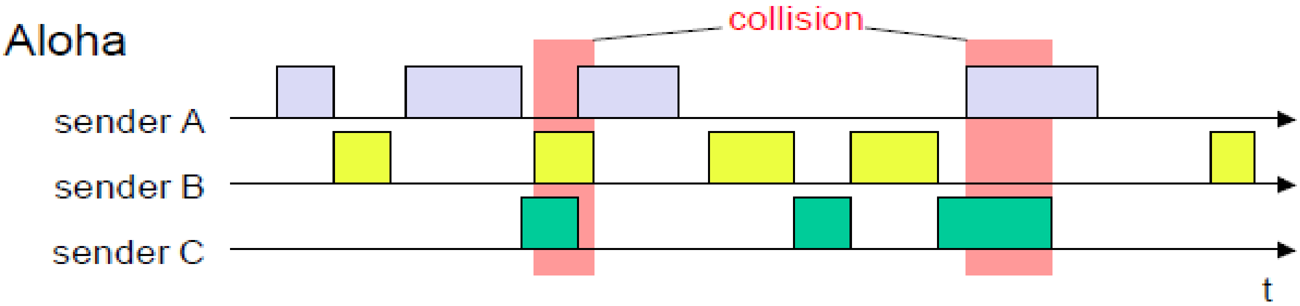


- The above figure shows to implement multiple access and a duplex channel between a base station and mobile station.
- Assigning different slots for uplink and downlink using the same frequency is called **time division duplex (TDD)**.
- the base station uses one out of 12 slots for the downlink, whereas the mobile station uses one out of 12 different slots for the uplink.
- Uplink and downlink are separated in time.

- Up to 12 different mobile stations can use the same frequency without interference
- Each connection is allotted its own up- and downlink pair.
- scheme still wastes a lot of bandwidth. It is too static, too inflexible for data communication.
- connectionless, demand-oriented TDMA schemes

Classical Aloha

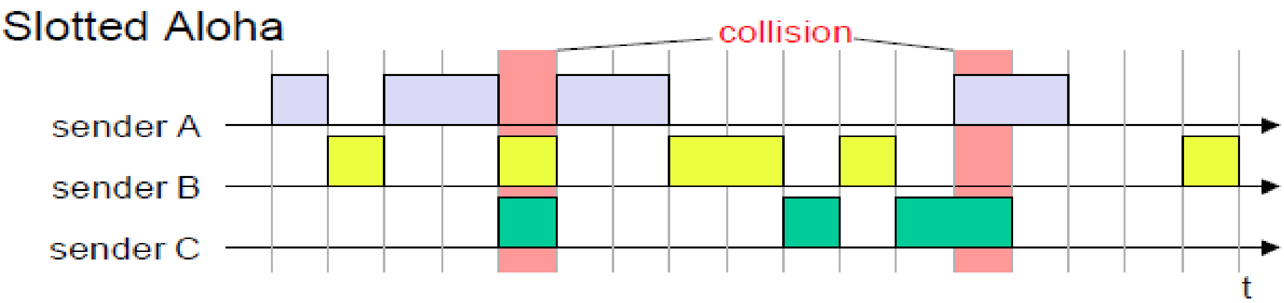
-TDM is applied without controlling medium access. Here each station can access the medium at any time as shown below:



- This is a random access scheme-without a central arbiter controlling access and coordination among the stations.
- If two or more stations access the medium at the same time, a **collision** occurs and the transmitted data is destroyed.
- Resolving this problem is left to higher layers (e.g., retransmission of data).
- The simple Aloha works ,not require any complicated access mechanisms

Slotted Aloha

The first refinement of the classical Aloha scheme is provided by the introduction of time slots (**slotted Aloha**). In this case, all senders have to be **synchronized**, transmission can only start at the beginning of a **time slot** as shown below.



slotting doubles the throughput from 18 per cent to 36 per cent

- Both basic Aloha principles - implement distributed access to a medium

Aloha systems work

- perfectly well under a light load,

-they cannot give any hard transmission guarantees,

- such as maximum (or) minimum delay before accessing the medium

Carrier sense multiple access

- to the basic Aloha is sensing the carrier before accessing the medium.

- Sensing the carrier and accessing the medium only if the carrier is idle decreases the probability of a collision. The different versions of CSMA are:

- **1-persistent CSMA**: Stations sense the channel if it's busy and transmit immediately

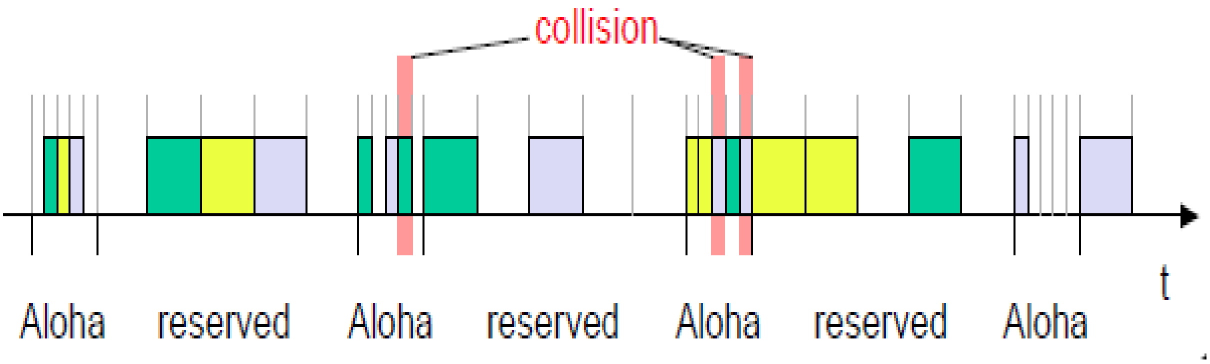
- when the channel becomes idle. It's called 1-persistent CSMA because the host transmits with a probability of 1 whenever it finds the channel idle.

- **non-persistent CSMA**: stations sense the carrier and start sending immediately if the medium is idle. If the medium is busy, the station pauses a random amount of time before sensing the medium again and repeating this pattern.
- **p-persistent CSMA**: systems nodes also sense the medium, but only transmit with a probability of p, with the station deferring to the next slot with the probability 1-p, i.e., access is slotted in addition

***Demand assigned multiple access* (DAMA)(or) reservation Aloha**

- DAMA assigns a pair of available channels based on requests issued from a user.
- Once the call is completed, the channels are returned to the pool for an assignment to another call.

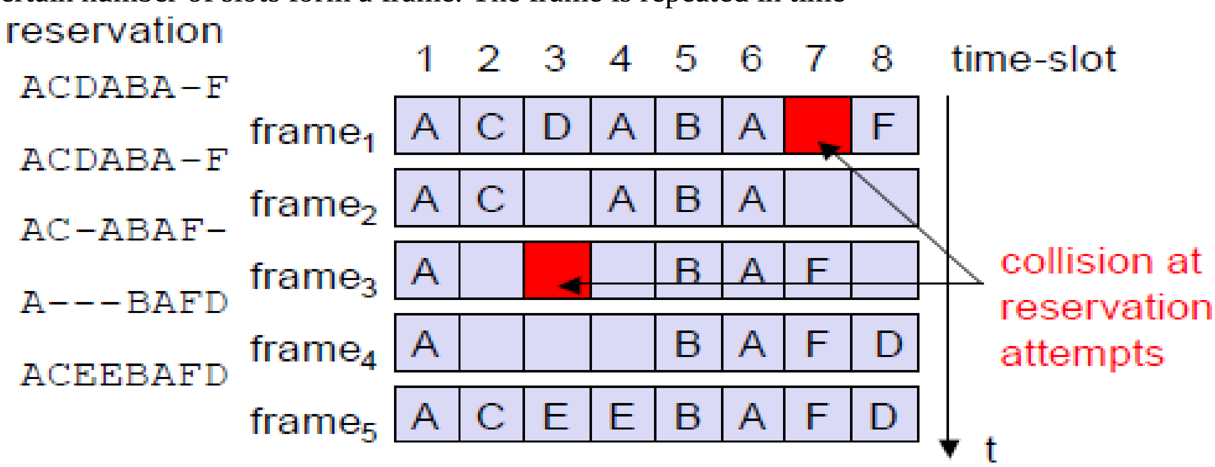
- The resources of the satellite are being used only in proportion to the occupied channels for the time it is a perfect environment for voice traffic and data traffic in batch mode.



- During a phase following the slotted Aloha scheme
- all stations can try to reserve future slots.
- Collisions during the reservation phase do not destroy data transmission,
- but only the short requests for data transmission. If successful, a time slot in the future is reserved
- To maintain the fixed TDM pattern of reservation and transmission,
- the stations have to be synchronized from time to time. DAMA is an **explicit reservation** scheme. Each transmission slot has to be reserved explicitly.

(PRMA) packet reservation multiple access

A certain number of slots form a frame. The frame is repeated in time



- The base station broadcasts the reservation status 'ACDABA-F' to all stations, here A to F.

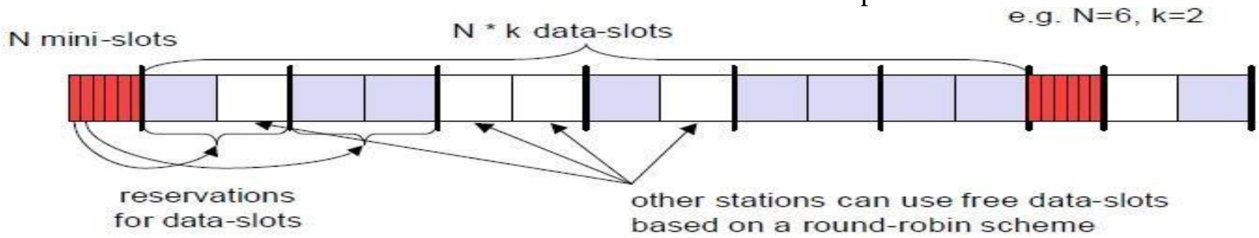
- This means that slots one to six and eight are occupied, but slot seven is free in the following transmission. All stations wishing to transmit can now compete for this free slot in Aloha fashion.
- The already occupied slots are not touched

Example

- The reservation of slot seven failed (still indicated as free) and that nothing has changed for the other slots. Again, stations can compete for this slot.
- station D has stopped sending in slot three and station F in slot eight.
- This is noticed by the base station after the second frame.
- Before the third frame starts, the base station indicates that slots three and eight are now idle.
- Station F has succeeded in reserving slot seven as also indicated by the base station.

Reservation TDMA

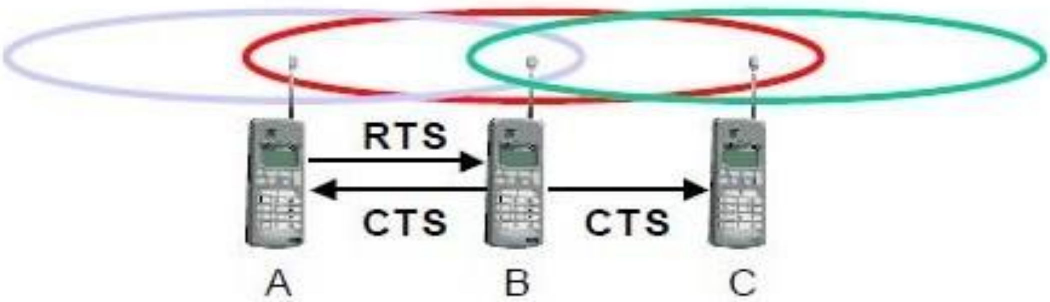
-a fixed TDM scheme N mini-slots followed by N·k data-slots form a frame that is repeated. Each station is allotted its own mini-slot and can use it to reserve up to k data-slots.



- This guarantees each station a certain bandwidth and a fixed delay.
- Other stations can now send data in unused data-slots as shown.
- Using these free slots can be based on a simple round-robin scheme or can be uncoordinated using an Aloha scheme.

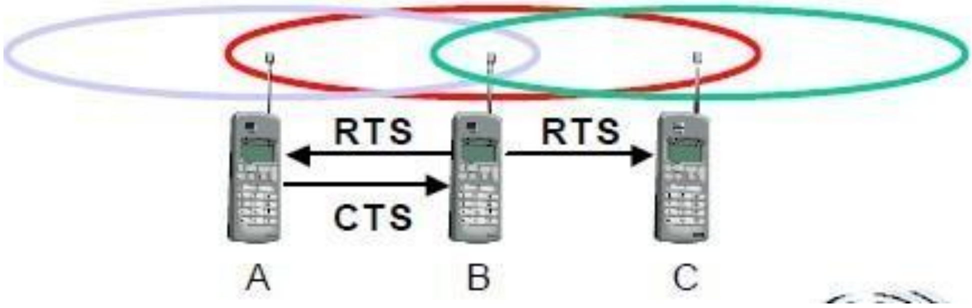
Multiple access with collision avoidance(MACA)

a simple scheme that solves the hidden terminal problem.



- A does not start its transmission at once, but sends a **request to send (RTS)** first.
- B receives the RTS that contains the name of sender and receiver.
- This RTS is not heard by C, but triggers an acknowledgement from B, called **clear to send (CTS)**.
- The CTS again contains the names of sender (A) and receiver (B) of the user data
- This CTS is now heard by C and the medium for future use by A is now reserved for the duration of the transmission.
- After receiving a CTS, C is not allowed to send anything for the duration indicated in the CTS toward B.
- A collision cannot occur at B during data transmission, and the hidden terminal problem is solved.
- Still collisions might occur when A and C transmits a RTS at the same time.
- B resolves this contention and acknowledges only one station in the CTS.
- No transmission is allowed without an appropriateCTS.

Now MACA tries to avoid the **exposed terminals** in the following way:



- B has to transmit an RTS first containing the name of the receiver (A) and the sender (B).
- C does not react to this message as it is not the receiver, but A acknowledges using a CTS which identifies B as the sender and A as the receiver of the following data transmission.
- C does not receive this CTS and concludes that A is outside the detection range.
- C can start its transmission assuming it will not cause a collision at A.
- The problem with exposed terminals is solved without fixed access patterns or a base station.

Polling

- Polling is a strictly centralized scheme with one master station and several slave stations.
- The master can poll the slaves according to many schemes: round robin randomly, according to reservations

Example: Randomly Addressed Polling

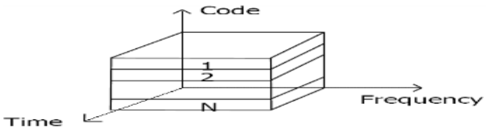
- base station signals readiness to all mobile terminals
- terminals ready to send transmit random number without collision using CDMA or FDMA
- the base station chooses one address for polling from list of all random numbers (collision if two terminals choose the same address)
- the base station acknowledges correct packets and continues polling the next terminal
- this cycle starts again after polling all terminals of the list

Inhibit sense multiple access

- used for the packet data transmission service Cellular Digital Packet Data (CDPD)
- the AMPS mobile phone system, is also known as **digital sense multiple access (DSMA)**.
- the base station only signals a busy medium via a busy tone (called BUSY/IDLE indicator) on the downlink

CDMA - Code division multiple access (CDMA) the transmission to separate different users in code pace and to enable access to a shared medium without interference.

- All terminals send on the same frequency probably at the same time and can use the whole bandwidth of the transmission channel.
- Each sender has a unique random number, the sender XORs the signal with this random number.
- The receiver can "tune" into this signal if it knows the pseudo random number, tuning is done via a correlation function



Disadvantages:

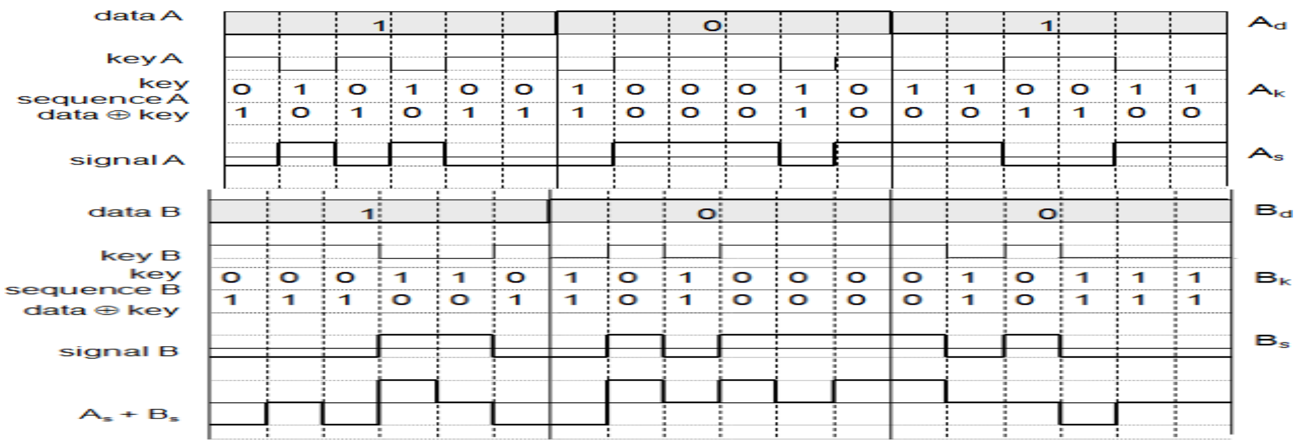
- higher complexity of a receiver (receiver cannot just listen into the medium and start receiving if there is a signal)
- all signals should have the same strength at a receiver

Advantages:

- all terminals can use the same frequency, no planning needed
- huge code space (e.g. 2^{32}) compared to frequency space
- interferences (e.g. white noise) is not coded
- forward error correction and encryption can be easily integrated

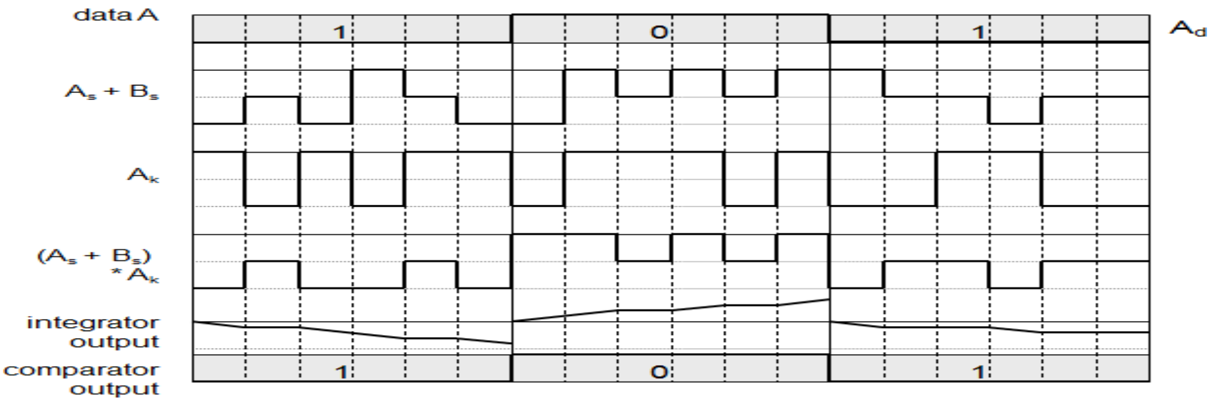
- Sender A
  - sends $A_d = 1$, key $A_k = 010011$ (assign: "0"= -1, "1"= +1)
  - sending signal $A_s = A_d * A_k = (-1, +1, -1, -1, +1, +1)$
- Sender B
  - sends $B_d = 0$, key $B_k = 110101$ (assign: "0"= -1, "1"= +1)
  - sending signal $B_s = B_d * B_k = (-1, -1, +1, -1, +1, -1)$
- Both signals superimpose in space
  - interference neglected (noise etc.)
  - $A_s + B_s = (-2, 0, 0, -2, +2, 0)$
- Receiver wants to receive signal from sender A
  - apply key A_k bitwise (inner product)
    - $A_e = (-2, 0, 0, -2, +2, 0) \bullet A_k = 2 + 0 + 0 + 2 + 2 + 0 = 6$
    - result greater than 0, therefore, original bit was "1"
  - receiving B
    - $B_e = (-2, 0, 0, -2, +2, 0) \bullet B_k = -2 + 0 + 0 - 2 - 2 + 0 = -6$, i.e. "0"

- The following figure shows a sender A that wants to transmit the bits 101.
- The key of A is shown as signal and binary sequence Ak.
- The binary "0" is assigned a positive signal value, the binary "1" a negative signal value. After spreading, i.e., XORing Ad and Ak, the resulting signal is As.



Coding and spreading of data from sender A and sender B

- The same happens with data from sender B with bits 100. The result is B_s. A_s and B_s now superimpose during transmission.
- The resulting signal is simply the sum $A_s + B_s$ as shown above. A now tries to reconstruct the original data from Ad.
- The receiver applies A's key, Ak, to the received signal and feeds the result into an integrator. The integrator adds the products, a comparator then has to decide if the result is a 0 or a 1 as shown below.
- the original signal form is distorted by B's signal, the result is quite clear. The same happens if a receiver wants to receive B's data.



Reconstruction of A's data

Soft handover or **soft handoff** refers to a feature used by the CDMA and WCDMA

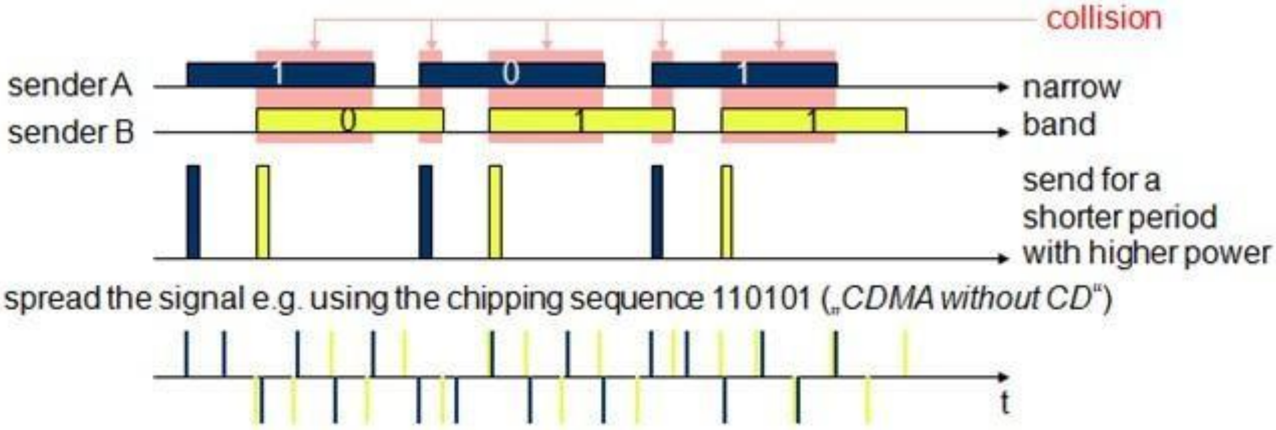
- where a cell phone is simultaneously connected to two or more cells (or cell sectors) during a call.
- If the sectors are from the same physical cell site (a sectorised site.
- This technique is a form of mobile-assisted handover, CDMA cell phones continuously make power measurements of a list of neighboring cell sites, and determine whether or not to request or end soft handover with the cell sectors on the list.

hard-handoff process - a definite decision is made on whether to hand off or not.

- The handoff is initiated and executed without the user attempting to have simultaneous traffic channel communications with the two base stations.
- With soft handoff, a c*onditional* decision is made on whether to hand off. Depending on the changes in pilot signal strength from the two or more base stations involved, a hard decision will eventually be made to communicate with only one.

Spread Aloha multiple access (SAMA)

- SAMA uses spread spectrum with only one single code (chipping sequence) for spreading for all senders accessing according to aloha.
- In SAMA, each sender uses the same spreading code, for ex 110101 as shown below.
- Sender A and B access the medium at the same time in their narrowband spectrum, so that the three bits shown causes collisions.
- The same data could also be sent with higher power for shorter periods as show.



- The main problem in using this approach is finding good chipping sequences.
- The maximum throughput is about 18 per cent, which is very similar to Aloha,
- the advantages of spread spectrum techniques: robustness against narrowband interference and simple coexistence with other systems in the same frequency band.