Mobile Computing

Unit 1 : Introduction

Outline

- Overview of Wireless and Mobile Infrastructure
- Preliminary Concepts
- Design Objectives and Performance Issues
- Radio resource Management
- Propagation and Path Loss Models
- Channel Interference and Frequency Reuse
- Cell Splitting
- Channel Assignment
- Overview of Generations

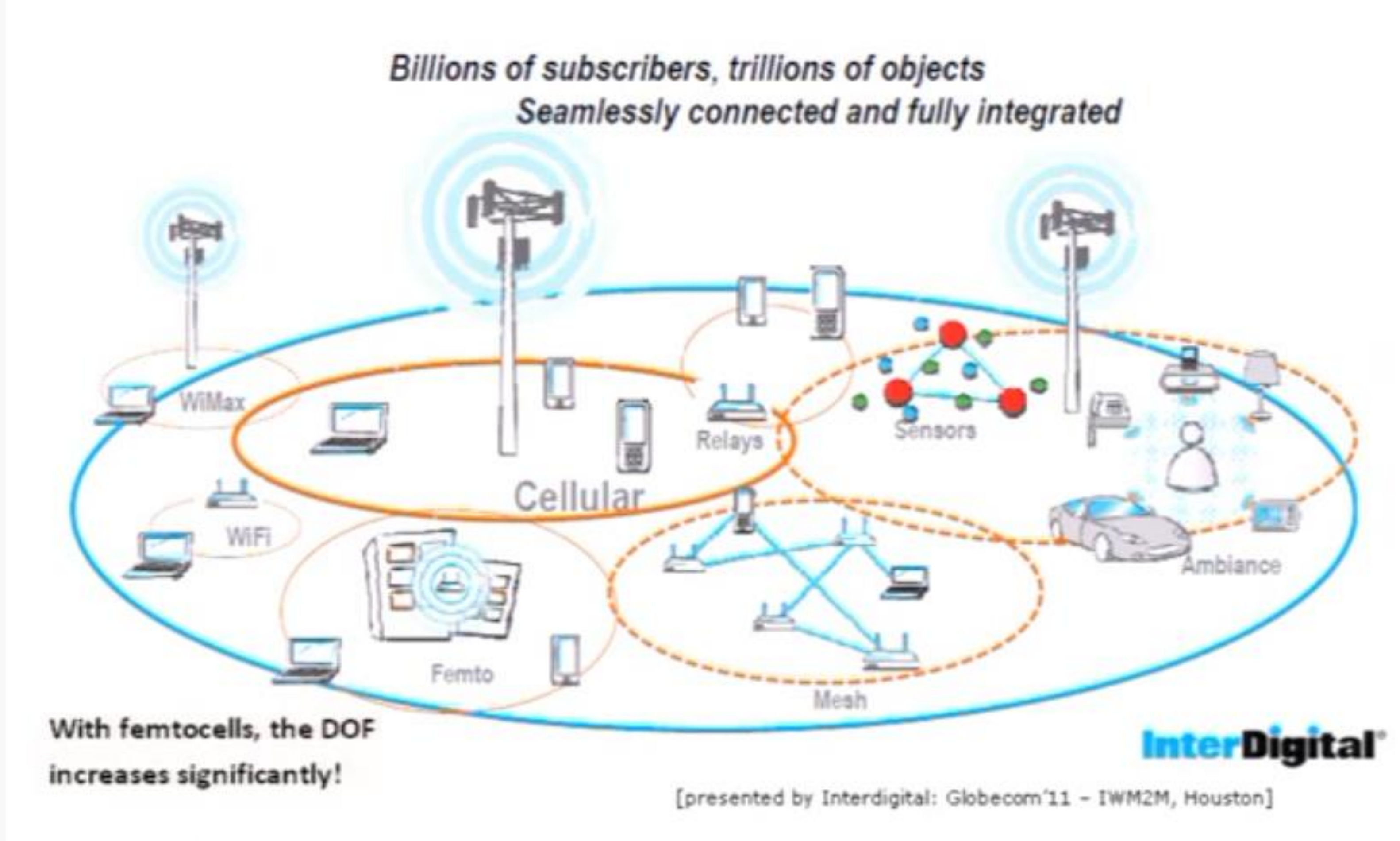
Why Mobile Computing?

- **Mobile refers to access in motion, no restriction on geographic location.**
- **With mobility comes lot of issues, techniques and solutions.**
- **80% of the world’s workforce is mobile.**
  - The demand for mobile communication creates the need for integration of wireless networks into existing fixed networks

Importance of Mobile Communication

- **Location Flexibility**
  - This has enabled users to work from anywhere as long as there is a connection established. A user can work without being in a fixed position.
- **Saves Time**
  - The time consumed or wasted while travelling from different locations or to the office and back, has been slashed
- **Enhanced Productivity**
  - Users can work efficiently and effectively from whichever location they find comfortable. This in turn enhances their productivity level.
- **Ease of Research**
  - Research has been made easier, since users earlier were required to go to the field and search for facts and feed them back into the system.
- **Entertainment**
- **Business processes are now easily available**

Heterogeneous



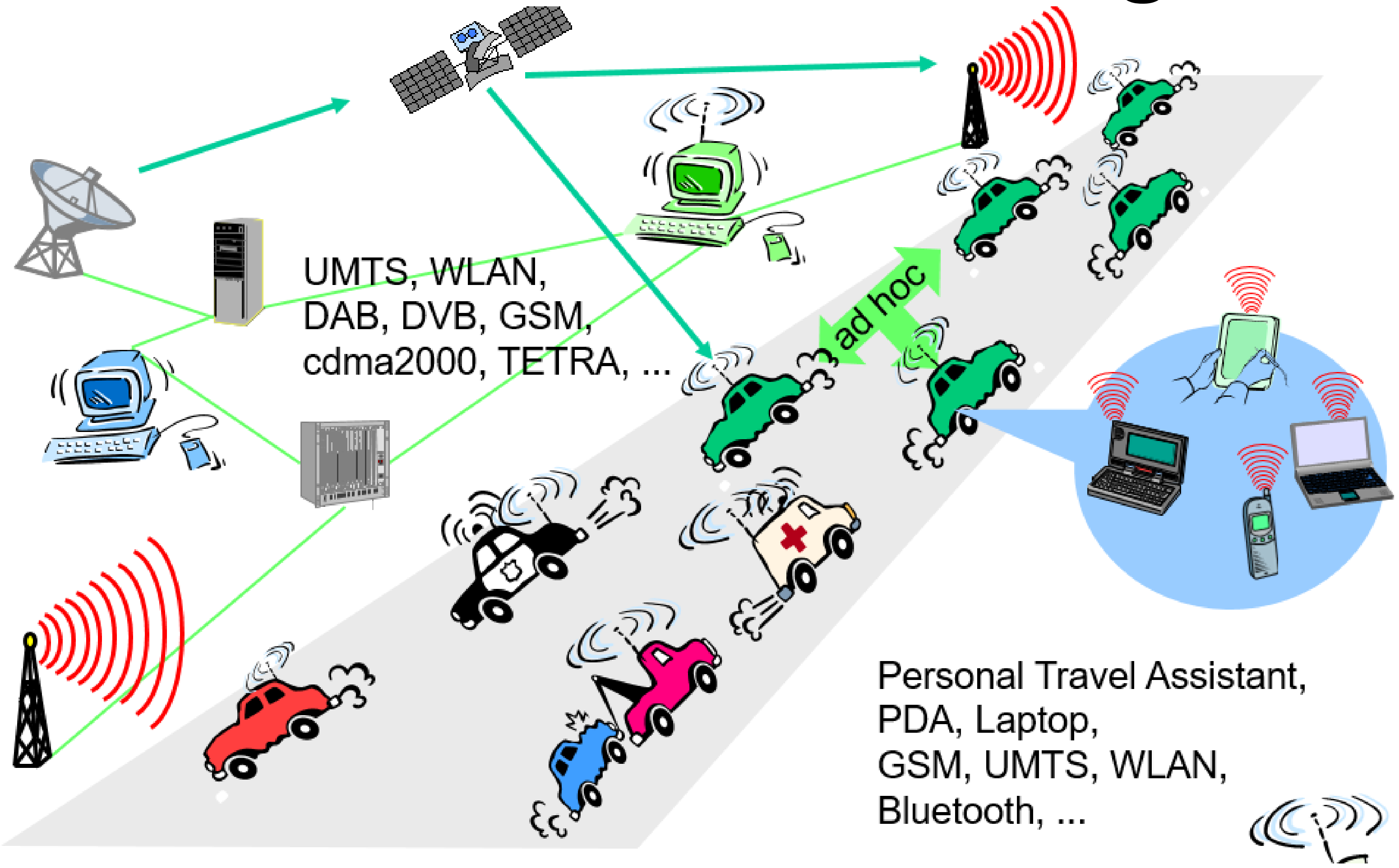
Applications

- Vehicles
  - transmission of news, road condition, weather, music via DAB
  - personal communication using GSM
  - position via GPS
  - 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
- 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.
  - Disaster Management like crisis, floods, pandemic, ...

Applications

- Travelling salesmen
  - direct access to customer files stored in a central location
  - consistent databases for all agents
  - mobile office
- Replacement of fixed networks
  - remote sensors, e.g., weather, earth activities
  - flexibility for trade shows
  - LANs in historic buildings
- Entertainment, education, ...
  - outdoor Internet access
  - intelligent travel guide with up-to-date location dependent information
  - ad-hoc networks for multi user games

Example : Road Traffic Monitoring



Services Provided

- ❑ 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

Design Objectives of Mobile Computing

- Type of Application (Native or Mobile Web) : Before designing mobile application you need to determine type of application. ...
- Target device
- User experience
- Resource Constraint
- Multiple Platforms
- Security
- Network Communication

Issues in Mobile Computing

- Security, secrecy, and privacy
- Resource and spectrum utilizations
- Communication infrastructure
- Energy efficiency enhancement
- Integration of wireless information and power transfer
- Wireless access techniques
- Dynamic architecture and network functions analysis
- Coding and modulation
- Resource and interference management

https://www.frontiersin.org/articles/10.3389/frcmn.2020.00001/full

Different types of Mobile Networks

GSM : **Global System for Mobile communication**

- **(2G, 900MHz, 1900MHz Bands)**

LTE - Long Term Evolution

- (4G , for GSM *700, 750, 800 , 850 , 1800 , 1900 , 2100 , 2600 MHz*

HSDPA - High Speed Downlink Packet Access

- Advanced to 3G ,3.5 G

EV-DO – Evolution Data-Only.

- It mainly runs on CDMA Networks for 3G

CDMA – Code Division Multiple Access

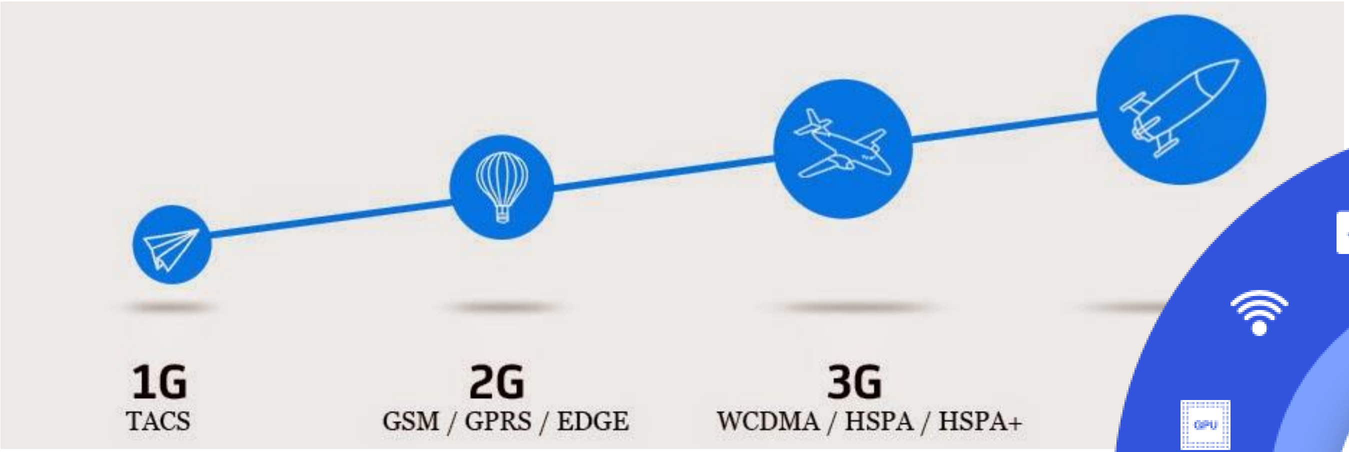
- **(3G Wireless, 450,800,1900MHz Bands)**

UMTS – Universal Mobile Telecommunications System

- (3G Technology WCDMA)

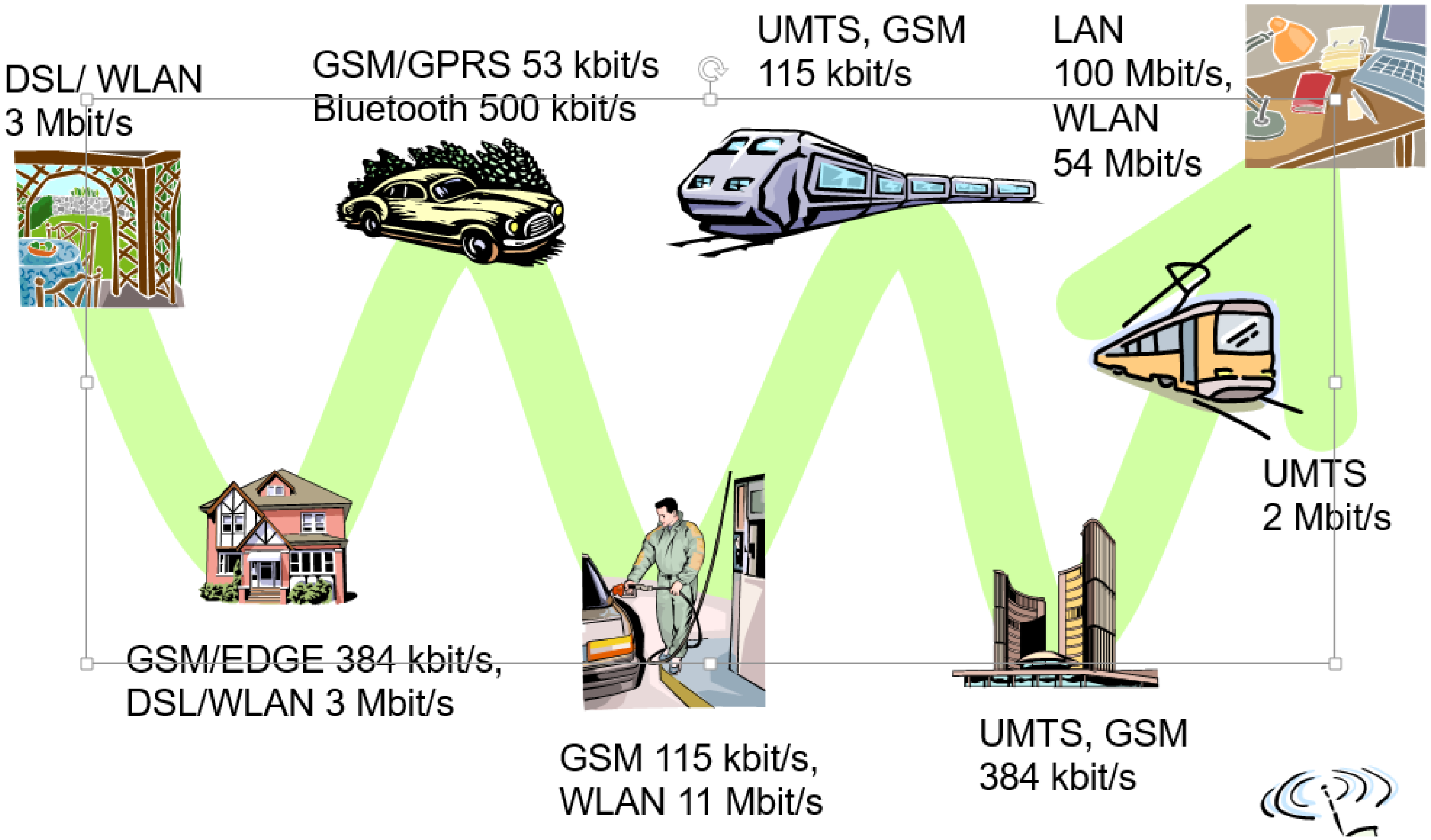
HSUPA – High Speed Uplink Packet Access

Types of Mobile Network



- Designed to connect virtually everyone and everything together including machines, objects, and devices.
- Deliver higher multi-Gbps peak data speeds

Mobile and Wireless Services



Two Aspects of Mobility

User Mobility	User mobility refers to a user who has access to the same or similar telecommunication services at different places, i.e., the user can be mobile, and the services will follow.
Device Portabilit y	Device portability refers to the communication device moves (with or without a user). Many mechanisms in the network and inside the device have to make sure that communication is still possible while the device is moving. E.g; Mobile Phone System

Wireless	V/s	Mobile	Examples
✘		✘	stationary computer
✘		✓	notebook in a hotel
✓		✘	wireless LANs in historic buildings
✓		✓	Personal Digital Assistant (PDA)

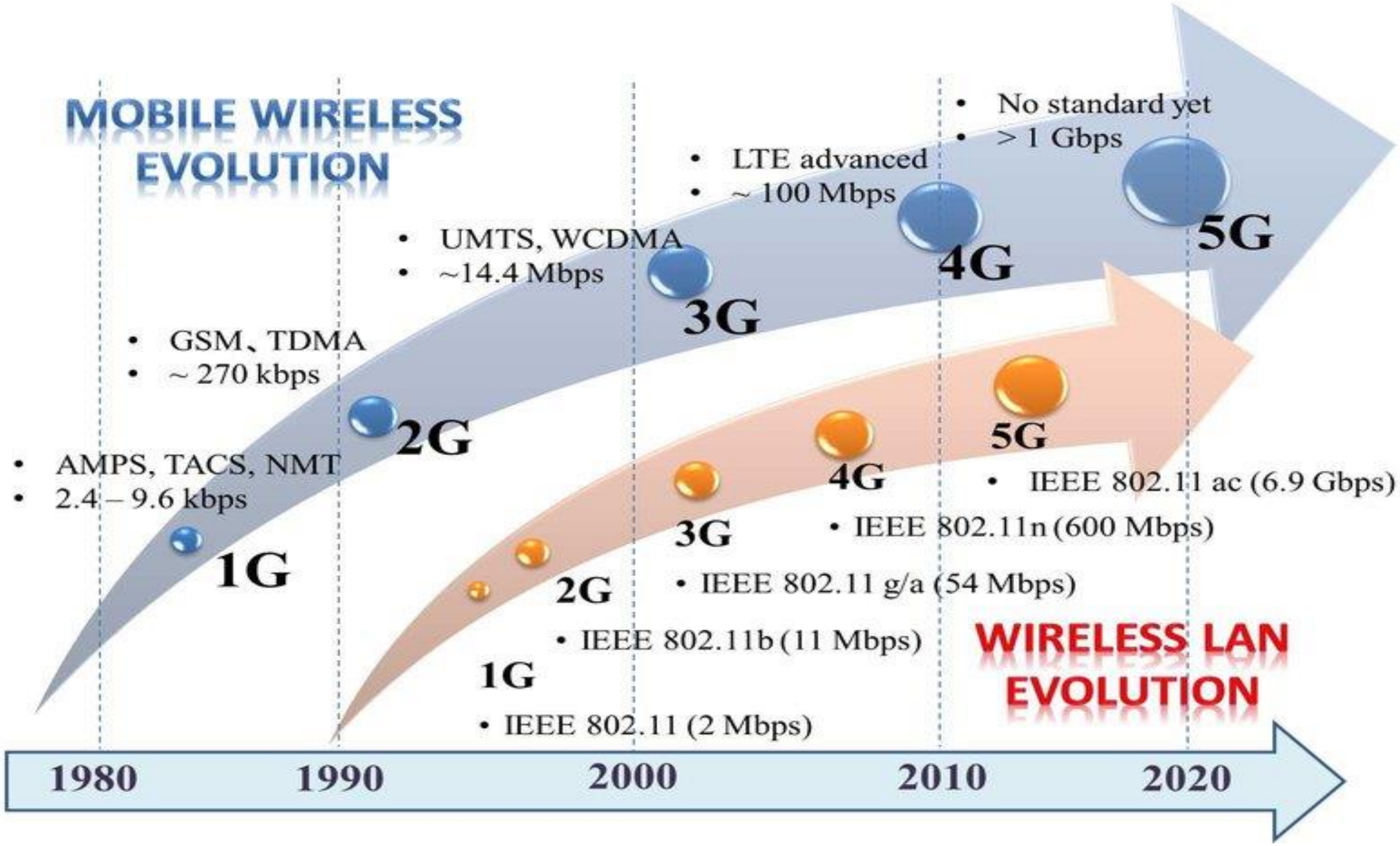
Effects of device Portability

- **Power consumption**
  - limited computing power, low quality displays, small disks due to limited battery capacity
  - CPU: power consumption ~ CV^2f
    - C: internal capacity, reduced by integration
    - V: supply voltage, can be reduced to a certain limit
    - f: clock frequency, can be reduced temporally
- **Loss of data**
  - higher probability, has to be included in advance into the design (e.g., defects, theft)
- **Limited user interfaces**
  - compromise between size of fingers and portability
  - integration of character/voice recognition, abstract symbols
- **Limited memory**
  - limited value of mass memories with moving parts
  - flash-memory or ? as alternative

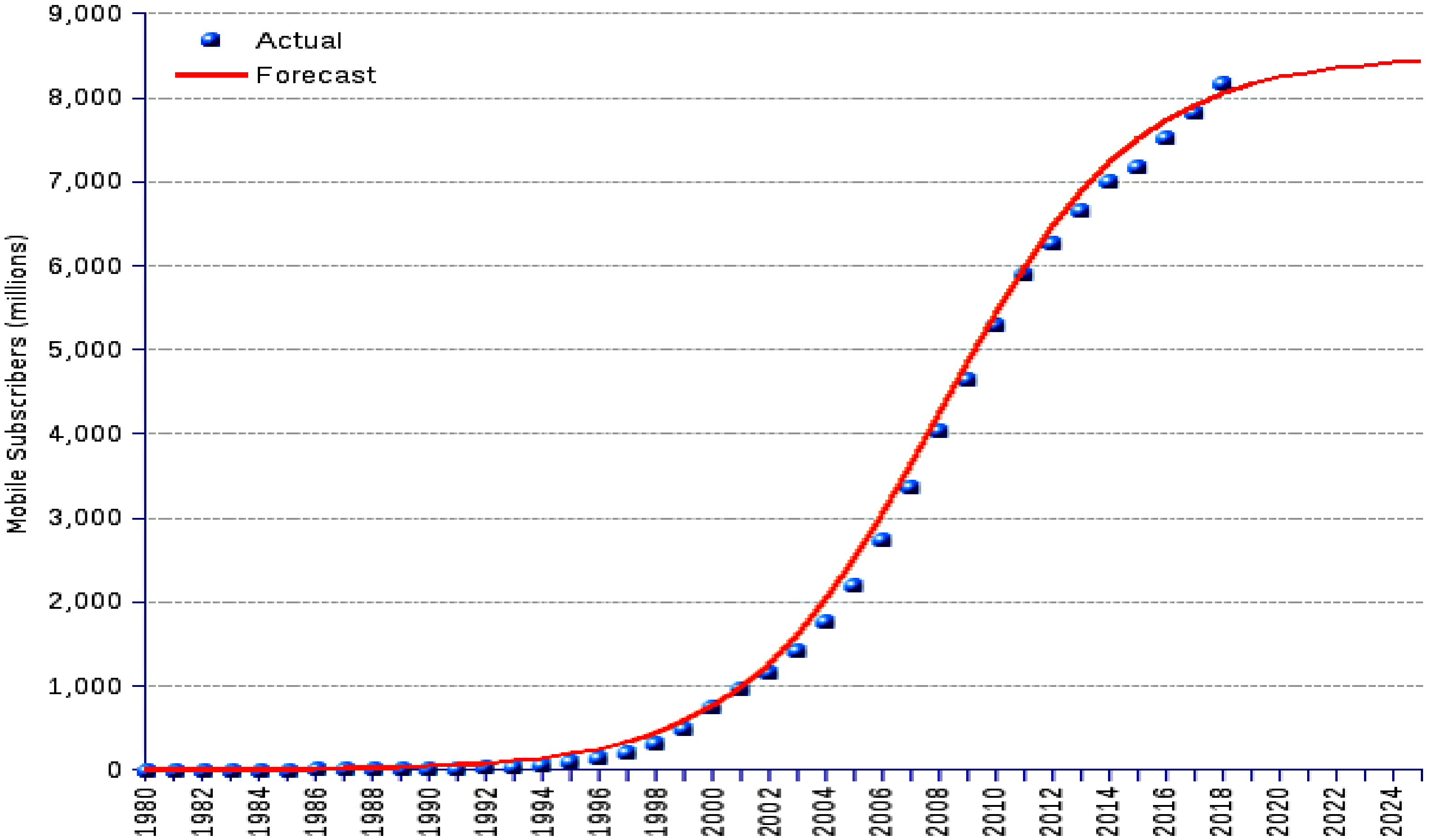
Wireless Networks in comparison with Fixed Networks

1. Higher loss-rates due to interference
    1. emissions of, e.g., engines, lightning
2. Restrictive regulations of frequencies
    1. frequencies have to be coordinated, useful frequencies are almost all occupied
3. Low transmission rates
    1. local some Mbit/s, regional currently, e.g., 53kbit/s with GSM/GPRS
4. Higher delays, higher jitter
    1. connection setup time with GSM in the second range, several hundred milliseconds for other wireless systems
5. Lower security, simpler active attacking
    1. radio interface accessible for everyone, base station can be simulated, thus attracting calls from mobile phones
6. Always shared medium
    1. secure access mechanisms important

History of Telecommunication

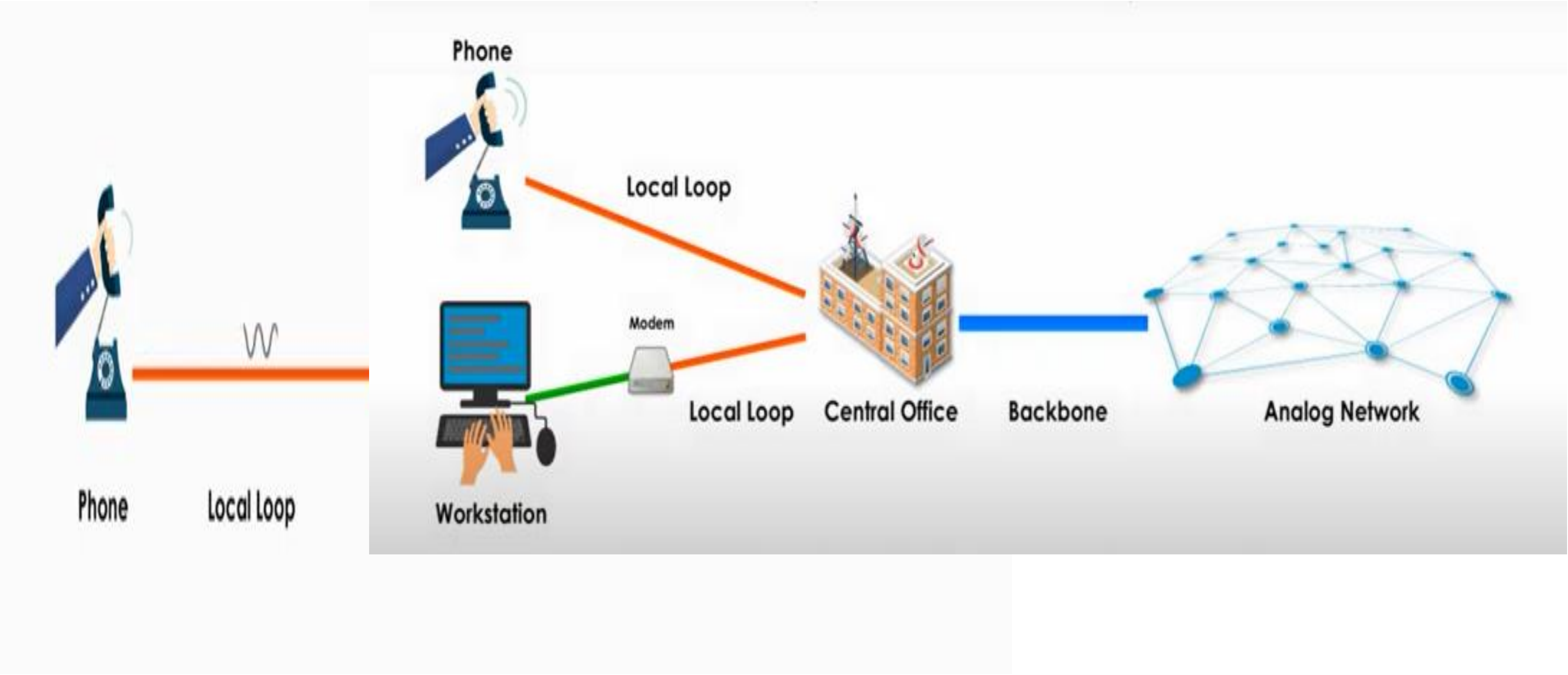


Cellular Subscribers World Wide



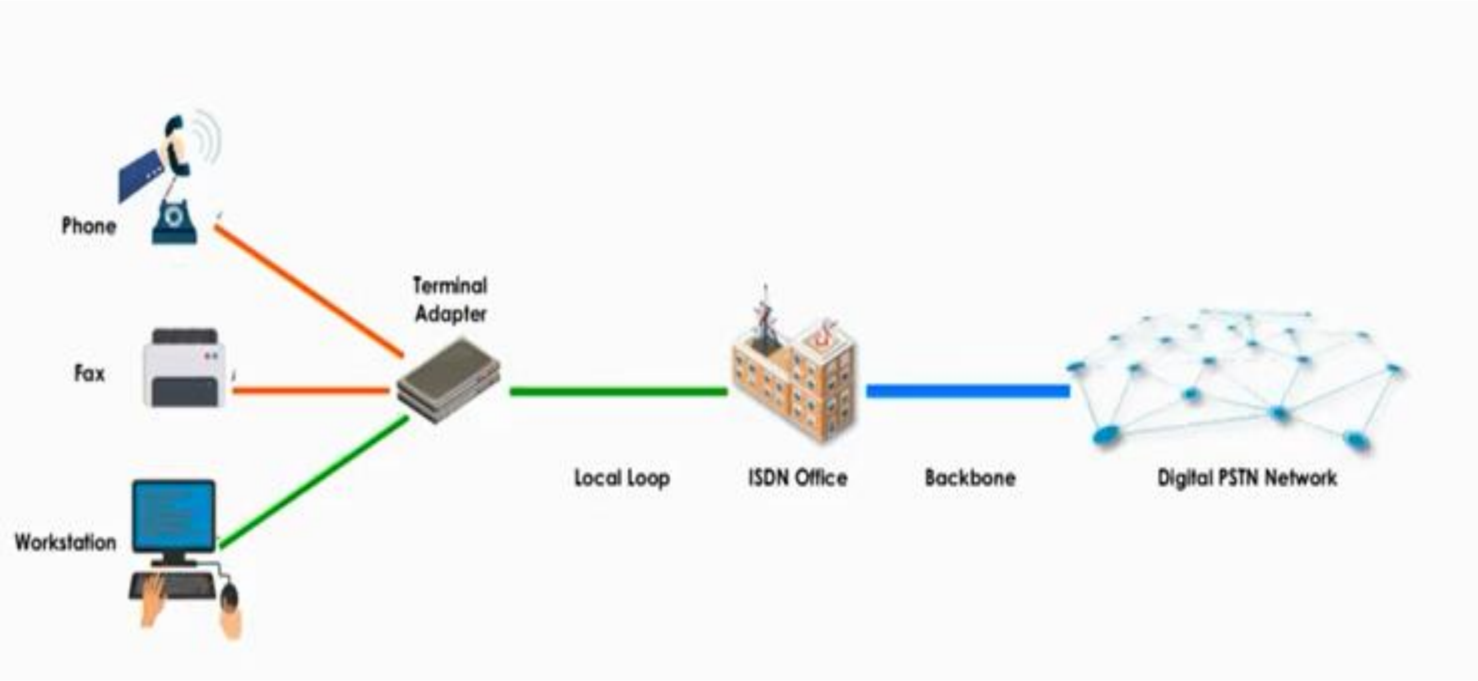
Common Services in Communication PSTN

USE of Analog Signals only



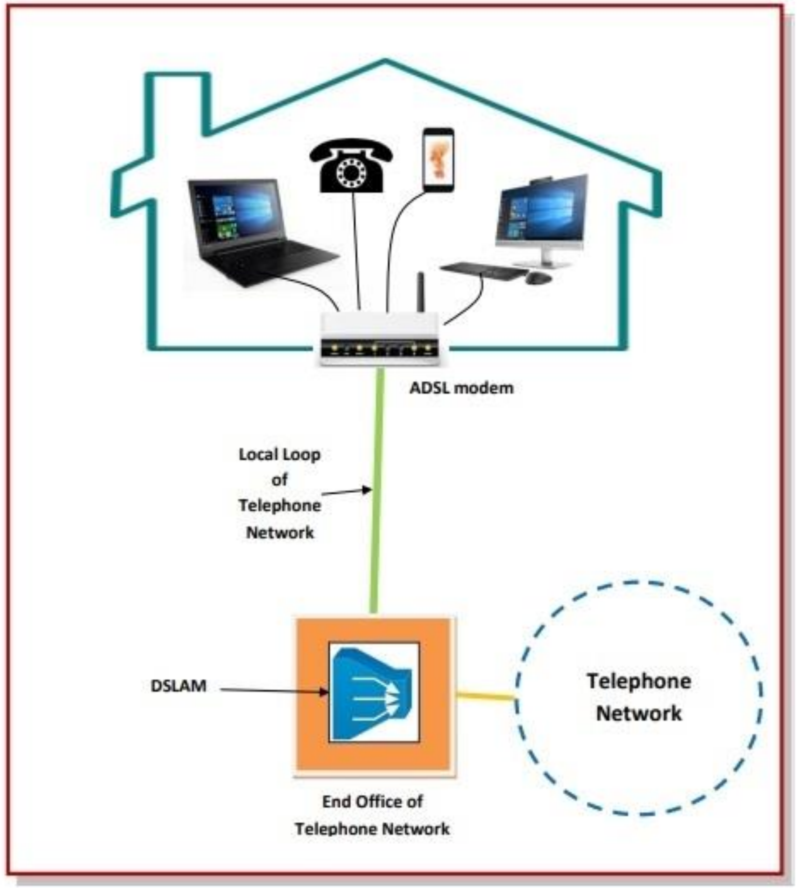
ISDN

- Digital network to transmit voice, image, video and text over circuit switched PSTN

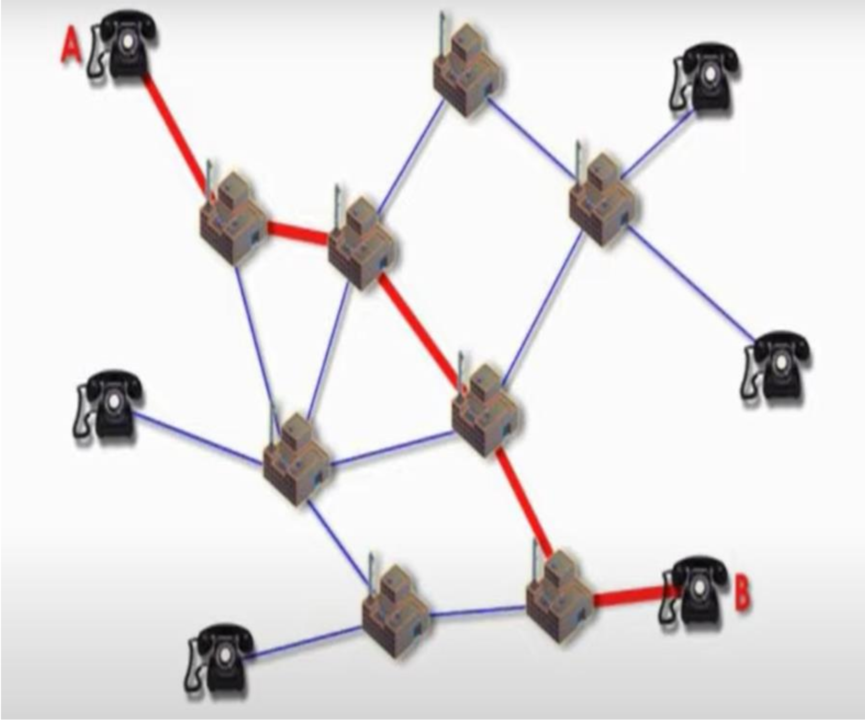


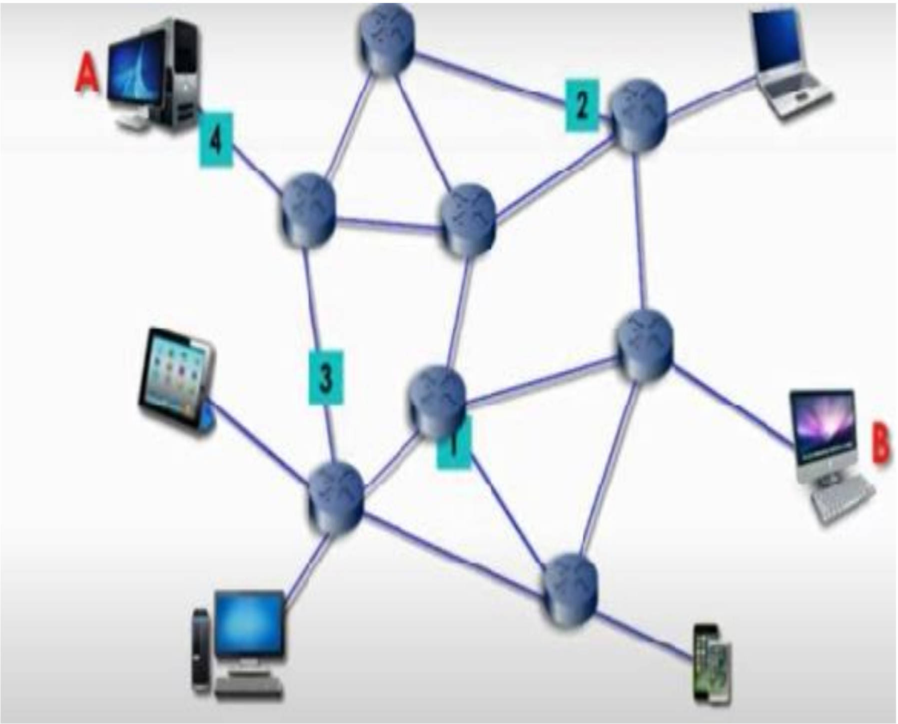
ADSL: *Asymmetric Digital Subscriber line*

- Type of Broadband internet connection.
- ADSL uses analog sinusoidal carrier waves for data transmission. The waves are modulated and demodulated at the customer premises with ADSL modems.



Circuit Switched V/S Packet switched

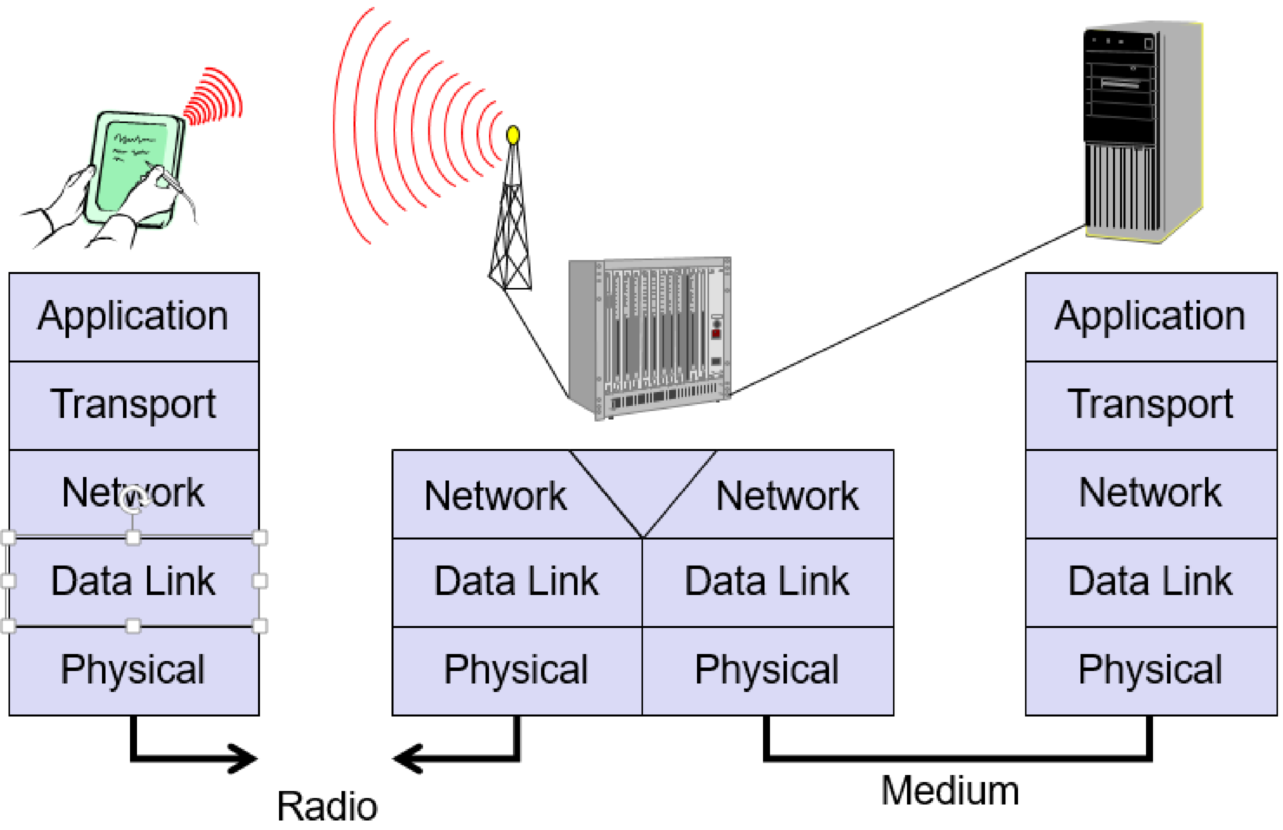




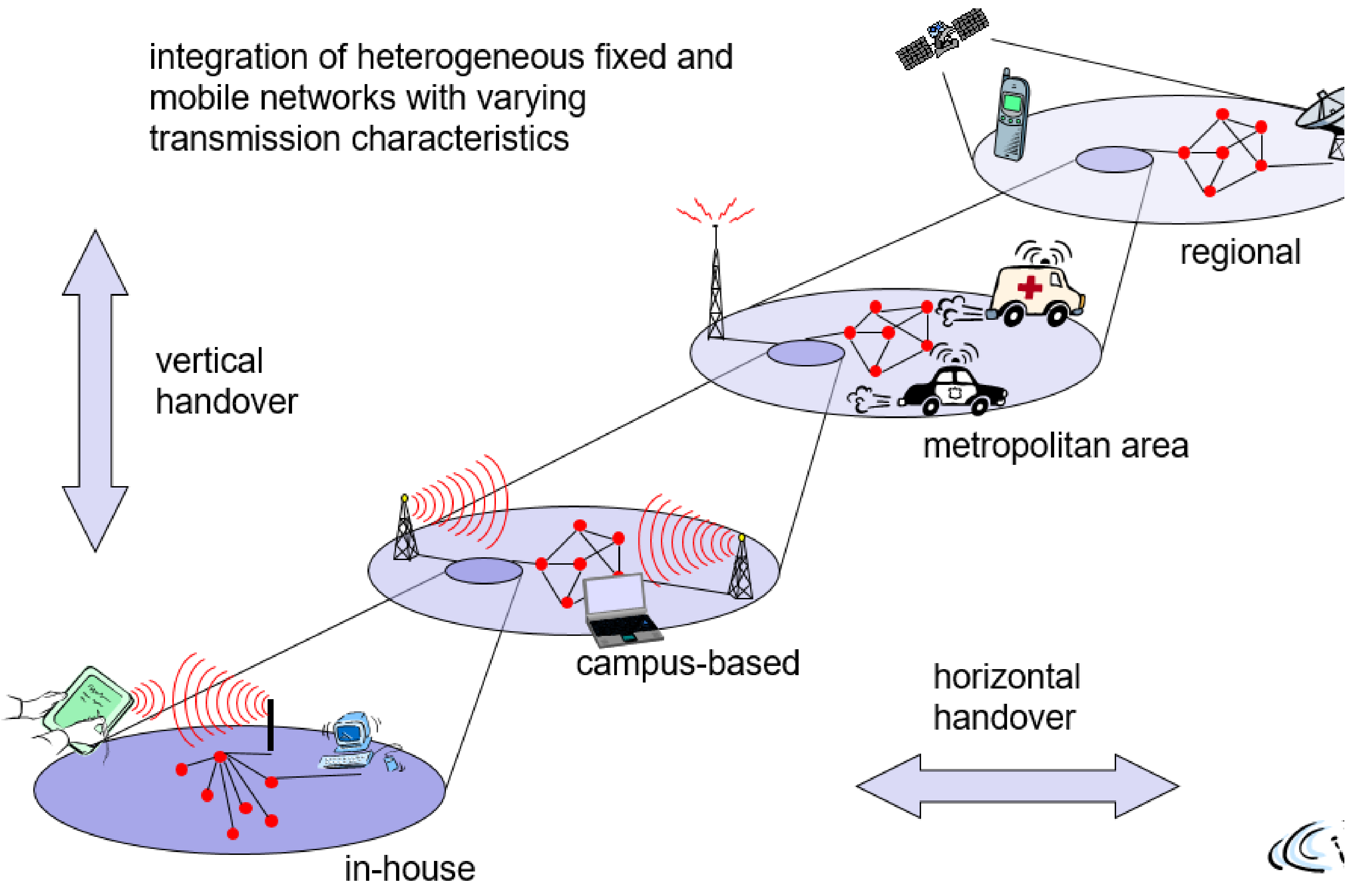
Circuit Switched Network

Packet Switched Network

Simple Reference Model



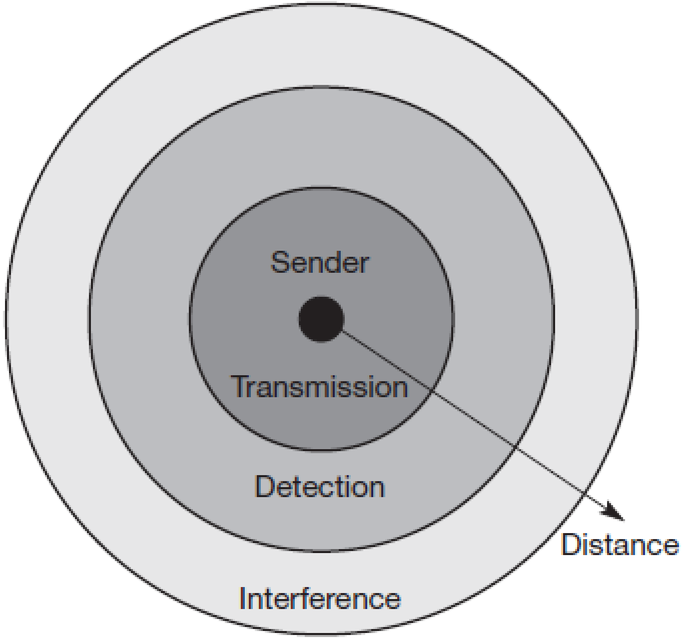
Overlay Networks: Global Goal



Radio resource management (RRM)

- **System level management of co-channel interference, Radio resources, and other radio transmission characteristics in wireless communication systems**.
- Cellular networks, wireless local area networks, wireless sensor systems, and radio broadcasting networks.

Signal Propagation



Transmission range: Within a certain radius of the sender transmission is possible, i.e., a receiver receives the signals with an error rate low enough to be able to communicate and can also act as sender.

● **Detection range**: Within a second radius, detection of the transmission is possible, i.e., the transmitted power is large enough to differ from background noise. However, the error rate is too high to

● **Interference range**: Within a third even larger radius, the sender may interfere with other transmission by adding to the background noise. A receiver will not be able to detect the signals, but the signals may disturb other signals.

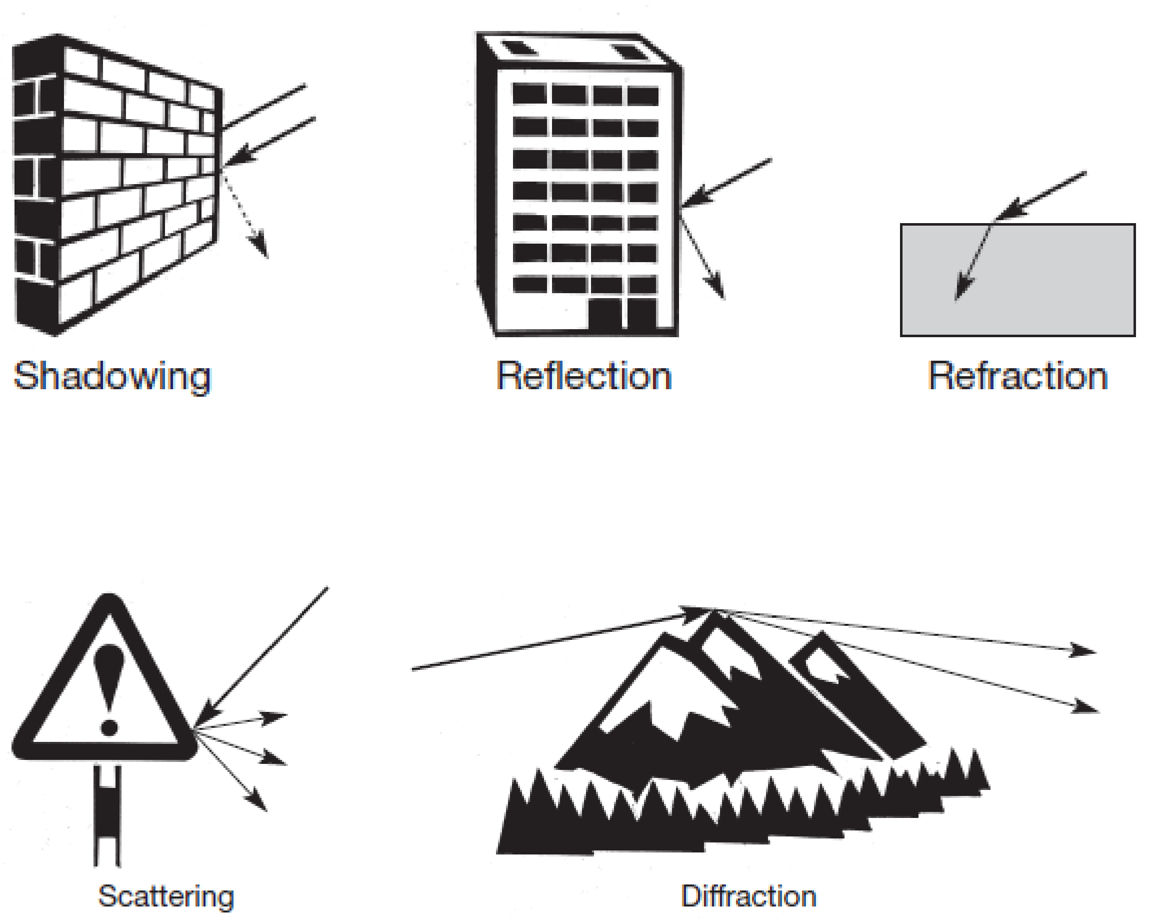
Path loss of radio signals

- In free space radio signals propagate as light.
- If such a straight line exists between a sender and a receiver it is called **line-of-sight (LOS)**.
- signal still experiences the **free space loss even in vacuum**
- Received power *Pr* is proportional to 1/*d*2 with *d* being the distance between sender and receiver. (**inverse square law**).
- radio transmission takes place through the atmosphere – signals travel through air, rain, snow, fog, dust particles, smog etc.
- While the **path loss** or **attenuation** does not cause too much trouble for short distances, the atmosphere heavily influences transmission over long distances.

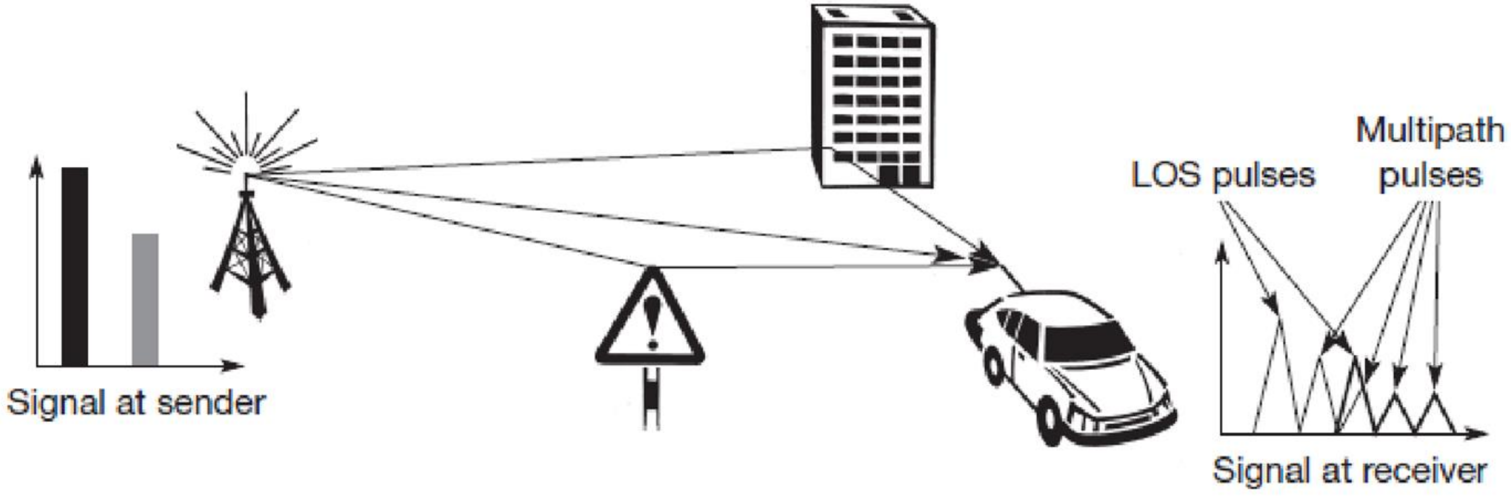
Radio Waves : Three Fundamental Propagations

Ground wave (<2 MHz): Waves with low frequencies follow the earth's surface and can propagate long distances. These waves are used for, e.g., submarine communication or AM radio.
Sky wave (2–30 MHz): Many international broadcasts and amateur radio use these short waves that are reflected2 at the ionosphere. This way the waves can bounce back and forth between the ionosphere and the earth's surface, travelling around the world.
Line-of-sight (>30 MHz): Mobile phone systems, satellite systems, cordless telephones etc. use even higher frequencies.

Effects of Signal Propagation



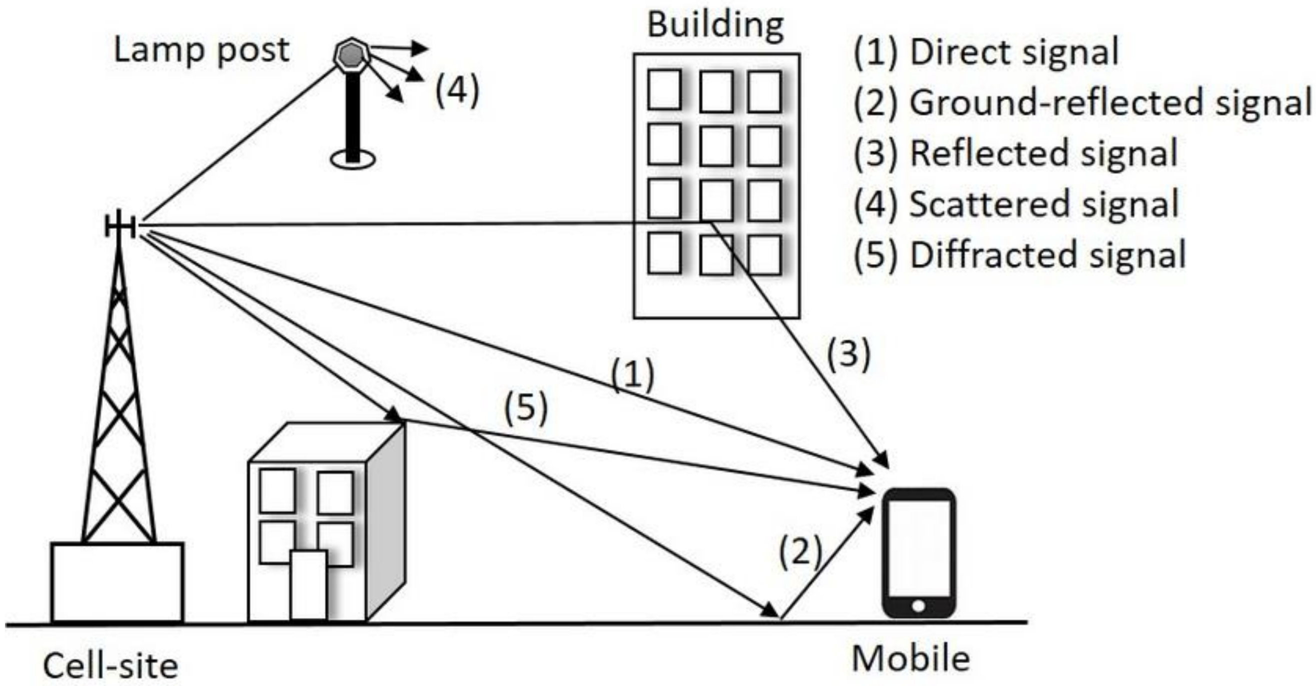
Multipath Propagation



Delay spread: the original signal is spread due to different delays of parts of the signal

Typical values for delay spread are approximately 3 μs in cities, up to 12 μs can be observed. GSM, for example, can tolerate up to 16 μs of delay spread, i.e., almost a 5 km path difference.

Multipath Propagation



Effects of Delay Spread

- Short impulse will be smeared out into a broader impulse, or rather into several weaker impulses.
- At the receiver, both impulses interfere, i.e., they overlap in time. The energy intended for one symbol now spills over to the adjacent symbol, an effect which is called **inter-symbol interference (ISI)**.
- ISI limits the bandwidth of a radio channel with multi-path propagation.

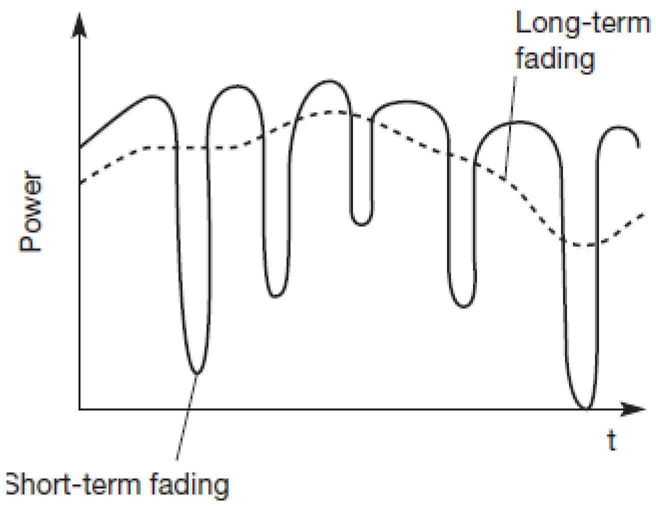
Avoid ISI:

1. Channel characteristics should be known.
2. Sender may first transmit a **training sequence** known by the receiver. The receiver then compares the received signal to the original training sequence.
3. Programs an **equalizer** that compensates for the distortion.

Effects of Signal Propagation

- ISI and delay spread already occur in the case of fixed radio transmitters and receivers, the situation is even worse if receivers, or senders, or both, move.
- Fading
    1. The power of the received signal changes considerably over time. These quick changes in the received power are also called **short-term fading.**
    2. **Depending on the different paths the signals take, these signals may have a different phase and cancel each other.**
    3. **The receiver now has to try to constantly adapt to the varying channel characteristics, e.g., by changing the parameters of the equalizer.**
    4. **If receiver is very fast, it cannot adapt fast enough and the error rate of transmission is high.**

Fading



Quick changes in the received power are also called **short-term fading**.

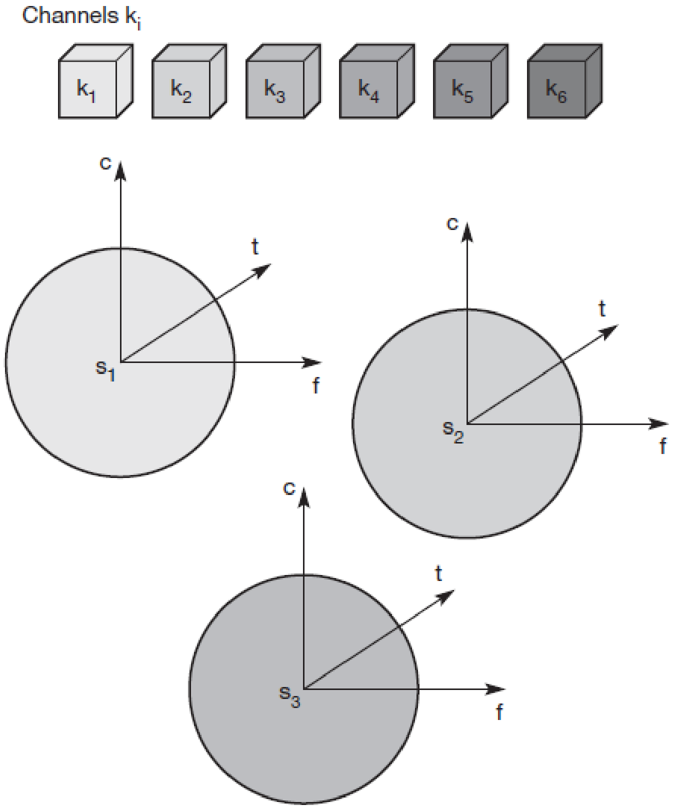
Long-term fading, shown here as the average power over time.

Multiplexing

- In telecommunications and computer networks
  - Multiplexing is a method by which multiple analog or digital signals are combined into one signal over a shared medium.
- Multiplexing describes how several users can share a medium with minimum or no interference.
- Multiplexing can be carried out in four dimensions:

  space, **time**, **frequency**, and **code**

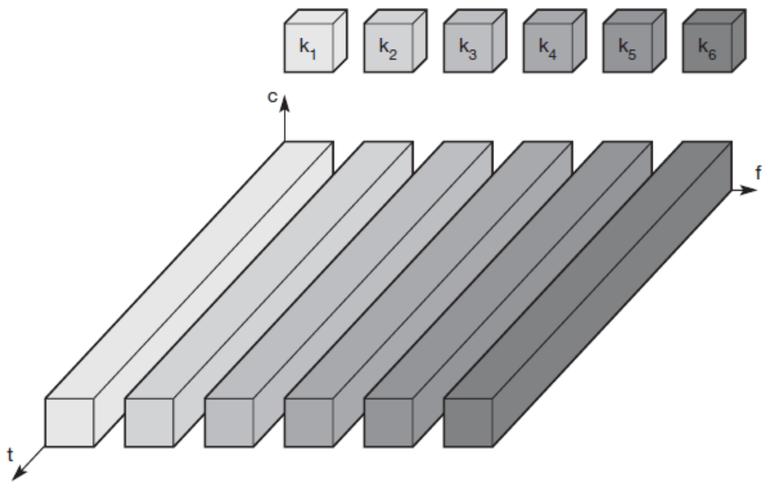
SDM : Space Division Multiplexing



- Space is represented via circles indicating the interference range.
- The space between the interference ranges is called **guard space**.
- In wireless transmission, SDM implies a separate sender for each communication channel with a wide enough distance between senders.
- Waste of space, principle used by the old analog telephone system.

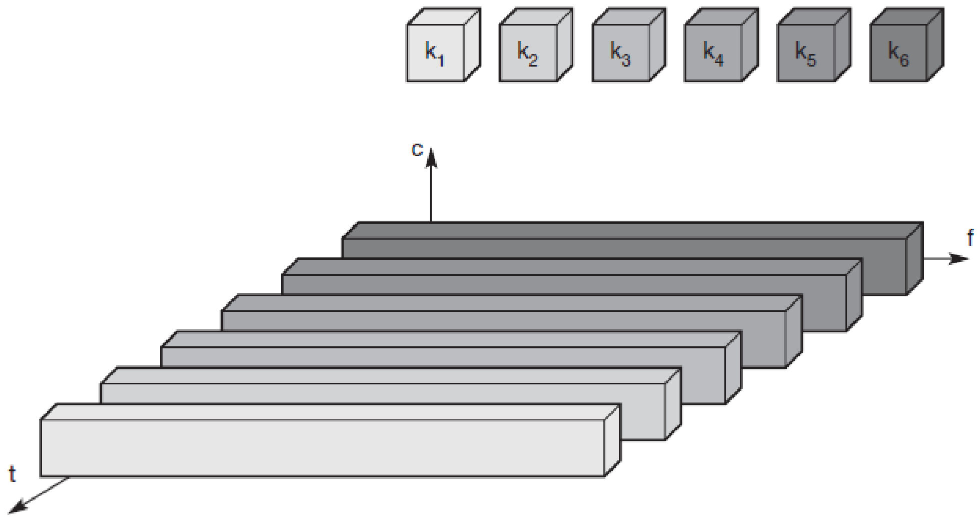
Frequency Division Multiplexing

1. **Frequency division multiplexing (FDM)** describes schemes to subdivide the frequency dimension into several non-overlapping frequency bands.
2. **Guard spaces** are needed to avoid frequency band overlapping (also called **adjacent channel interference**).
3. Scheme is used for radio stations within the same region, where each radio station has its own frequency.
4. Radio stations broadcast 24 hours a day, mobile communication typically takes place for only a few minutes at a time.
5. Assigning a separate frequency for each possible communication scenario would be a tremendous waste of (scarce) frequency resources.

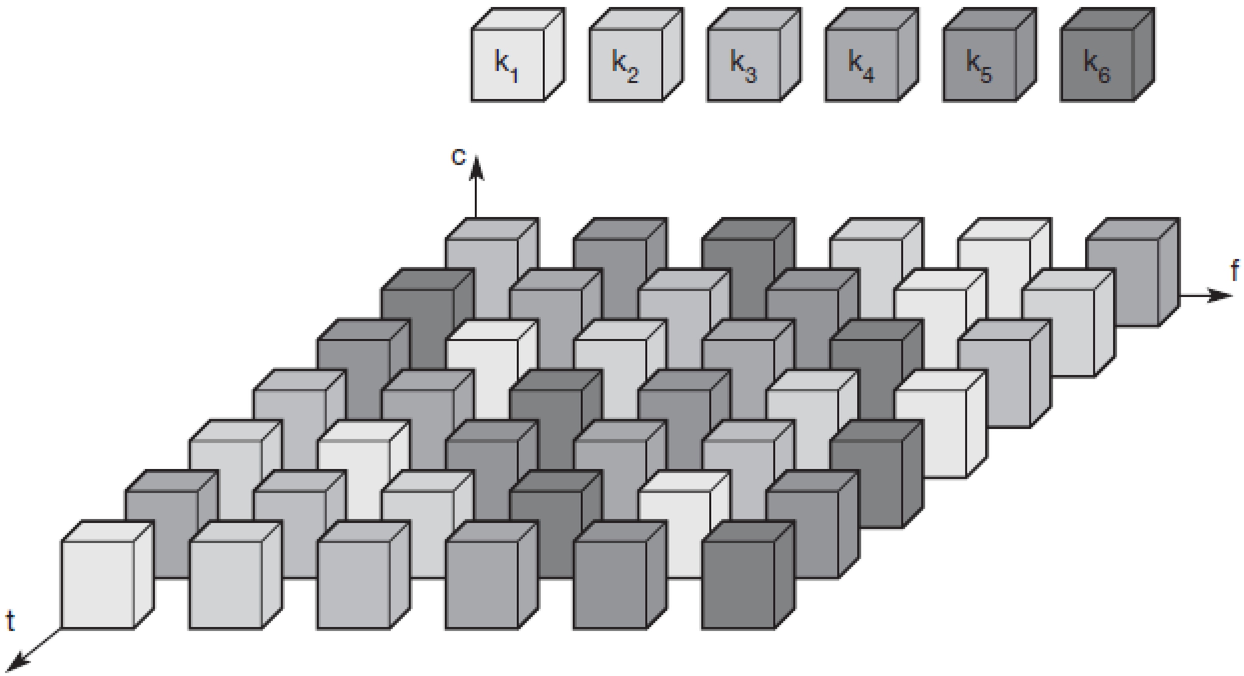


Time Division Multiplexing

1. Flexible multiplexing scheme for typical mobile communications is **time division multiplexing (TDM)**.
2. Channel ki is given the whole bandwidth for a certain amount of time, i.e., all senders use the same frequency but at different points in time.
3. Guard spaces, represent time gaps.
4. If two transmissions overlap in time, this is called co-channel interference.

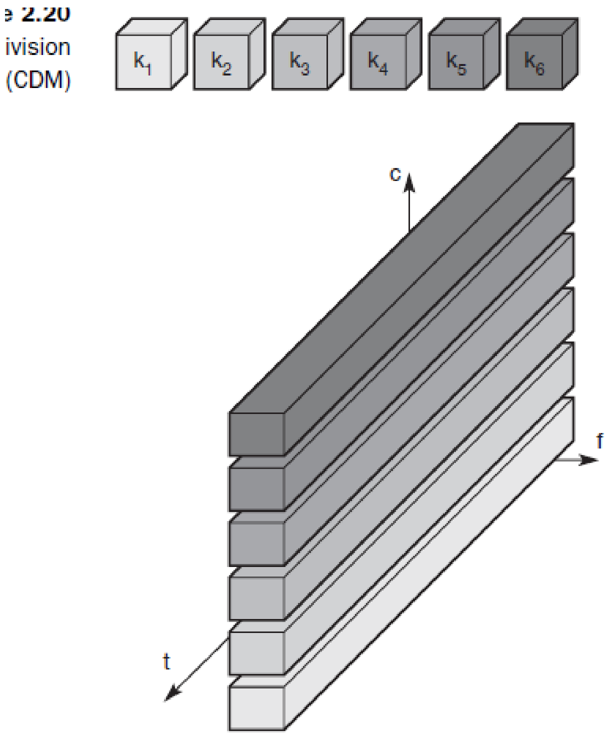


Time and Frequency Division Multiplexing (Used by GSM)



Code division multiplexing (CDM)

- Separation is now achieved by assigning each channel its own ‘code’, **guard spaces** are realized by using codes with the necessary ‘distance’ in code space, e.g., **orthogonal codes**.
- CDM for wireless transmission is that it gives good protection against interference and tapping.
- Receiver is highly complex.



Modulation Techniques

- $g(t) = At \cos(2\pi\, ftt + \varphi t)$ Signal Representation

  amplitude At, frequency ft, and phase φt which may be varied in accordance with data or another modulating signal.
- **Digital modulation :** digital data (0 and 1) is translated into an analog signal (baseband signal). Required if digital data has to be transmitted over a medium that only allows for analog transmission.
- In wireless networks, digital transmission cannot be used.
- The binary bit-stream has to be translated into an analog signal first.
- Schemes used for this translation are:
  1. **amplitude shift keying (ASK)**
  2. **frequency shift keying (FSK)**
  3. **phase shift keying (PSK)**.
- digital modulation translates a 1 Mbit/s bit-stream into a baseband signal with a bandwidth of 1 MHz.
- In wireless transmission, an **analog modulation** that shifts the center frequency of the baseband signal generated by the digital modulation up to the radio carrier is needed

Brain Storming

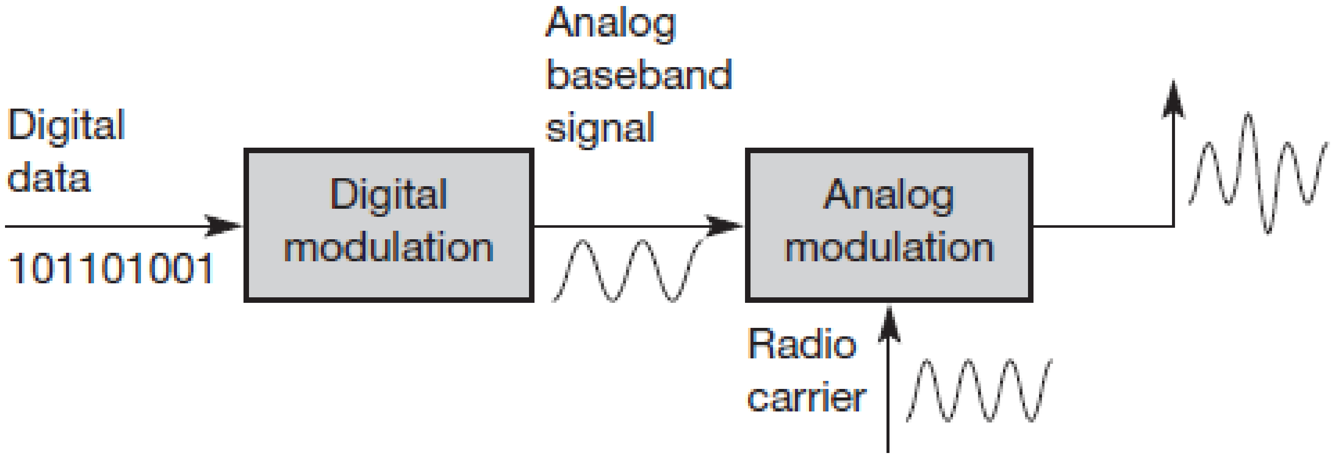
why
this baseband signal cannot be directly transmitted in a wireless system?

Reasons

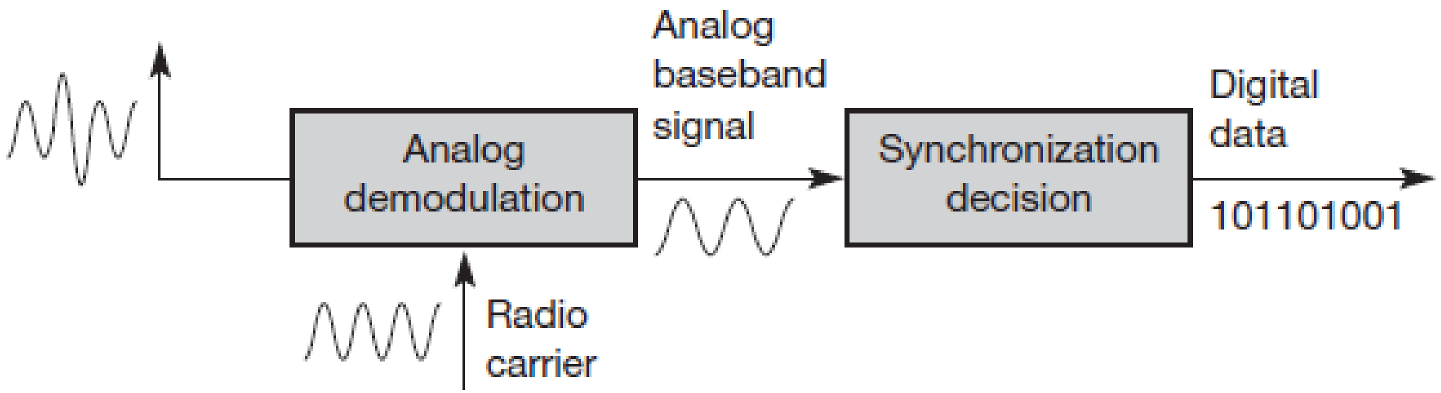
- **Antennas**: An antenna must be the order of magnitude of the signal’s wavelength in size to be effective. For the 1 MHz signal in the example this would result in an antenna some hundred meters high.
- **Frequency division multiplexing**: Using only baseband transmission, FDM could not be applied. Analog modulation shifts the baseband signals to different carrier frequencies. The higher the carrier frequency, the more bandwidth that is available for many baseband signals.
- **Medium characteristics**: Path-loss, penetration of obstacles, reflection, scattering, and diffraction –depend heavily on the wavelength of the signal.

Depending on the application, the right carrier frequency with the desired characteristics has to be chosen.

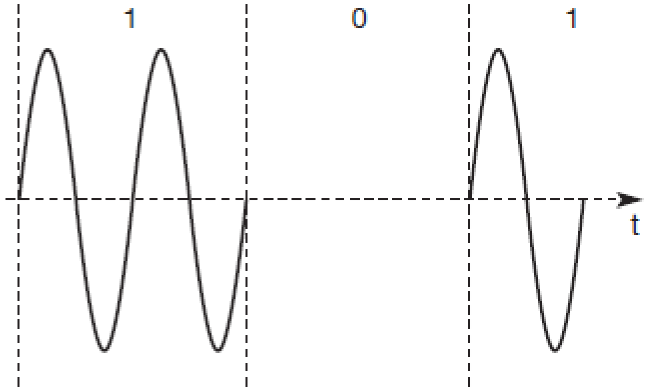
Modulation : Radio Transmitter for digital Data



Demodulation and data reconstruction in a receiver

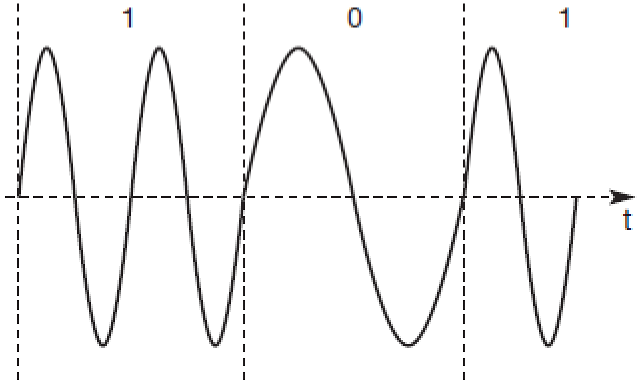


Amplitude shift keying (ASK), the most simple digital modulation scheme.



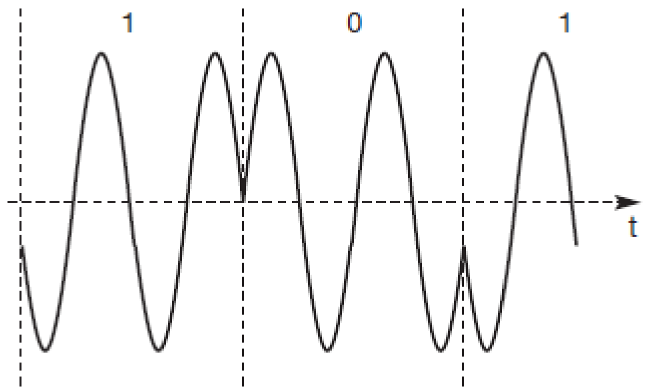
- The two binary values, 1 and 0, are represented by two different amplitudes.
- This simple scheme only requires low bandwidth, but is very susceptible to interference.
- Effects like multi-path propagation, noise, or path loss heavily influence the amplitude.

Binary FSK
(BFSK)



- One frequency f1 to the binary 1 and another frequency f2 to the binary 0.
- To implement FSK is to switch between two oscillators, one with the frequency f1 and the other with f2, depending on the input.

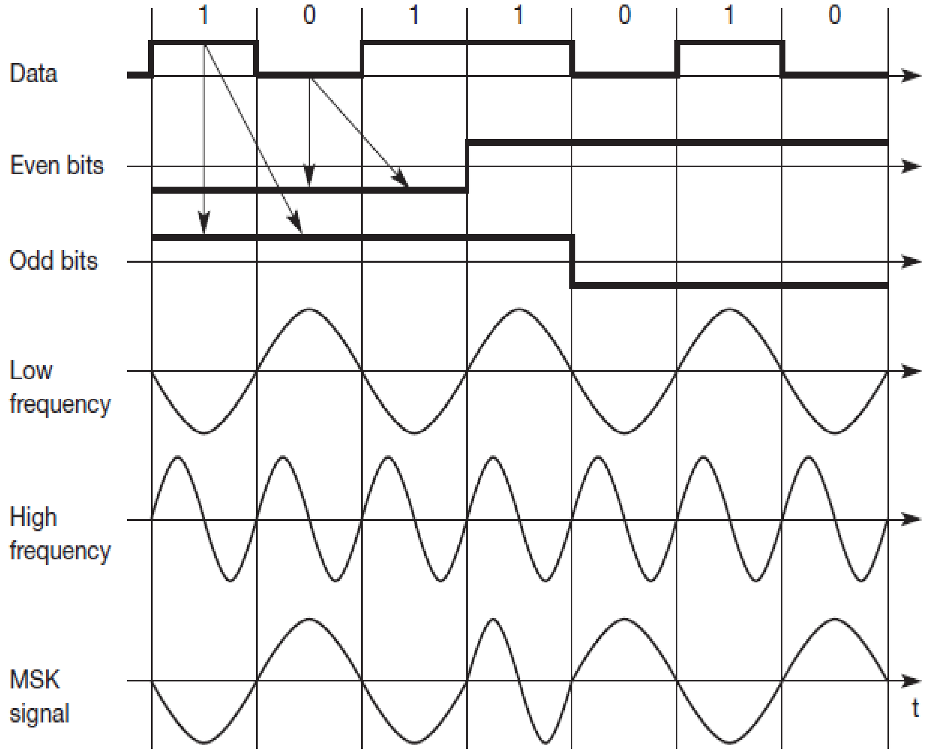
Phase shift keying (PSK)



- Phase shift of 180° or π as the 0 follows the 1.
- Shifting the phase by 180° each time the value of data changes, is also called **binary PSK (BPSK).**
- To receive the signal correctly, the receiver must synchronize in frequency and phase with the transmitter. This can be done using a **phase lock loop (PLL)**.

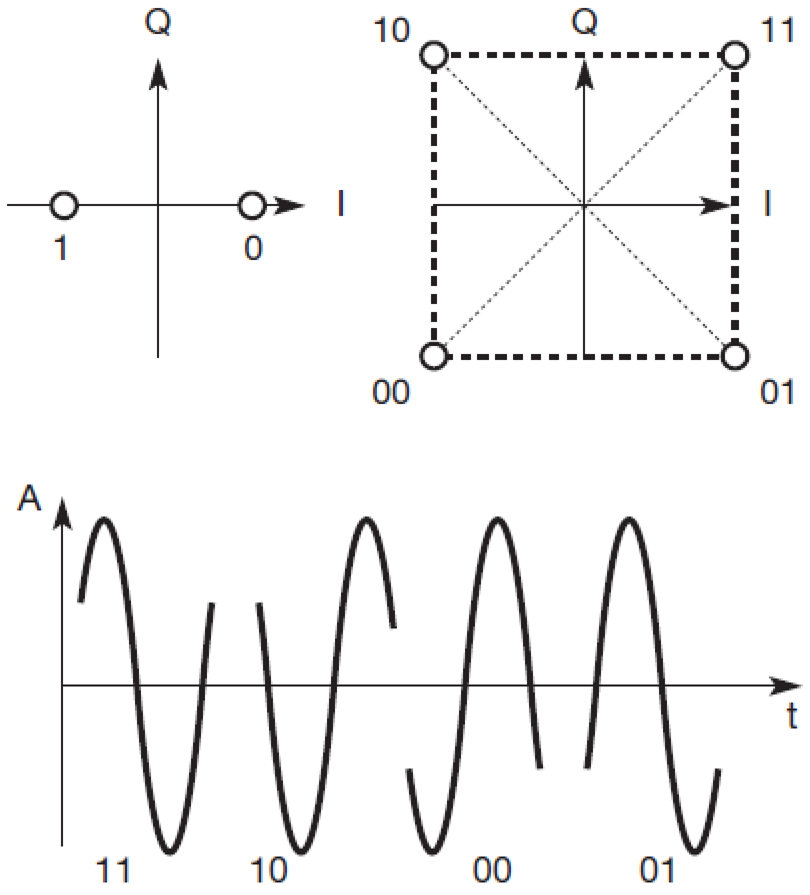
Advanced frequency shift keying

MSK is basically BFSK without abrupt phase changes.



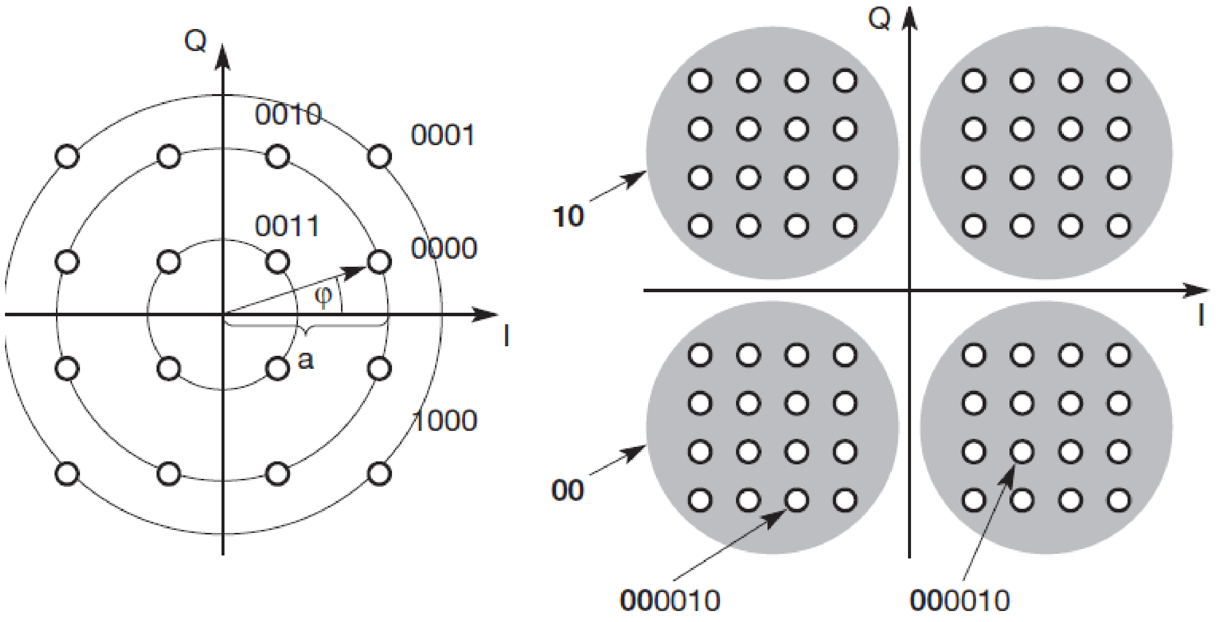
- data bits are separated into even and odd bits, the duration of each bit being doubled.
- The scheme also uses two frequencies: f1, the lower frequency, and f2, the higher frequency, with f2 = 2f1.
- if the even and the odd bit are both 0, then the higher frequency f2 is inverted (i.e., f2 is used with a phase shift of 180°);
  ● if the even bit is 1, the odd bit 0, then the lower frequency f1 is inverted.
- if the even bit is 0 and the odd bit is 1, as in columns 1 to 3, f1 is taken without changing the phase,
- if both bits are 1 then the original f2 is taken.

Advanced phase shift keying



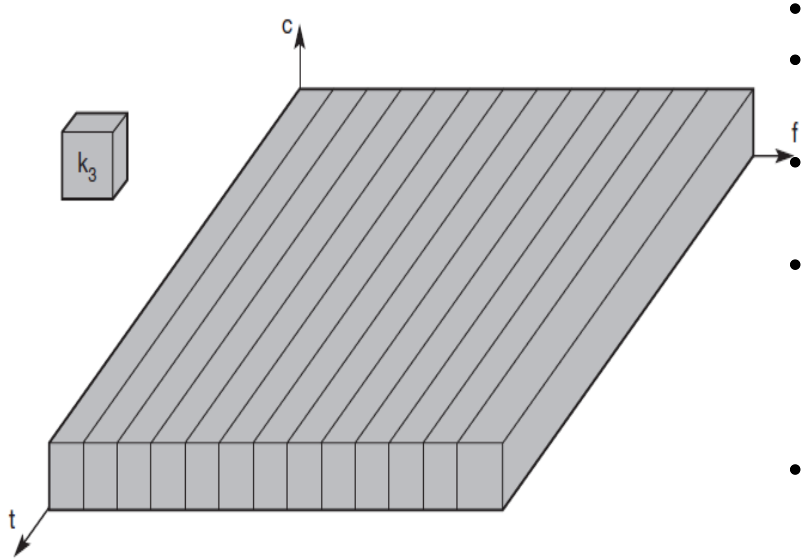
- QPSK (and other PSK schemes) can be realized in two variants.
- The phase shift can always be relative to a **reference signal** (with the same frequency).
- If this scheme is used, a phase shift of 0 means that the signal is in phase with the reference signal.
- A QPSK signal will then exhibit a phase shift of 45° for the data 11, 135° for 10, 225° for 00, and 315° for 01 – with all phase shifts being relative to the reference signal.

Quadrature amplitude modulation (QAM)

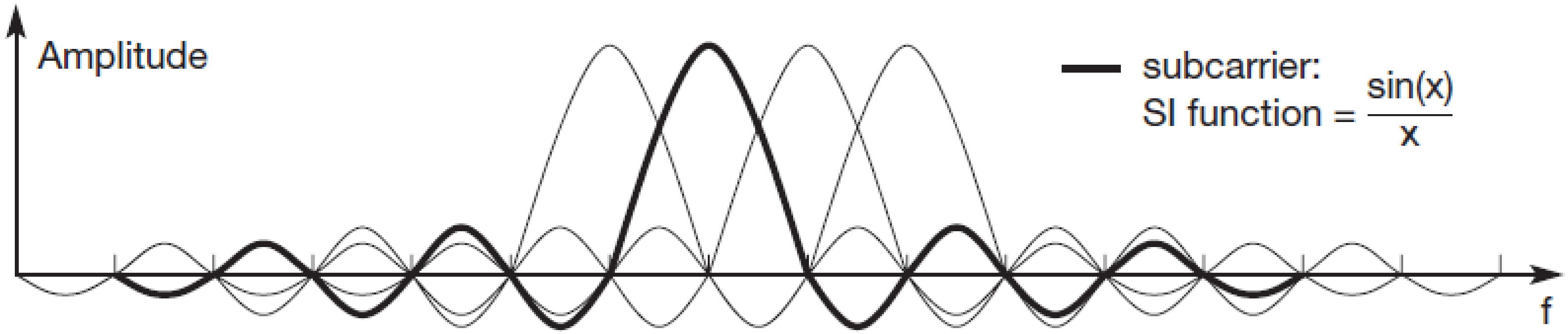


- Three different amplitudes and 12 angles are combined coding 4 bits per phase/amplitude change.
- The more ‘points’ used in the phase domain, the harder it is to separate them.

Multi-carrier modulation



- MCM has good ISI mitigation property.
- Higher bit rates are more vulnerable to ISI.
- MCM splits the high bit rate stream into many lower bit rate streams.
- Each stream is sent using an independent carrier frequency.
- If, for example, n symbols/s have to be transmitted, each subcarrier transmits n/c symbols/s with c being the number of subcarriers.
- One symbol could, for example represent 2 bit as in QPSK

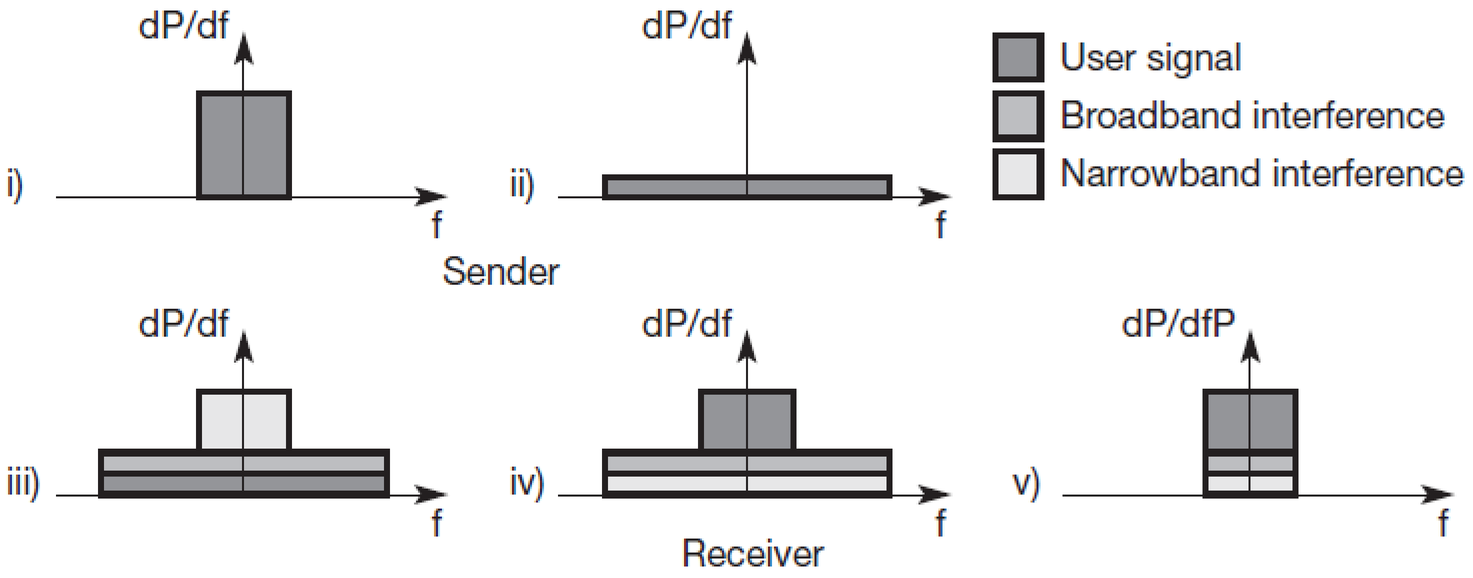


Spread Spectrum

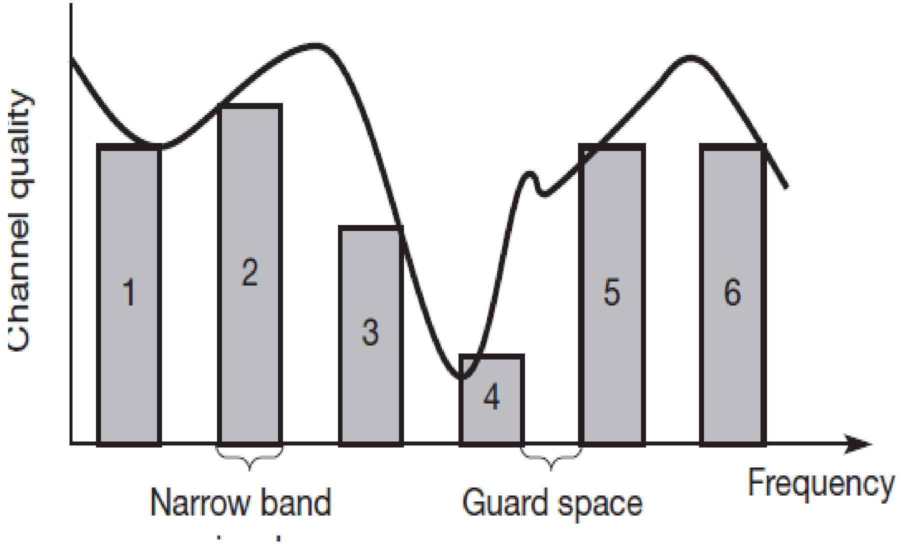
Spread spectrum techniques involve spreading the bandwidth needed to transmit data.

Advantages:

1. Resistance to **narrowband interference.**

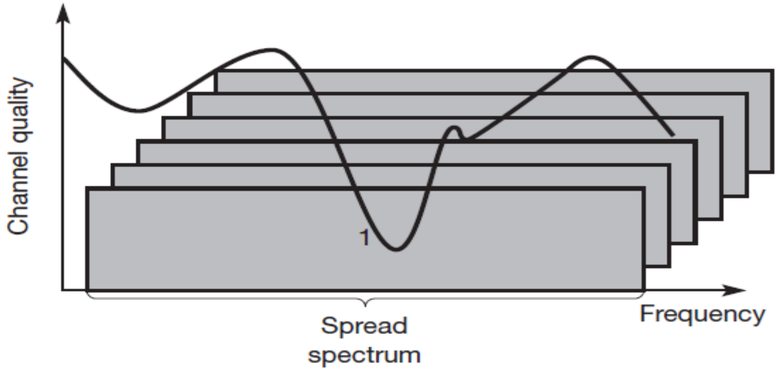


Narrow Band Interference without spread spectrum



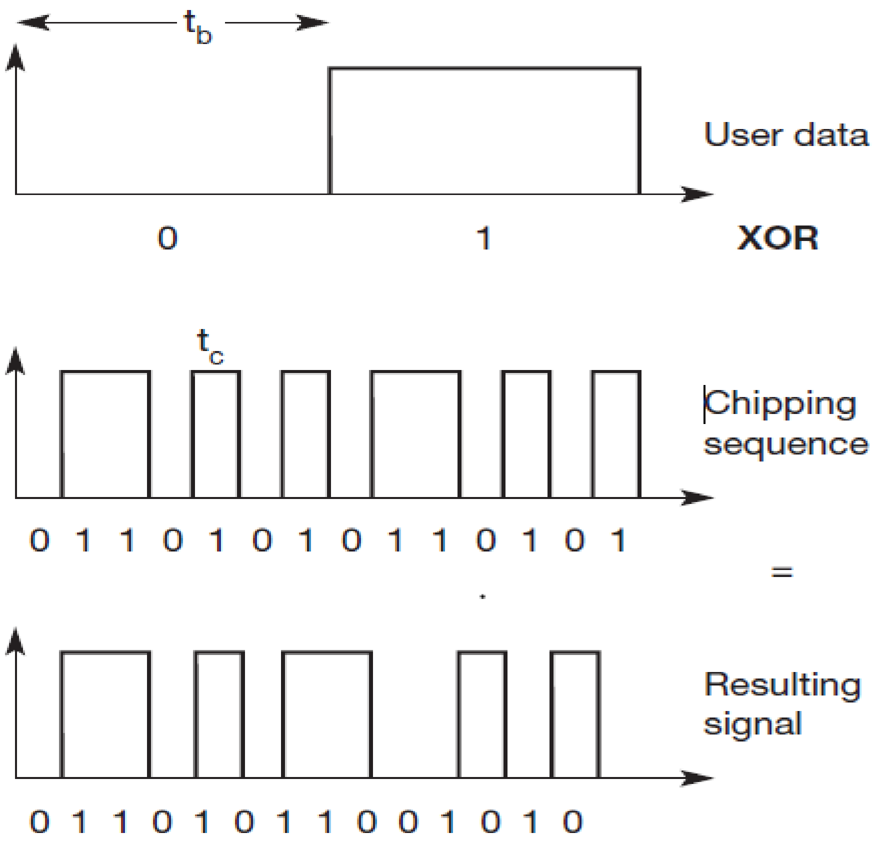
- Six different channels use FDM for multiplexing, each channel has its own narrow frequency band for transmission.
- Between each frequency band a guard space is needed to avoid adjacent channel interference.
- Channel quality also changes over time – the diagram only shows a snapshot at one moment.
- Narrowband interference destroys the transmission of channels 3 and 4.

Spread Spectrum to avoid Narrow Band Interference



- All narrowband signals are now spread into broadband signals using the same frequency range.
- Application shows the tight coupling of CDM and spread spectrum to recover signal at the receiver.
- One disadvantage is the increased complexity of receivers that have to despread a signal.
- Another problem is ,Large frequency band is needed due to the spreading of the signal.

Spreading the spectrum can be achieved in two different ways

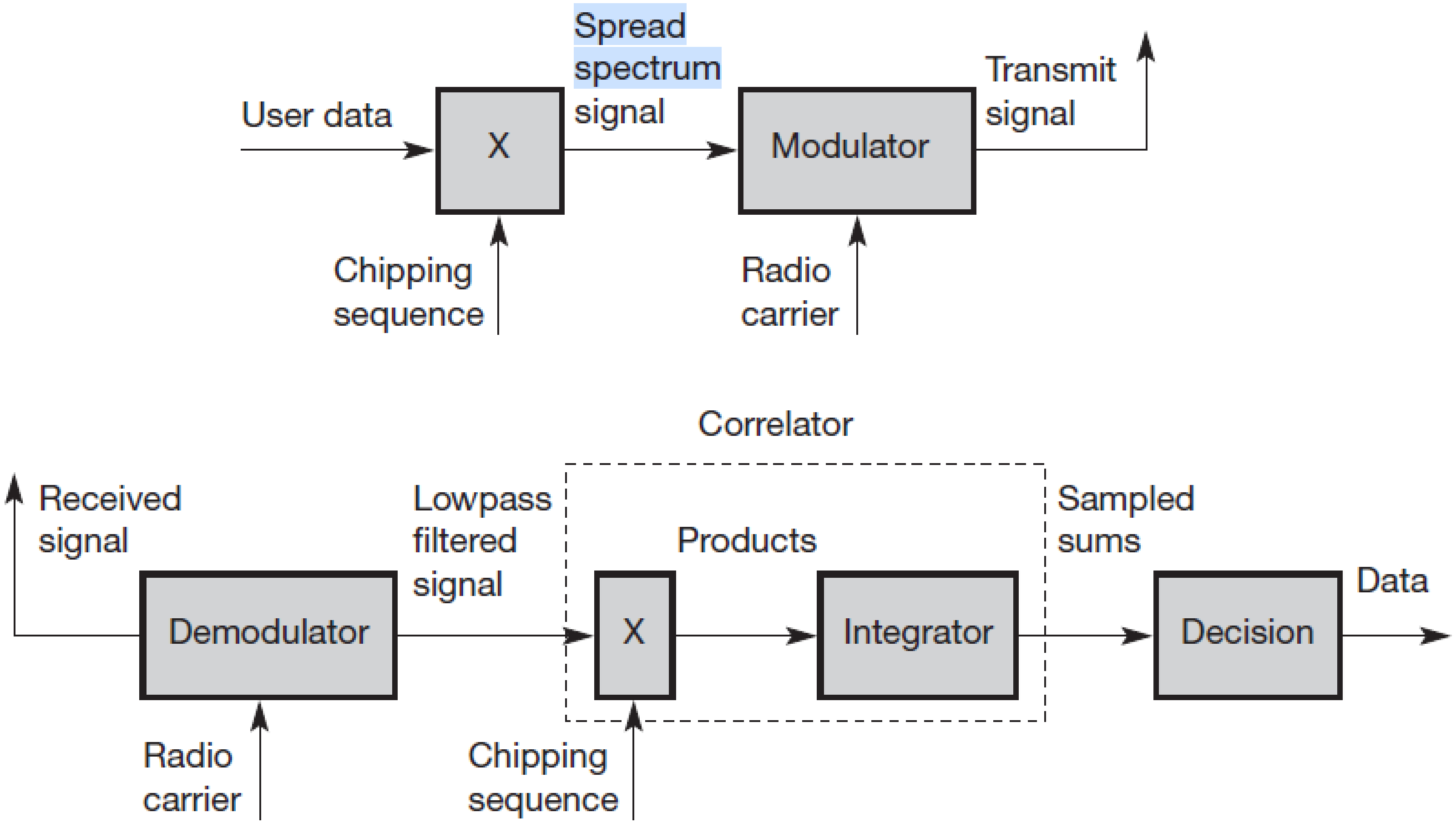


Direct sequence spread spectrum (DSSS): System take a user bit stream and perform an (XOR) with a so-called **chipping sequence.**

DSSS

- Result is either the sequence 0110101 (if the user bit equals 0) or its complement 1001010 (if the user bit equals 1).
- 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 determines the bandwidth of the resulting signal.
- If the original signal needs a bandwidth w, the resulting signal needs s·w after spreading.

DSSS Transmitter and Receiver



Challenges in DSSS

- Receiver has to know the chipping sequence.
- Sequences at the sender and receiver have to be precisely synchronized because the receiver calculates the product of a chip with the incoming signal.
- Chip Sequence:

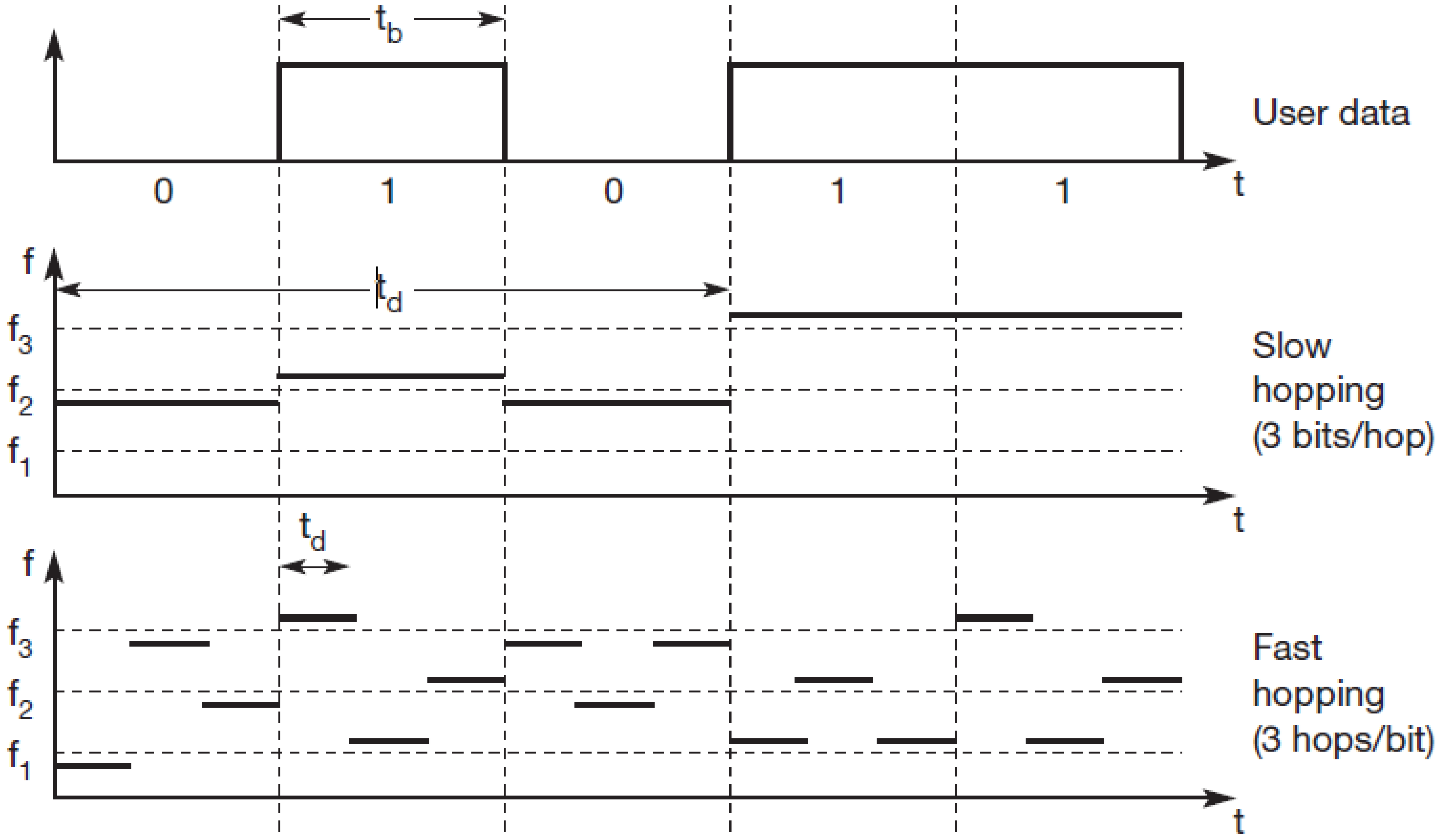
Sending the user data 01 and applying the 11-chip Barker code 10110111000 results in the spread 'signal' 0110111000010010000111.

There are several paths and signals due to multi path propagation, so there is need of rake receiver.

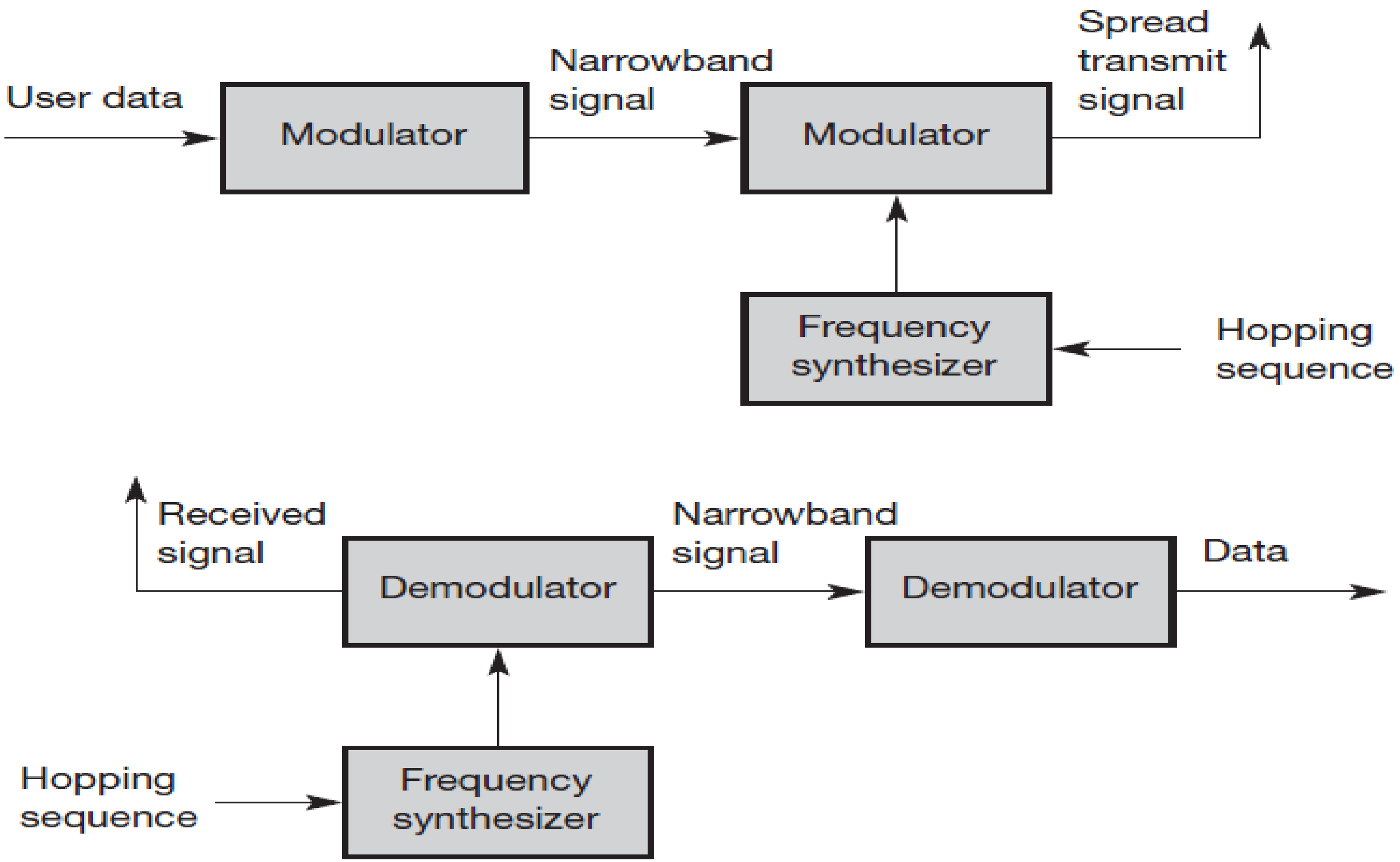
Frequency hopping spread spectrum (FHSS)

- 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.
- 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**.

FHSS: Slow and Fast



FHSS: Transmitter & Receiver

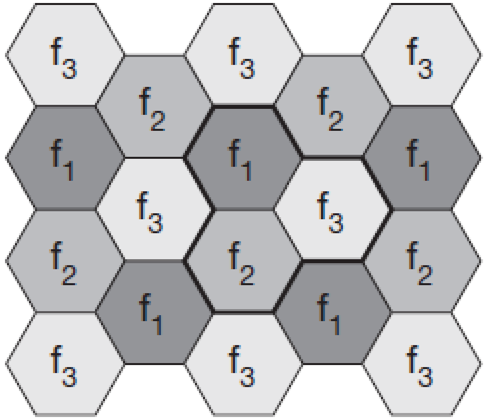


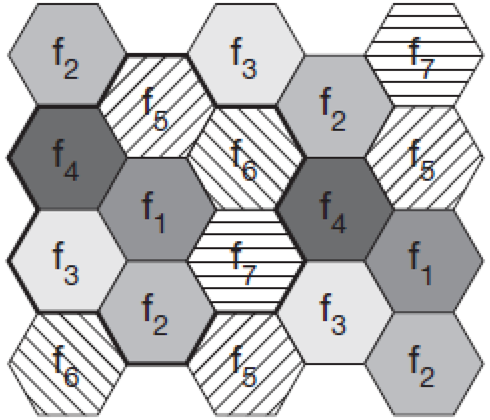
DSSS V/s FHSS

- FHSS systems only use a portion of the total band at any time, while DSSS systems always use the total bandwidth available.
- DSSS systems are more resistant to fading and multi-path effects.
- DSSS signals are much harder to detect – without knowing the spreading code, detection is virtually impossible.
- If each sender has its own pseudo-random number sequence for spreading the signal (DSSS or FHSS), the system implements CDM.

Cellular Systems – Frequency Reuse

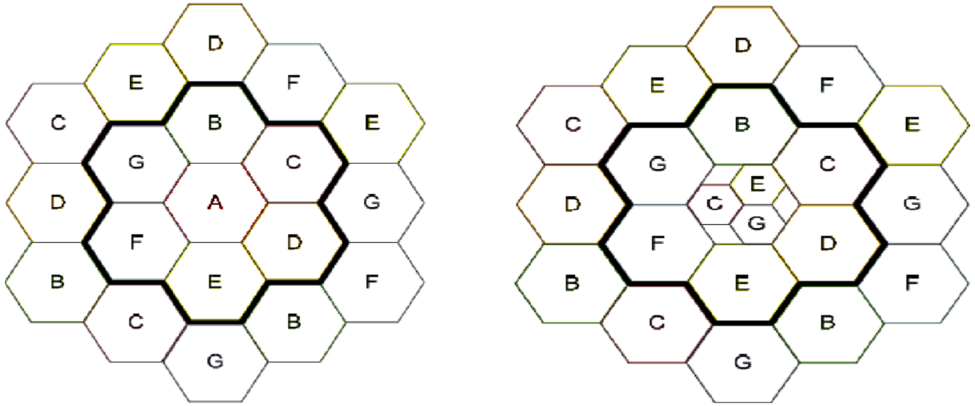
- Cellular systems for mobile communications implement SDM.
- Each transmitter, called a **base station**, covers a certain area, a **cell**.
- In Mobile telecommunication systems, a mobile station within the cell around a base station communicates with this base station and vice versa.





Cell Splitting

- Cell splitting is **the process of subdividing a congested cell into smaller cells, each with its own base station and a corresponding reduction in antenna height and transmitter power**.
- Cell splitting increases the capacity of a cellular system since it increases the number of times that channels are reused.



(a) Original cell distribution (b) After splitting cell A
Figure 1.5: Example of cell splitting

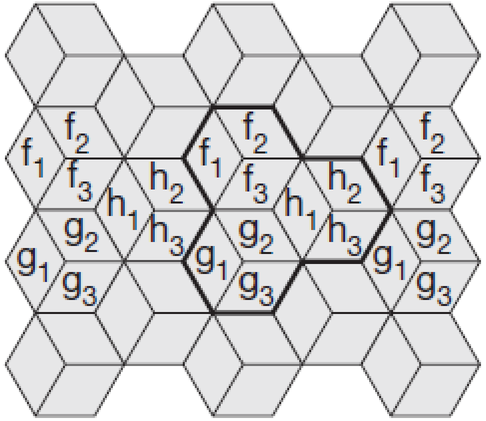
Advantages of Small Cells

- **Higher capacity**: Implementing SDM allows frequency reuse. As most mobile phone systems assign frequencies to certain users (or certain hopping patterns), this frequency is blocked for other users. But frequencies are a scarce resource and, the number of concurrent users per cell is very limited. **Huge cells do not allow for more users.**
- **Less transmission power**: A receiver far away from a base station would need much more transmit power than the current few Watts.
- **Local interference only**: With small cells, mobile stations and base stations only have to deal with ‘local’ interference.
- **Robustness**: Cellular systems are decentralized and so, more robust against the failure of single components.

Disadvantages of Small Cells

- **Infrastructure needed**: Cellular systems need a complex infrastructure to connect all base stations.
- **Handover needed**: The mobile station has to perform a handover when changing from one cell to another. Depending on the cell size and the speed of movement, this can happen quite often.
- **Frequency planning**: To avoid interference between transmitters using the same frequencies, frequencies have to be distributed carefully.

Channel Allocation-Cellular System with 3 Cell Cluster



- Fixed Channel Allocation
- Dynamic Channel Allocation
- Borrowing Channel Allocation

All cells within a cluster use disjointed sets of frequencies. One cell in the cluster uses set f_1, another cell f_2, and the third cell f_3.

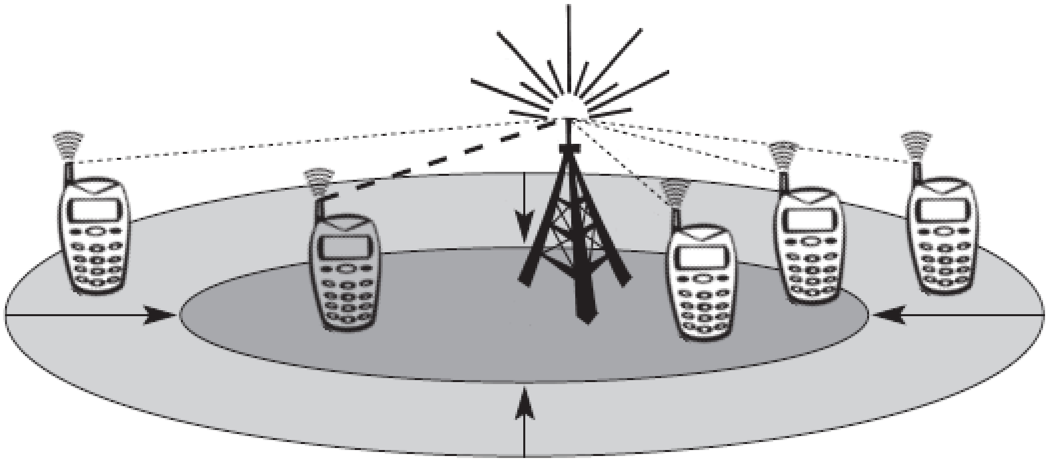
Cellular systems using CDM

Users are separated through the code they use, not through the frequency.

Cell size depends on the current load.

CDM cells are commonly said to '**breathe**'.

Cell can cover a larger area under a light load, it shrinks if the load increases.



Thank You