

Mobile infocommunication systems
Mobile infocommunication networks
- Mobile network basics -

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Basic principles of networking

- Two main differences compared to fixed networks
  - endpoints (terminals, user devices) are mobile
    - can go to anywhere in the network
    - can access the network anywhere
    - this motion should be supported while having an ongoing communications
    - this motion should be supported while the terminal is idle, that is it does not have an active communications
      - it does not have a communications channel assigned
    - the mobile should be able to initiate a communication session (voice or video call, data upload or download) any time, anywhere
    - the mobile should be able to receive a communication session
      - mobile terminated incoming call or data flow
    - regardless their geographical position
    - the position of the terminal does not prove its right to communicate
      - unlike fixed access, where the endpoint is associated to the premises of the customer
      - therefore authentication mechanism is needed, to ensure that a terminal has rights to access the network

Basic principles of mobile networking

- Two main differences compared to fixed networks
  - the physical medium to be used is radio channel
    - it is a shared medium, namely any terminal can listen to it or transmit over it (unlike a fixed point-point cable connection)
      - the medium has to be shared somehow among the different terminals
      - sharing the medium (radio channel): this is medium access control (MAC) procedure
      - different MAC protocols can be used to provide the sharing mechanism
      - shared medium enables the evesdropping of others' communications
      - therefore strong security/cryptography solutions are needed to encrypt the communications of the radio channels
      - shared medium allows a malicious terminal to disturb the communications physically (by means of emitting disturbing signals)
        - » this should be handled at policy and regulation level
        - » and/or the radio technology used for communications itself should have mechanisms to mitigate malicious disturbing signals

Basic principles of mobile networking

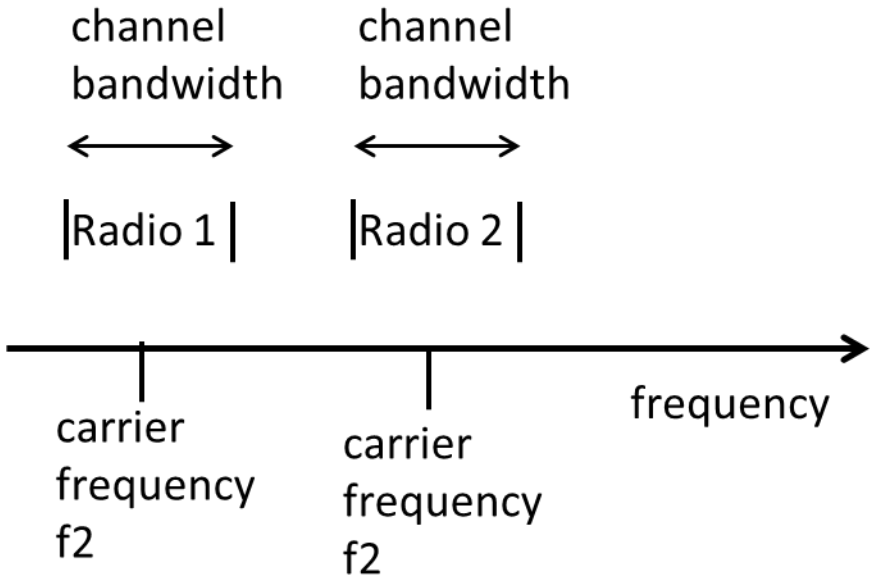
- Two main differences compared to fixed networks
  - the physical medium to be used is radio channel
    - it is a shared medium, namely any terminal can listen to it or transmit over it (unlike a fixed point-point cable connection)
      - due to the shared nature of the channel, valid terminals' standard signals may and does cause disturbance to others
      - this is called interference
      - communication over radio interface has to cope with interference
  - the radio channel has bad properties
    - thermal noise is always present
    - channel attenuation is very high and is dependent on
      - weather
      - distance (attenuation rises sharply with distance)
      - environment, buildings, terrain
      - carrier frequency used for communications (the higher the frequency, the higher the attenuation)

Basic principles of mobile networking

- Two main differences compared to fixed networks
  - the radio channel has bad properties
    - the signal propagates from transmitter to receiver over several propagation paths
      - mult-path propagation
    - each path has random delay and attenuation and the sum signal arrives to the receiver
    - reveiced signal level is random and has very sudden random changes
      - this is called *fading*
      - basic cause of the fading is the movement of the receiver and the movement of surrounding objects and the multipath propagation
      - *shadowing, shadow fading:* due to terminal mobility the signal level drops when it arrives to a faded area (e.g. behind buildings)
    - attenuation is frequency-selective
      - due to multipath propagation the channel attenuation is differnet and is random in frequency domain as well (different frequencies has different attenuations)
      - frequency-selective fading

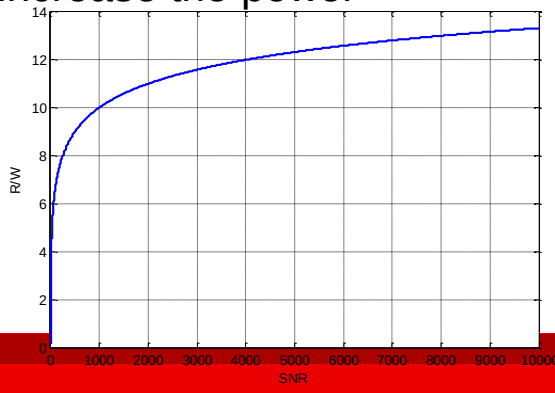
Radio channels

- mobile communication uses radio signals
- every (not just radio) signal can be described in frequency domain (-> *spectrum* of the signal)
- the channel can be described in frequency domain as well
  - most important property is the physical bandwidth (in Herz) of the channel
  - not to be confused by the transmission capacity, or bitrate of the channel (bits/second) which is often called bandwidth
  - although the two has strong connection



Radio channels

- different channels do not disturb each other if they don't overlap
- the whole frequency spectrum is a scarce and expensive national resource
  - regional and national authorities control the access and use of frequency channels
- Shannon's theorem: $R \leq W \cdot log_2(1 + \frac{P_{Signal}}{P_{noise}})$
- R: achievable bitrate at the receiver, bits/second
- W: bandwidth of the channel (Hz)
- Psignal: power of the received signal, Pnoise: power of the noise (both in Watts)
- the ratio $\frac{P_{Signal}}{P_{noise}}$ is SNR, Signal to Noise Ratio
- the bitrate scales linearly with bandwidth -> for high bitrate, high bandwidth is needed
- the bitrate scales logarithmically with power: it is not as useful to increase the power
- spectral efficiency: R/W, bps/Hz: how efficiently the band is used



Radio channels

- in comms. engineering we often treat interference as noise
- Shannon

$$R \leq W \cdot log_2(1 + \frac{P_{Signal}}{P_{noise} + P_{interference}})$$

- the ratio $\frac{P_{Signal}}{P_{noise} + P_{interference}}$ is SINR signal to interference and noise ratio

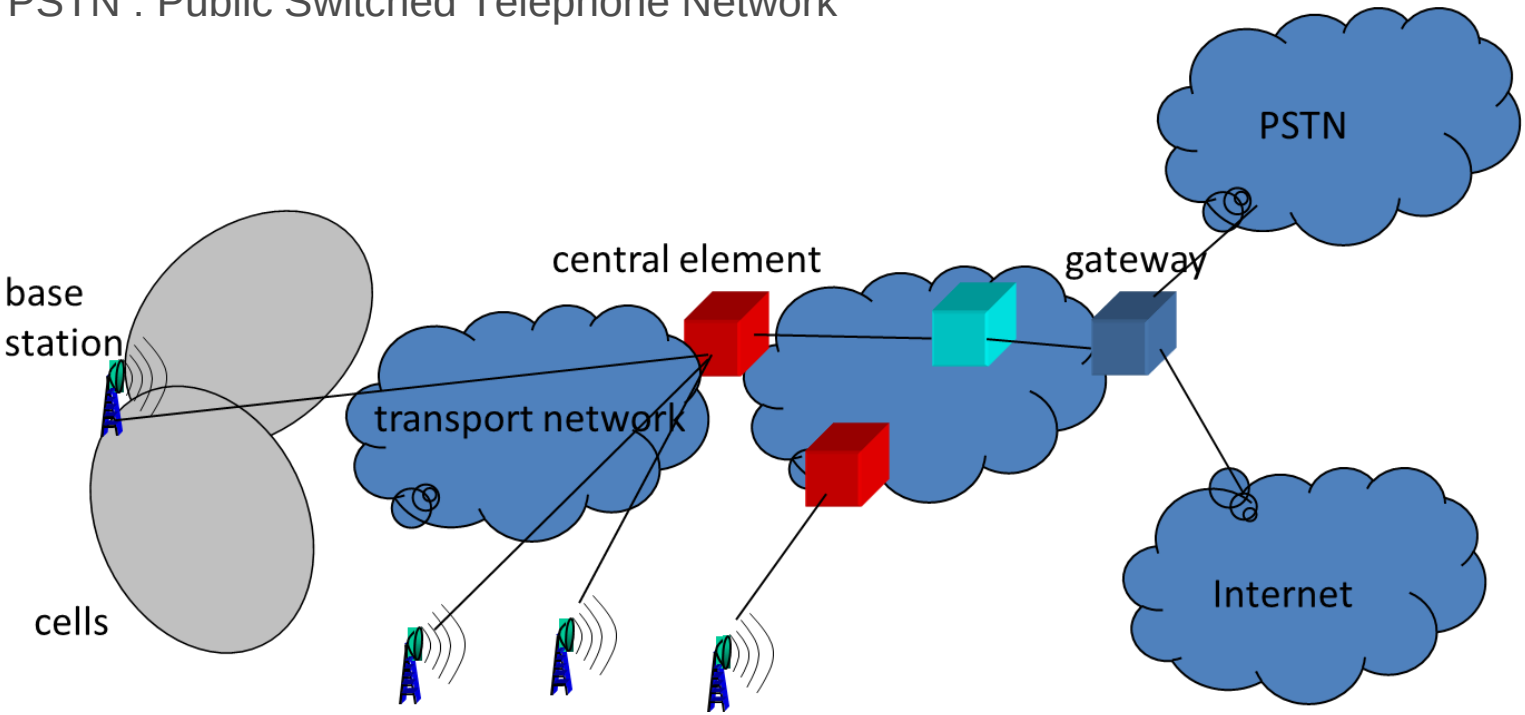
- radio communication channels are coupled through interference
- increase power on my link communications link -> increase interference of another link -> increase power on that link -> increase interference on my link

Shared channel

- how to share the channel:
  - FDMA Frequency division multiple access: users's channels are separated in frequency domain
  - TDMA Time -||- : users have different timeslots for communications, their channels are separated in time
  - CDMA: Code -||-: users have special signal formats (codes) that allow their channels to be separated at the receiver
  - radio resource: band, timeslot, code
- controlled access
  - there is a central entity (the newtork) that assigns the channels to users (bands, or timeslots or codes)
- random access
  - there is no central control, the users access the channel using a distributed random mechanism
    - collision may occur: two or more users use the same radio resource concurrently –y receiver cannot receive either's signal

Cellular network basics

- basic network view
  - cell: a geographical area, where a given transceiver (transmitter + receiver) of a base station can be reached with good quality
  - transport network: large network composed of multiple routers/switches etc.
  - central element: mobile network specific device
  - gateway: connection to the rest of the world
  - PSTN : Public Switched Telephone Network

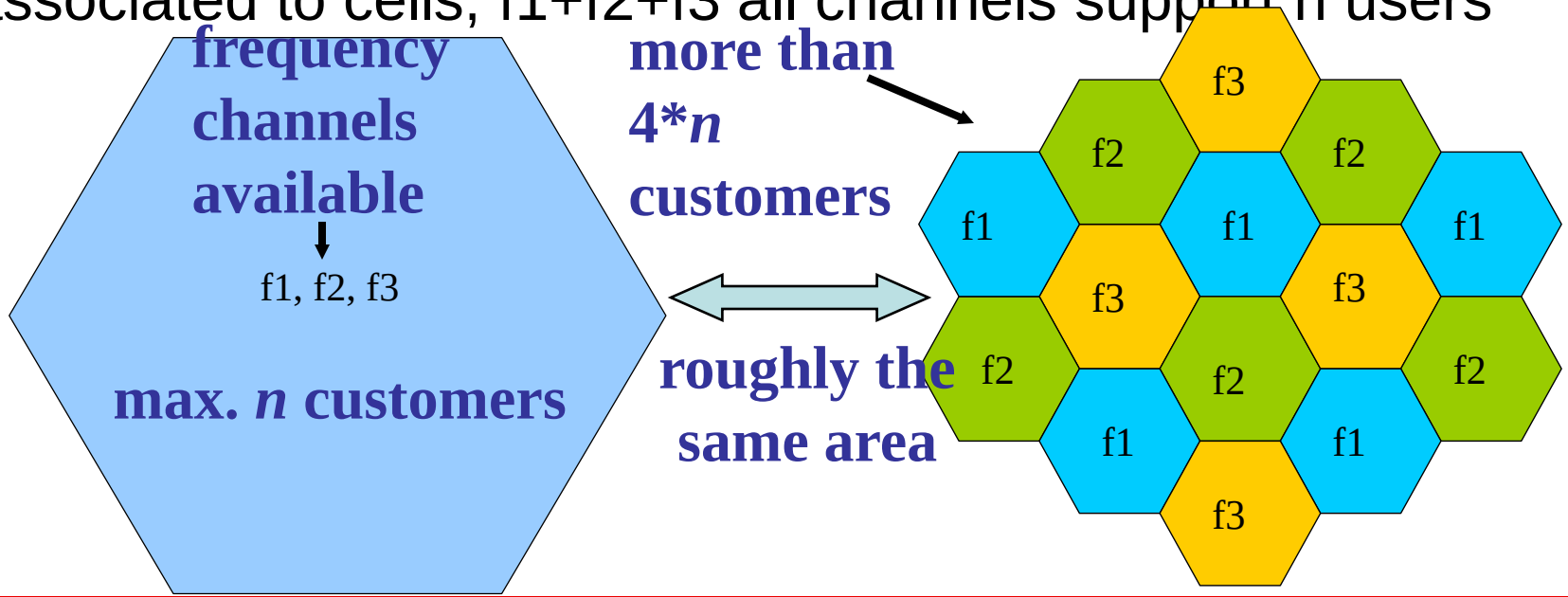


Cellular network basics

- mobile phone is physically connected to a base station, through the transceiver that covers a cell
- radio cells:
  - no fixed and strict borders, not regular shapes
  - rather probabilities of having a given signal quality in certain locations
    - due to the random nature of the radio channel
- in every cell a certain amount of frequency channels can be used -> a given capacity, according to Shannon
- cells using the same frequency channels cause interference to each others
- why cells? why not a single big cell over a big area?
  - propagation loss issues, power is not enough to reach very big distances
  - protocol issues: radio signal formats may limit the maximum cell size (see later)
  - but the main reason is: to ***provide more capacity***
    - the idea of frequency –reuse
  - more smaller cells in an area -> higher capacity over the area -> higher number of customers and higher total traffic over the area
  - doe not increase, or even decrease the maximum bitrate of a single user!

Frequency reuse

- in every cell, only a couple of frequency channels are used from the the total set of frequencies
- same frequencies are re-used in cells that are far away (-> to decrease interference)
- much more capacity over the ares
- example: hexagons are cells, frequency channels are associated to cells, f1+f2+f3 all channels support n users



Mobility management

- mobile phone is physically connected to a base station, through the transceiver that covers a cell (-> mobile is in a cell)
  - the mobile has an active connection or data flow
  - while moving, the mobile may arrive to a place where the serving signal quality becomes bad (-> the mobile reaches the cell edge, mobile is going out of the cell)
  - the call/flow has to be switched to another cell, whose signal quality is better
  - without interrupting the call
  - this process is ***handover***
- handover
  - handover at radio level: the call to be switched to another transceiver
  - handover in the network: the data flow to be routed to the new cell or new base station
  - handover is handled in the network
  - HOW?
    - mobile constantly measures the quelity of serving cell and neighboring cells (yes, meanwhile having a conversation)
    - reports the measurements
    - the network decides and order the mobile to attach to another cell
    - the network handles the re-routing of the data flow to the new place

Mobility management

- Location management
  - when a mobile is turned on, but there's no connection
  - a mobile terminated call/data arrives to the network
  - the data should be routed to the mobile
    - to the base station, to the cell where the mobile currently is
- How does the system know it?
  - option 0: mobile reports its position using e.g. GPS
    - wrong, due to multiple reasons, I'll ask in the exam
  - option 1: the mobile constantly measures the qualities of all cells, selects the best one and reports the Id. of this cell to the network very often. The network keeps a database containing the Id. of best cell for all mobiles. Problems:
    - this reporting needs network capacity and signalling, setting up of signalling communication
    - too often, too much signalling especially for fast mobiles in small-cell area
    - due to the random nature of radio channel, best cell can change very often -> reporting should be done very often
  - option 2: don't report and don't store mobile positions at all, but operate a broadcast channel (paging channel) in the network. This should be listened to by all mobiles. In case of incomiung data, send a notification to the paging broadcast channel in the whole network -> mobile will answer through its best cell. Problem:
    - paging channel should be so huge, to contain all the incoming notiications of all mobiles

Mobility management

- Location management
  - solution: Location Areas (later: Routing Areas, Tracking Areas)
  - a group of cells (say 20-30)
  - has a unique Id. as well LAC Location Area Code
  - the mobile constantly reads the LAC of its best cell
  - if ther is a new LAC -> then sends the new LAC to the network
  - the network stores the current LAC for the mobile
  - upon arrival of a call the notification is sent to the paging channel of all the cells with in the location area

Some concepts

- Error correction coding Forward Error Correction, FEC
  - error detection: existence false bits (wrongly received) can be detected, like Cyclyc Redundancy Check (CRC)
  - with given clever coding erroneous bits also can be corrected -> error correction coding
  - this needs adding redundancy to the information: not just the useful bits, but redundancy also has to be transmitted
  - the probavility of receiving a bit wrongly is increased if the SNR decreases
  - so for bad (low) SNR -> stronger error correction coding -> more redundancy -> less useful bits -> less bitrates
  - some coding used in mobile systems: convolutional coding, turbo coding, Reed-Solomon coding
- Acknowledgement/retransmission:
  - upon reception of packets or frames, the receiver sends ACKnowledgement to the sender
  - if erroneous packet received, NegativeACKnowledgement, or no acknowledgement is sent
  - the transmitter then retransmit
  - this is the other method for error correction
- In real systems both methods are used in combination