



Mobile and Sensor Systems

Lecture 1: Introduction to Wireless Systems

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About Me



- Reader in Mobile Systems
 - NetOS Research Group
- Research on Mobile, Social and Sensor Systems
- More specifically,
 - Human Mobility and Social Network modelling
 - Opportunistic Mobile Networks
 - Mobile Sensor Systems and Networks



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In This Course



- General understanding and applications of, challenges and solutions for various types of:
 - Mobile Systems and Networks
 - Sensor Systems and Networks

List of Lectures



- Lecture 1: *Wireless Systems.*
- Lecture 2: *Mobile Mac Layer.*
- Lecture 3: *Telecommunication Systems.*
- Lecture 4: *Wireless LAN, Bluetooth, Ad Hoc Networks.*
- Lecture 5: *Ad Hoc and Delay Tolerant Routing.*
- Lecture 6: *Sensor Systems and MAC Layer Protocols.*
- Lecture 7: *Sensor Networking Routing Protocols.*
- Lecture 8: *Sensor Systems Reprogramming and Mobile Sensing.*

What is a Mobile System?



Mobile vs Wireless



- Two aspects of mobility:
 - user mobility: users communicate (wireless) “anytime, anywhere, with anyone”
 - device portability: devices can be connected anytime, anywhere to the network
- Wireless vs. mobile Examples

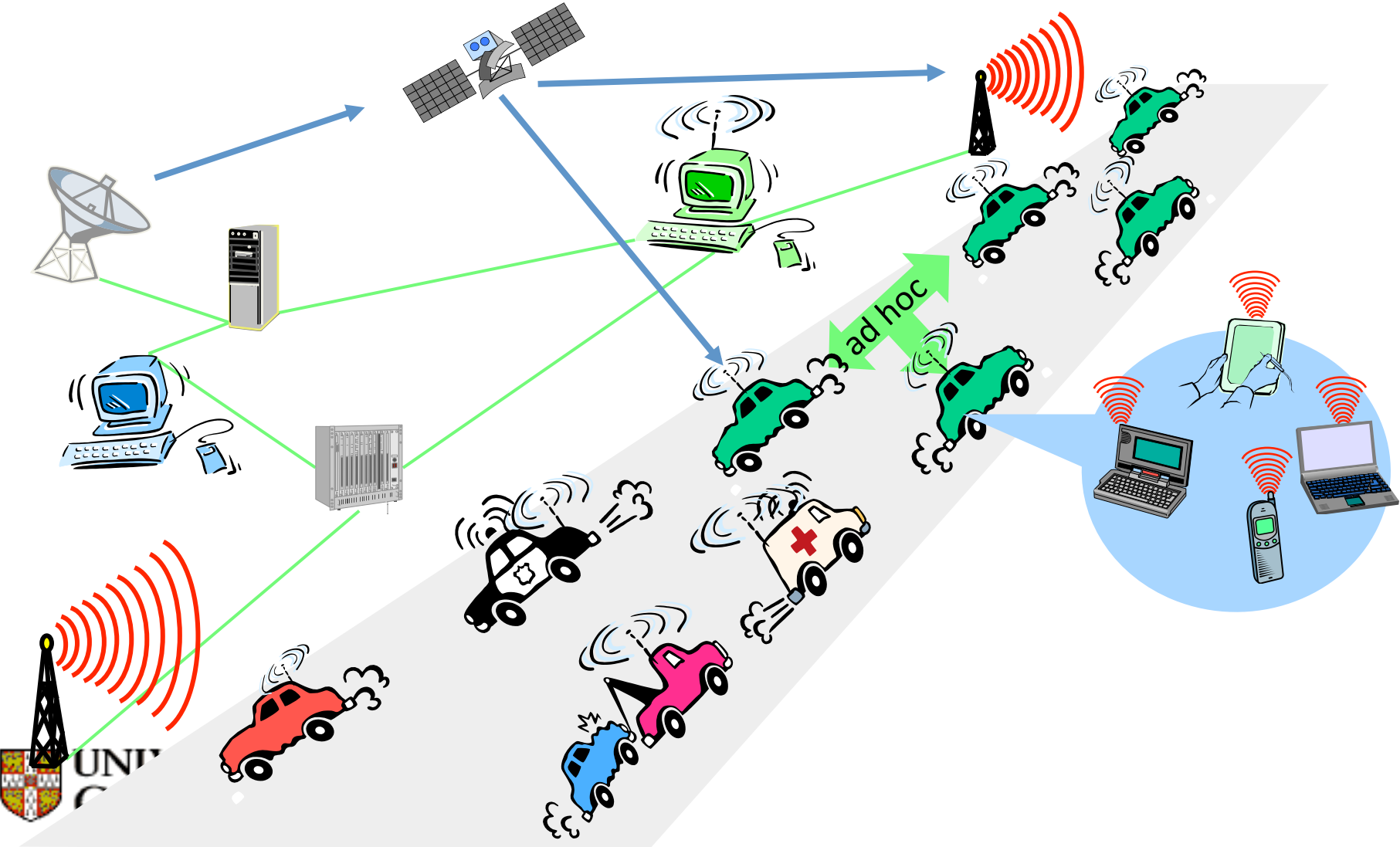
x	x	stationary computer
x	✓	notebook [connected via Ethernet in various places]
✓	x	wireless LANs in historic buildings
✓	✓	mobile phone/laptop (with 3G/WIFI)
- The demand for mobile communication creates the need for integration of wireless networks into existing fixed networks

Applications



- Vehicles/Phones
 - transmission of news, road condition, weather, music
 - personal communication using GSM/UMTS
 - position via GPS
 - local ad-hoc network with vehicles close-by to prevent accidents, guidance system, redundancy
 - Traffic and route 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.

Typical application: road traffic



Mobile and wireless services

Always Best Connected



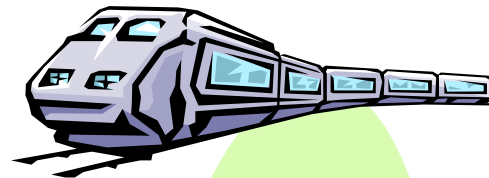
DSL/ WLAN
3 Mbit/s



GSM/GPRS 53 kbit/s
Bluetooth 500 kbit/s



UMTS, GSM
115 kbit/s



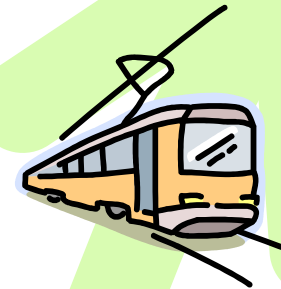
LAN
100 Mbit/s,
WLAN
54 Mbit/s



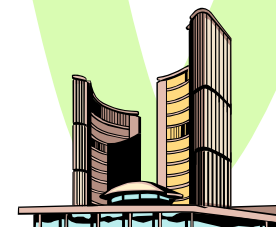
GSM/EDGE 384 kbit/s,
DSL/WLAN 3 Mbit/s



GSM 115 kbit/s,
WLAN 11 Mbit/s



UMTS
2 Mbit/s



UMTS, GSM
384 kbit/s

Location dependent services



- 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 “Pizza Hut”?
- Support services
 - caches, intermediate results, state information etc. “follow” the mobile device through the fixed network
- Privacy
 - who should gain knowledge about the location?



Effects of device portability



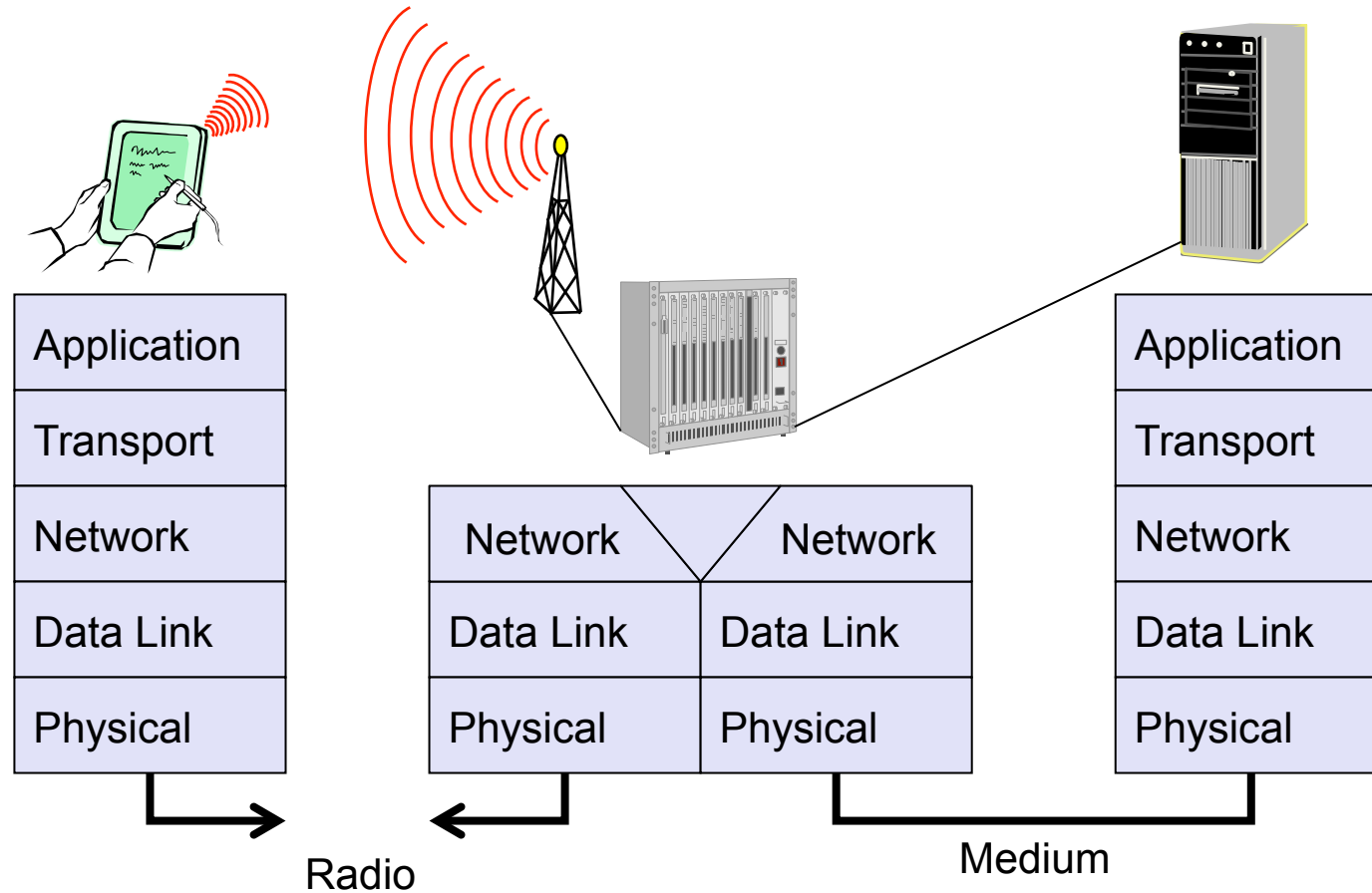
- Power consumption
 - limited computing power, limited transmission, trading off with quality displays
- Loss of data
- Limited user interfaces
 - compromise between size of fingers and portability
 - integration of character/voice recognition
- Limited memory
 - flash-memory as alternative

Wireless networks vs fixed networks



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

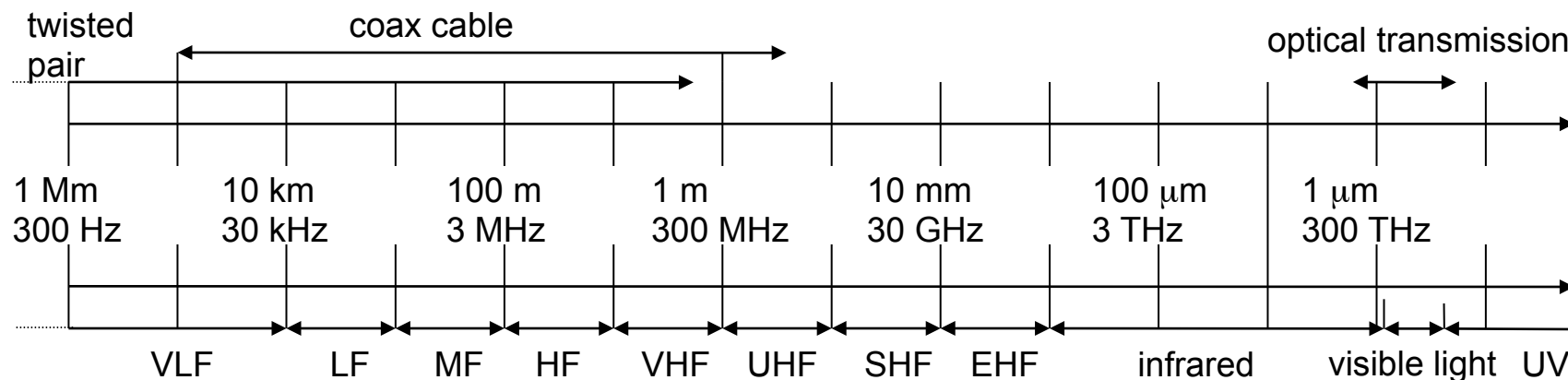
Simple reference model



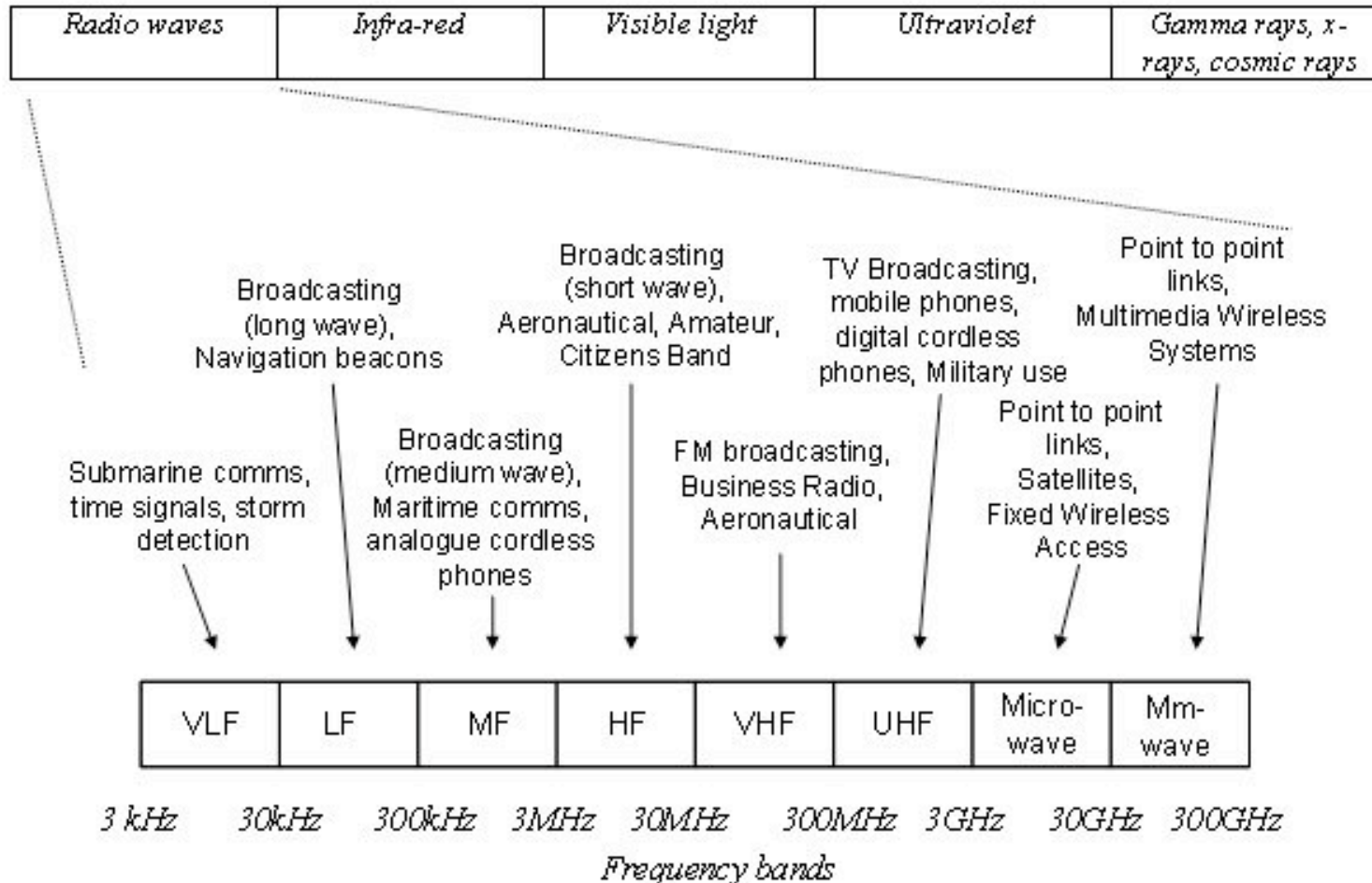
Frequencies for communication



- VLF = Very Low Frequency
 - LF = Low Frequency
 - MF = Medium Frequency
 - HF = High Frequency
 - VHF = Very High Frequency
 - UHF = Ultra High Frequency
 - SHF = Super High Frequency
 - EHF = Extra High Frequency
 - UV = Ultraviolet Light
- Frequency and wave length
 - $\lambda = c/f$
 - wave length λ , speed of light $c \approx 3 \times 10^8 \text{ m/s}$, frequency f



Spectrum Bands

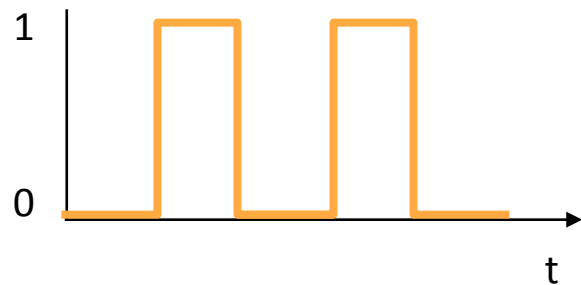


Mobile systems based on radio communication

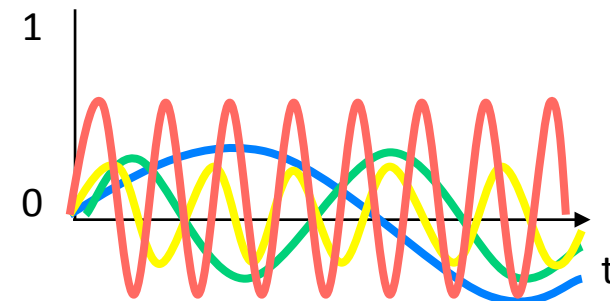
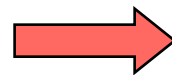


- Characterized by radio propagation
- Signal does not travel on a wire but in the air
- Recap:

$$g(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2\pi nft) + \sum_{n=1}^{\infty} b_n \cos(2\pi nft)$$



ideal periodic signal

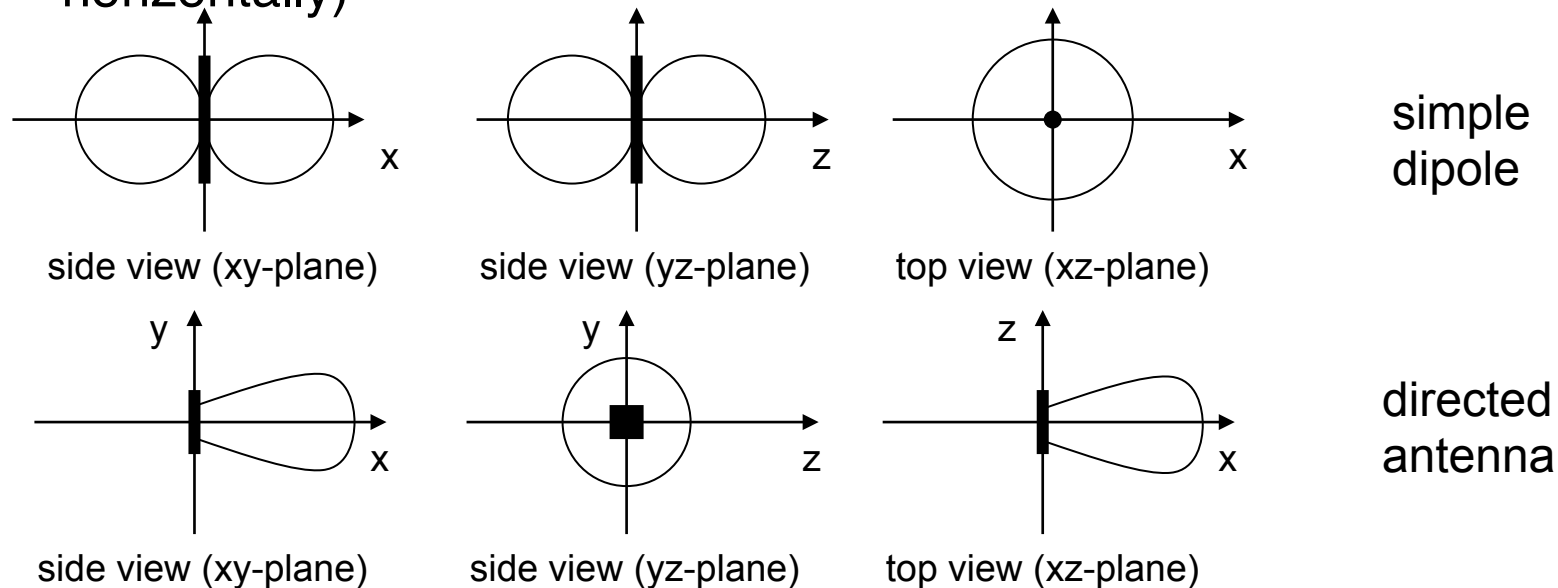


real composition
(based on harmonics)

Antennas



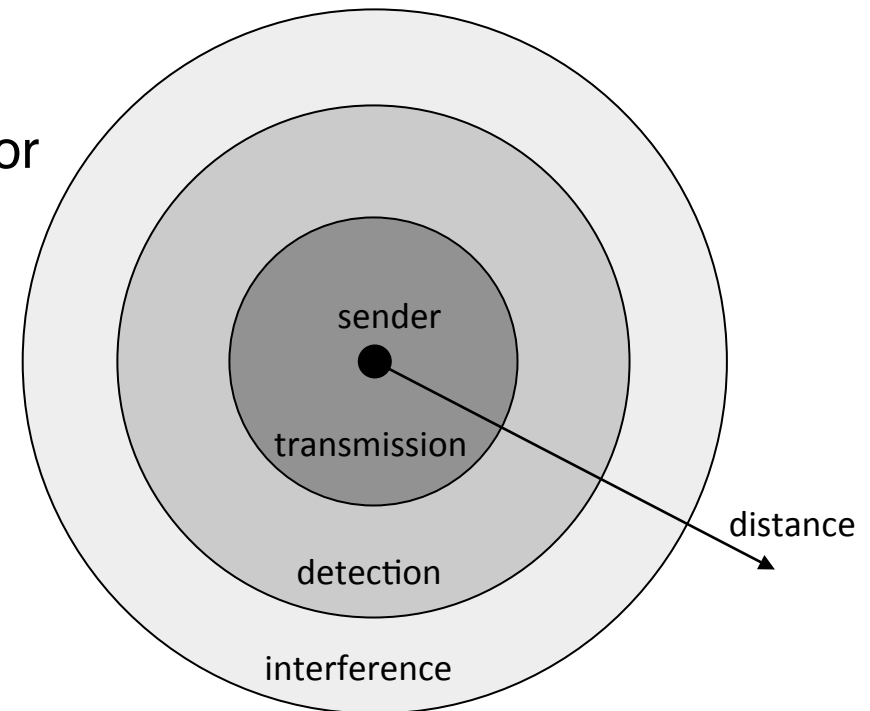
- Radiation and reception of electromagnetic waves, coupling of wires to space for radio transmission
- Isotropic radiator: equal radiation in all directions (three dimensional)
- only a theoretical reference antenna
- Real antennas always have directive effects (vertically and/or horizontally)



Signal propagation ranges (in theory!)



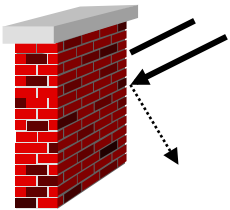
- Transmission range
 - communication possible, low error rate
- Detection range
 - detection of the signal possible, no communication possible
- Interference range
 - signal may not be detected and adds to the background noise



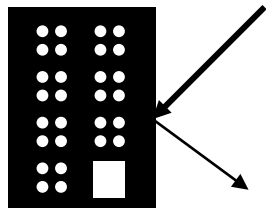
Signal propagation



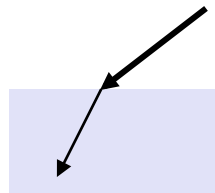
- Propagation in free space always like light (straight line)
- Receiving power proportional to $1/d^2$ in vacuum – much more in real environments
(d = distance between sender and receiver)
- Receiving power additionally influenced by
- fading (frequency dependent)
- shadowing
- reflection at large obstacles
- refraction depending on the density of a medium
- scattering at small obstacles
- diffraction at edges



shadowing



reflection



refraction

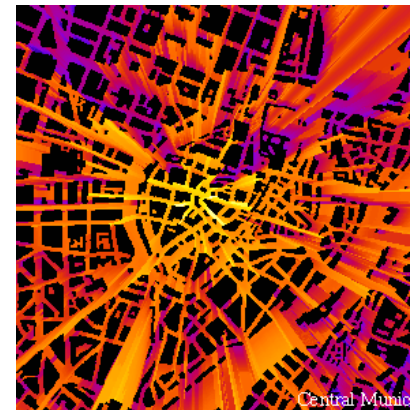
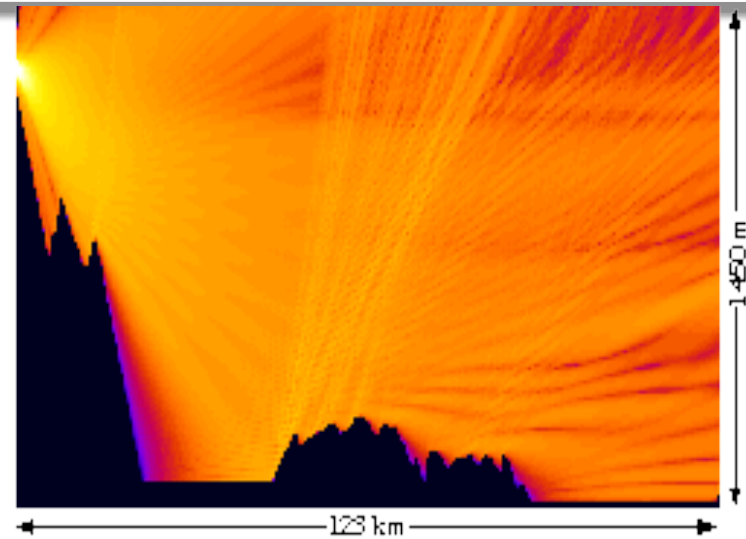
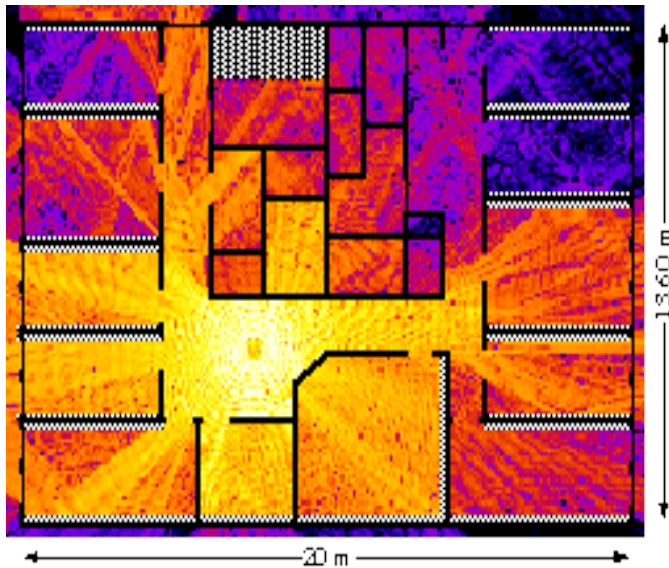


scattering

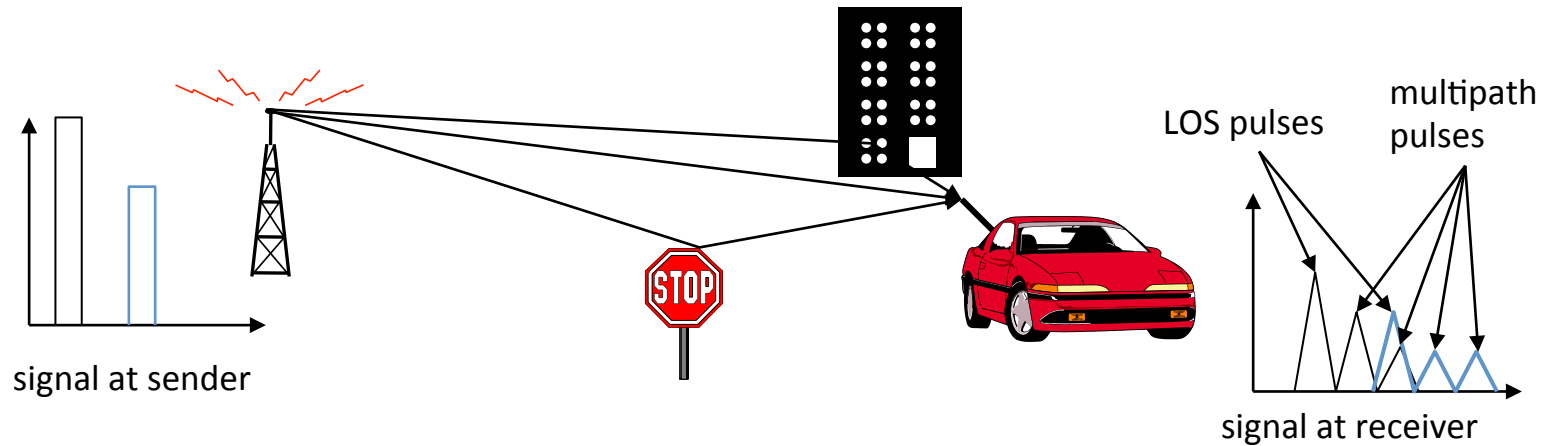


diffraction

Real world example



Multipath propagation

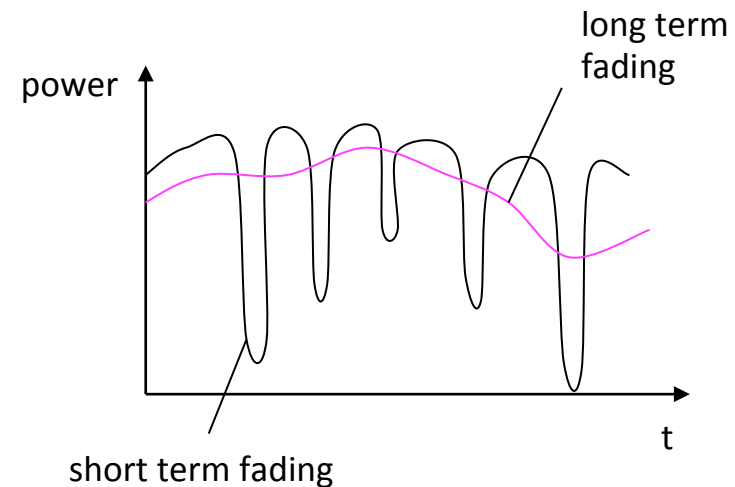


- Signal can take many different paths between sender and receiver due to reflection, scattering, diffraction
- The signal reaches a receiver directly and phase shifted
- Distorted signal depending on the phases of the different parts

Effects of mobility



- Channel characteristics change over time and location
 - signal paths change
 - different delay variations of different signal parts
 - different phases of signal parts
- Quick changes in the power received (short term fading)
- Additional changes in
 - distance to sender
 - obstacles further away
- Slow changes in the average power received (long term fading)



Shared Medium

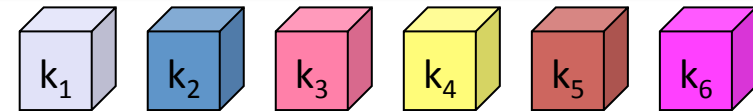


- How is the medium within a certain spectrum band shared about various competing entities who want to communicate?

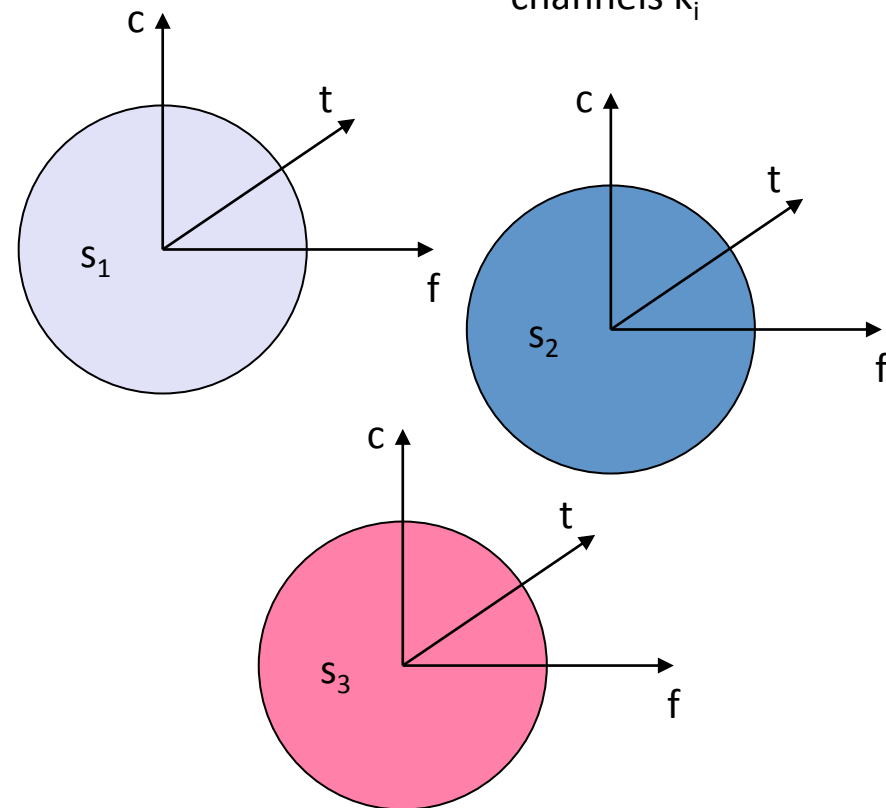
Multiplexing



- Multiplexing in 4 dimensions
 - space (s_i)
 - time (t)
 - frequency (f)
 - code (c)
- Goal: multiple use of a shared medium
- Important: guard spaces needed!



channels k_i



Example of multiplexing: Cell structure

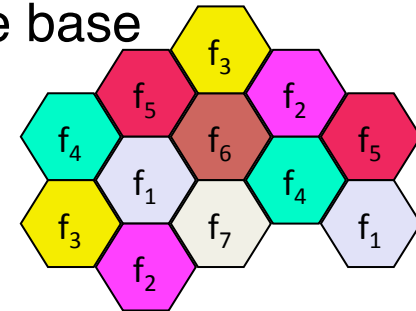


- Implements **space division multiplex**: base station covers a certain transmission area (cell)
- Mobile stations communicate only via the base station
- Advantages of cell structures:
 - higher capacity, higher number of users, less transmission power needed, more robust, decentralized, base station deals with interference, transmission area etc. locally
- Problems: fixed network needed for the base stations, handover (changing from one cell to another) necessary, interference with other cells
- Cell sizes from some 100 m in cities to, e.g., 35 km on the country side (GSM) - even less for higher frequencies

Frequency planning I



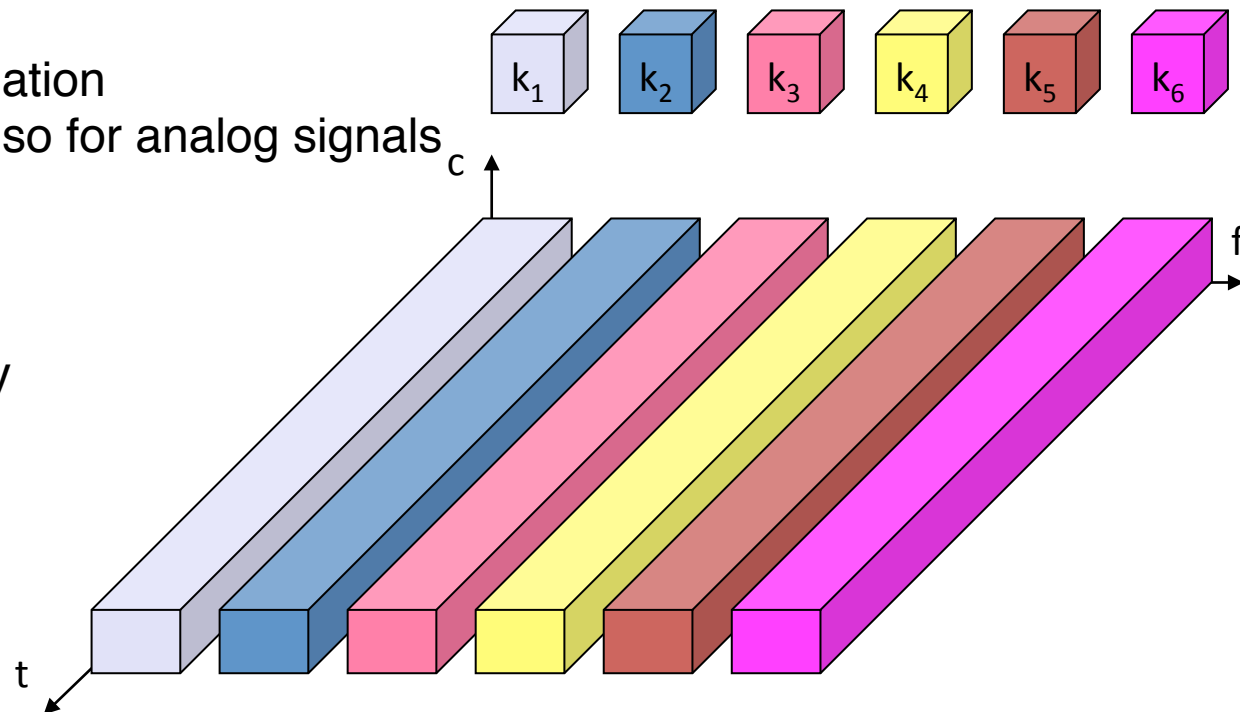
- Frequency reuse only with a certain distance between the base stations
- Standard model using 7 frequencies:
- Fixed frequency assignment:
 - certain frequencies are assigned to a certain cell
 - problem: different traffic load in different cells
- Dynamic frequency assignment:
 - base station chooses frequencies depending on the frequencies already used in neighbour cells
 - more capacity in cells with more traffic
 - assignment can also be based on interference measurements



Frequency multiplex



- Separation of the whole spectrum into smaller frequency bands
- A channel gets a certain band of the spectrum for the whole time
- Advantages:
 - no dynamic coordination necessary, works also for analog signals
- Disadvantages:
 - waste of bandwidth if the traffic is distributed unevenly
 - inflexible
 - guard spaces



GSM

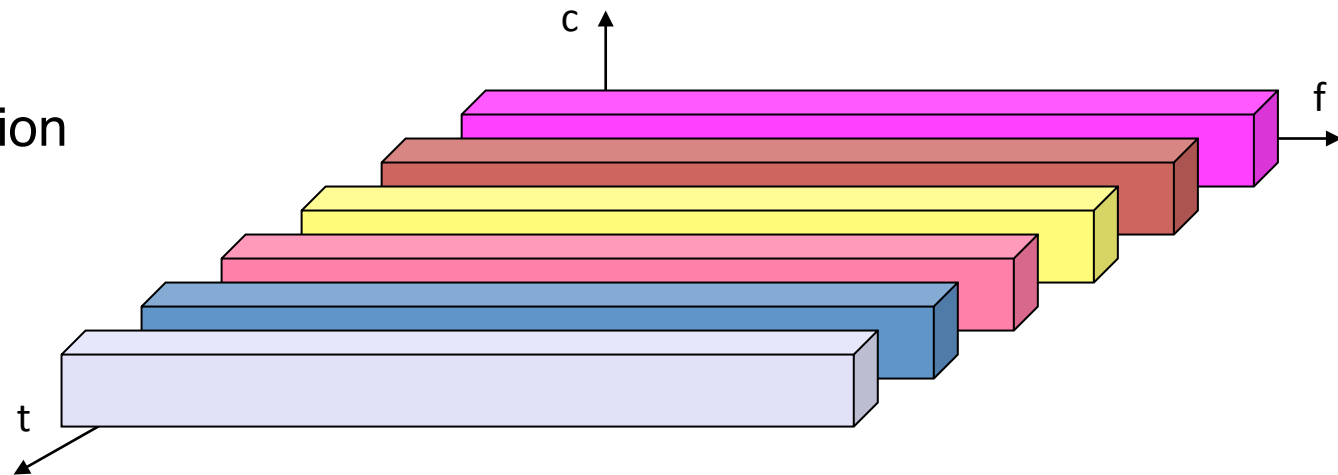
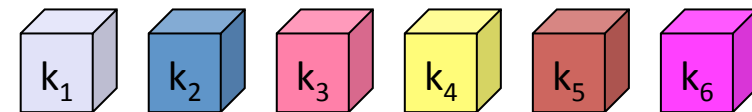


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- GSM uses FDM
 - A duplex channel for each mobile station and base station couple:
 - Uplink channels use a frequency band and downlink channel another one.
 - Each MS is associated to a pair of uplink/downlink channel

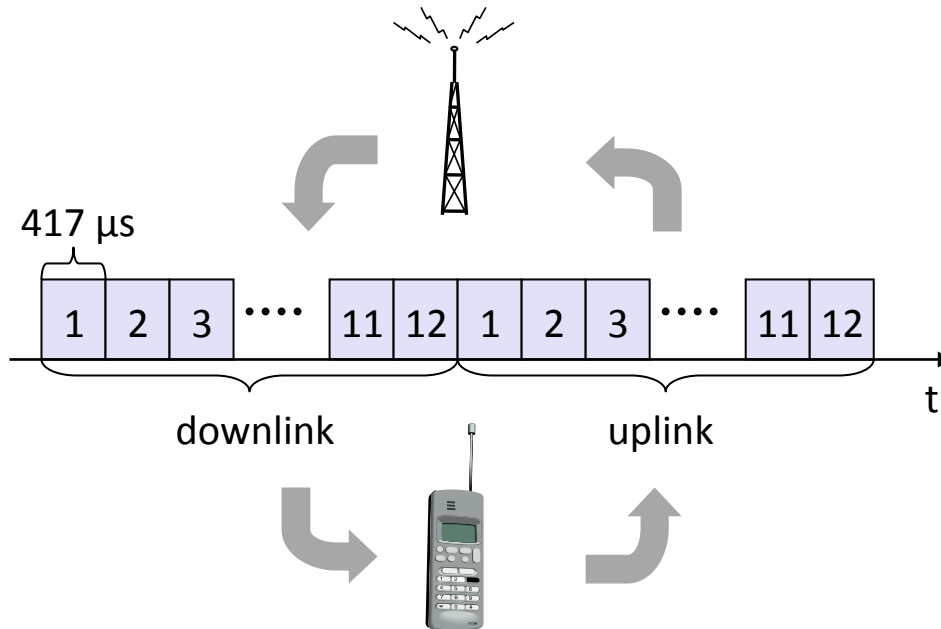
Time multiplex



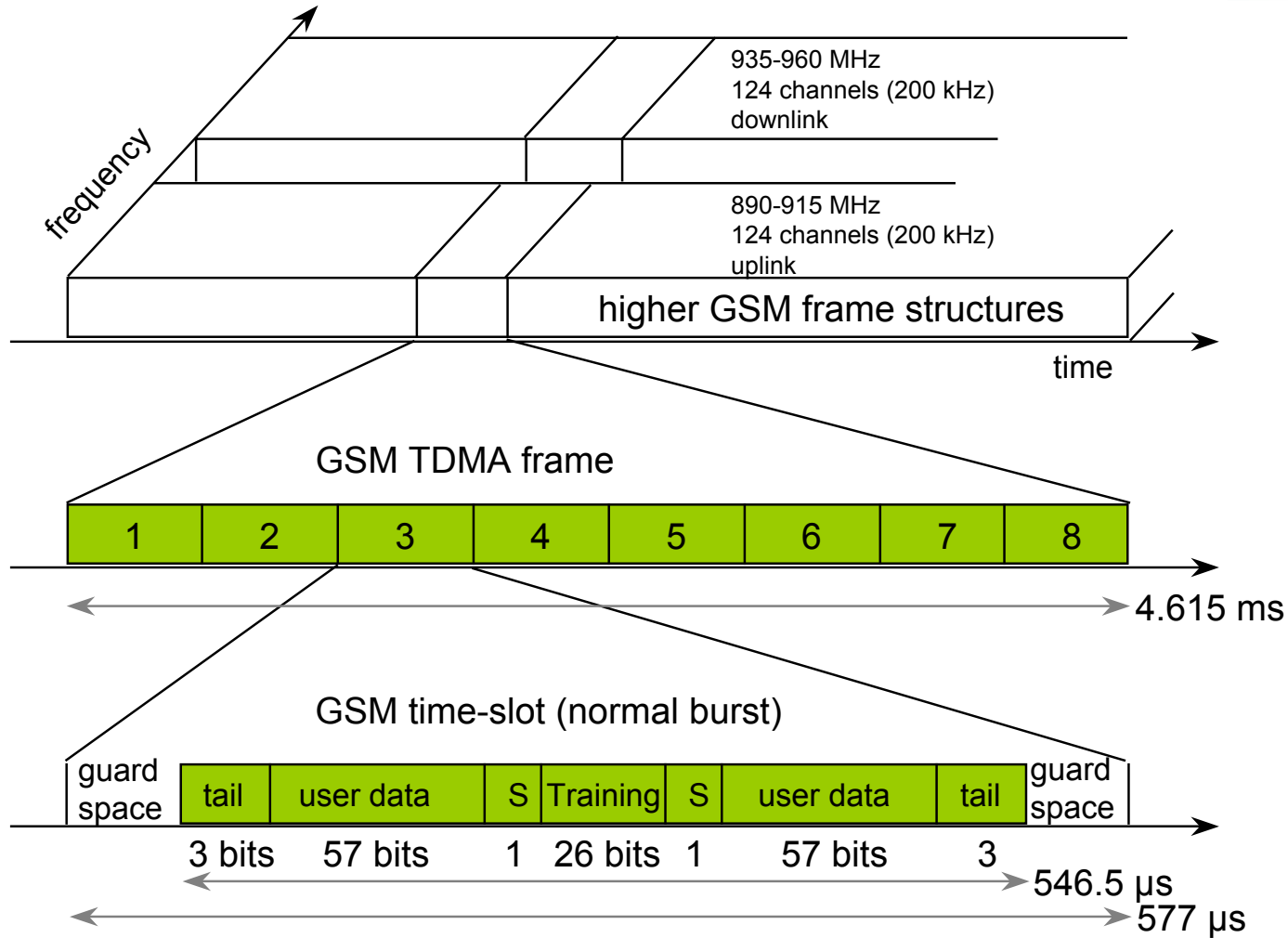
- A channel gets the whole spectrum for a certain amount of time
- Advantages:
 - only one carrier in the medium at any time
 - throughput high even for many users
- Disadvantages:
 - precise synchronization necessary



TDD/TDMA - general scheme



FDM and TDM in GSM



Time and frequency multiplex



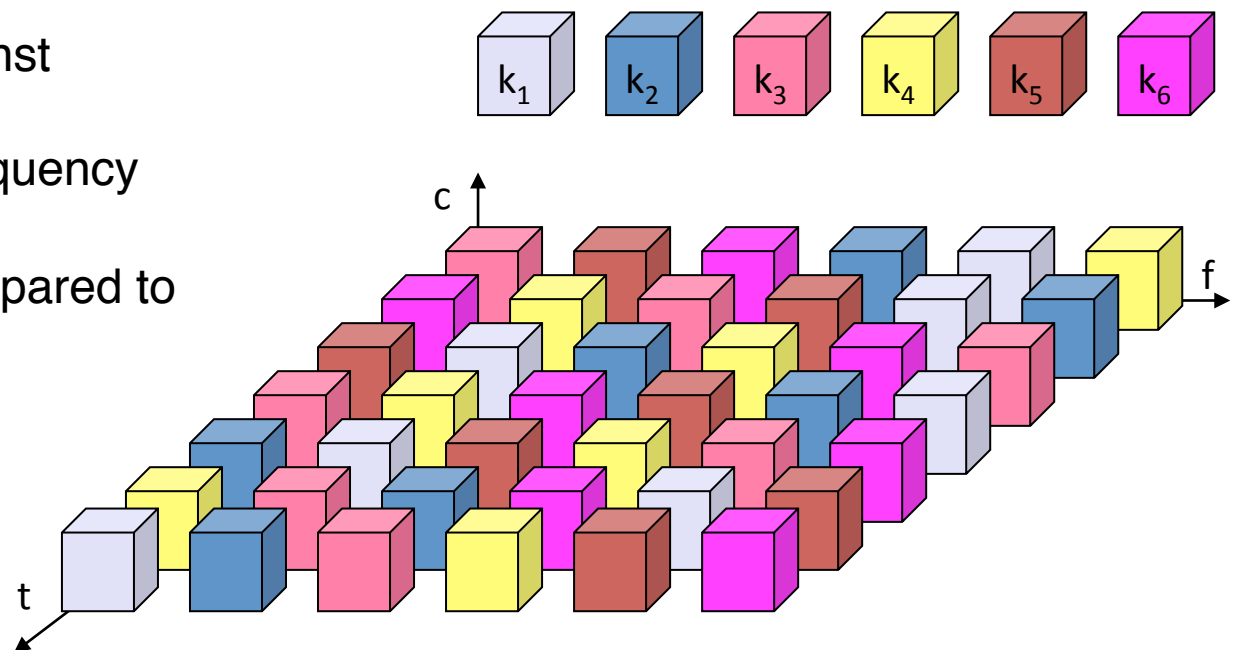
- A channel gets a certain frequency band for a certain amount of time

Example: GSM

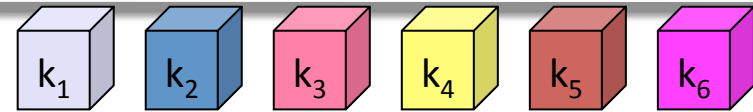
- Advantages:

- better protection against tapping
- protection against frequency selective interference
- higher data rates compared to code multiplex

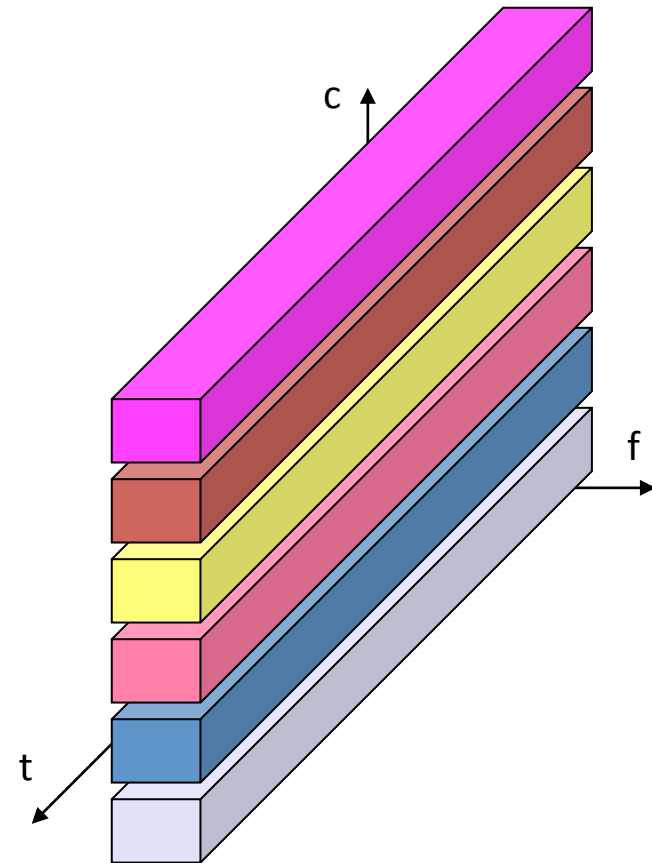
- but: precise coordination required



Code multiplex



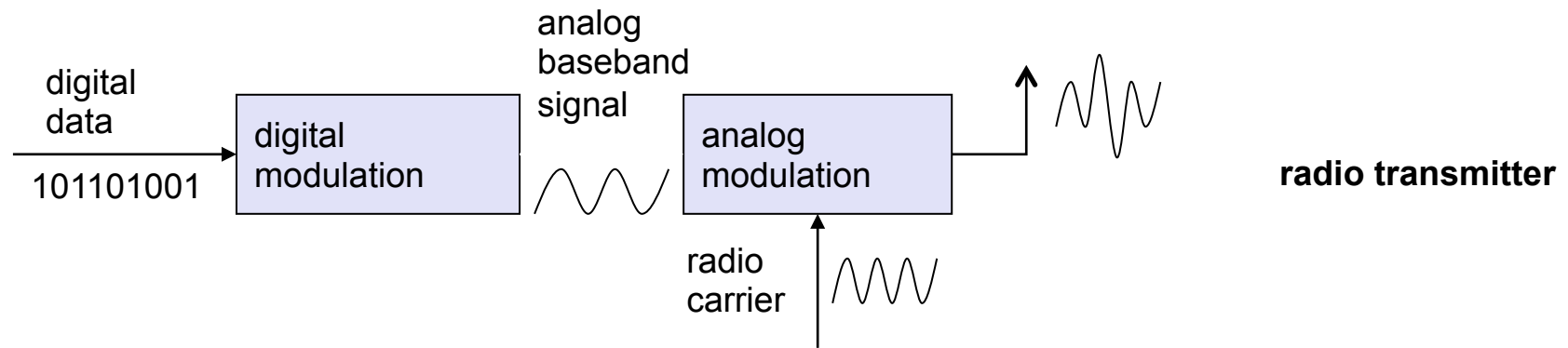
- Each channel has a unique code
- All channels use the same spectrum at the same time
- Advantages:
 - bandwidth efficient, no coordination and synchronization necessary, good protection against interference and tapping
- Disadvantages:
 - lower user data rates, more complex signal regeneration, Implemented using spread spectrum technology



Modulation



- When a digital signal needs to be transmitted over wireless it needs to be translated into analog.

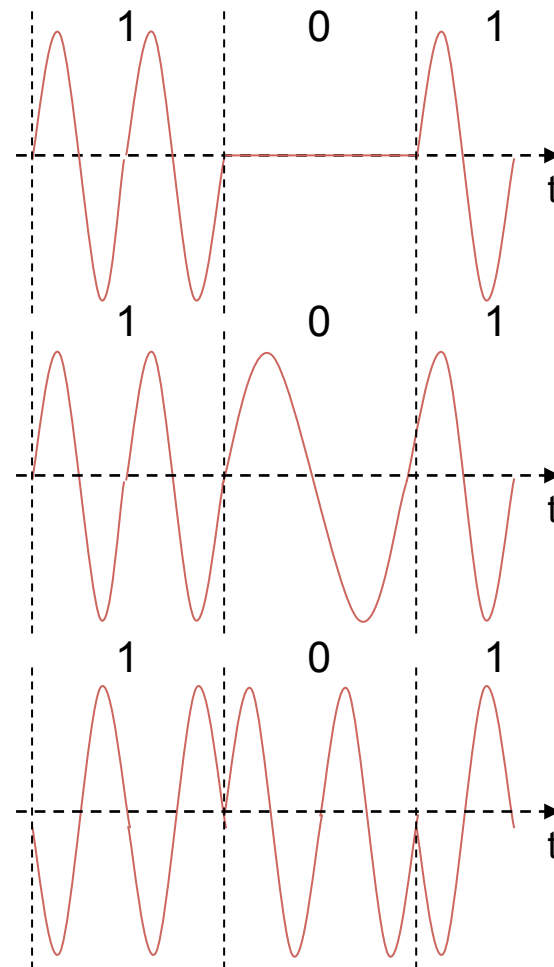


- Basic methods:
 - Amplitude shift keying
 - Frequency shift keying
 - Phase shift keying

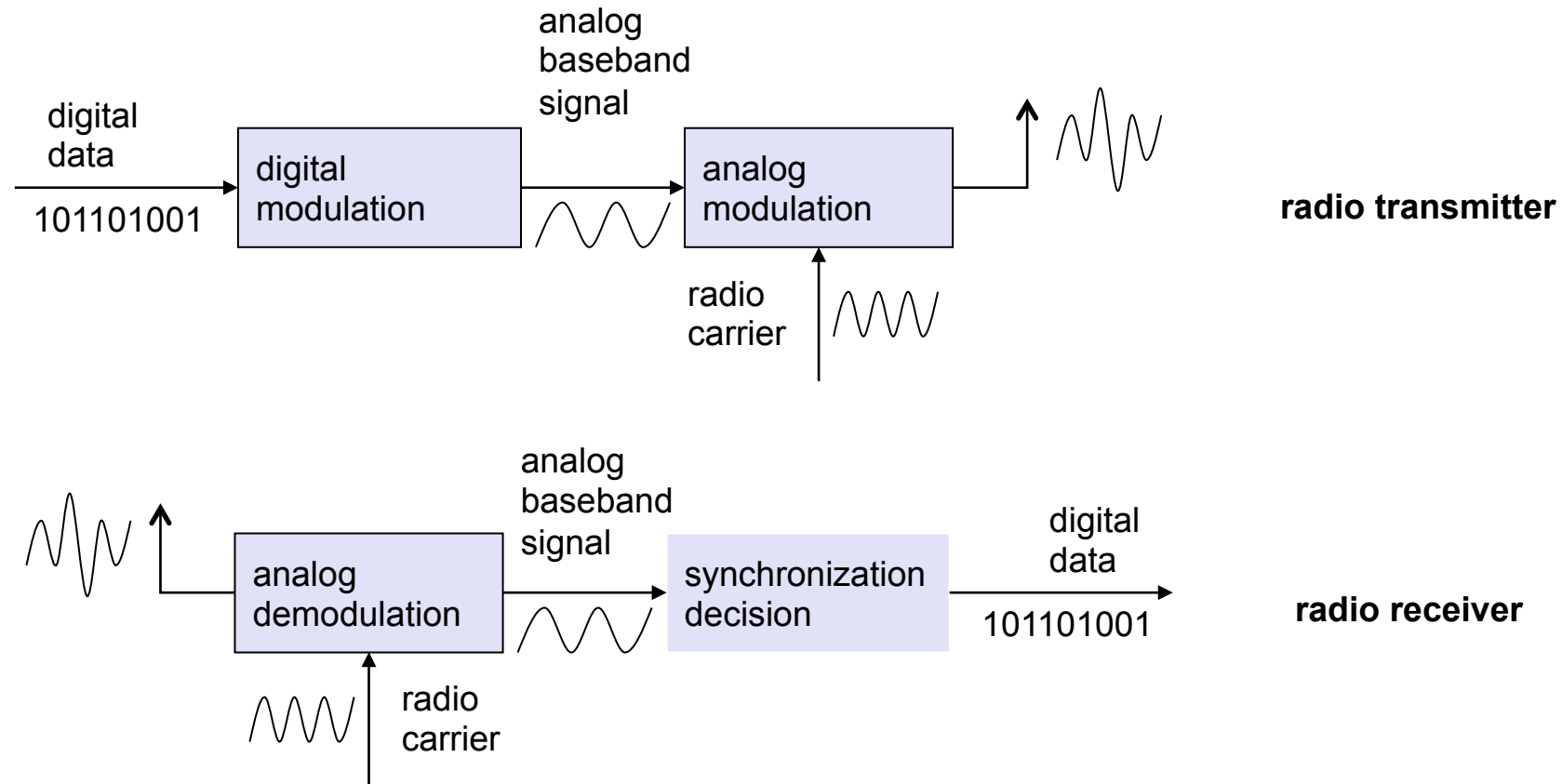
Digital modulation



- Modulation of digital signals known as Shift Keying
- Amplitude Shift Keying (ASK):
 - very simple
 - low bandwidth requirements
 - very susceptible to interference
- Frequency Shift Keying (FSK):
 - Frequency 1 to 1 and frequency 2 to 0
 - needs larger bandwidth
- Phase Shift Keying (PSK):
 - Signal phase is shifted
 - more complex
 - robust against interference



Modulation and demodulation



Summary



- In this lecture we have discussed the issues imposed by the propagation of signal in wireless networks and indicated some solutions
- **Main Reference for Mobile Part:**
J. Schiller. Mobile Communications. Addison Wesley. 2000.

Acknowledgement: some slides have been taken from supporting material associated with the above book.