Mobile communications

This moodle course can be used stand alone as a basic introduction to mobile communication.
It consists of 10 chapters of different depth with respect to the content.
The topics will be explained in the following.

Besides the use as a stand-alone self-paced online resource, the course has been designed to fit in a blended learning concept.
Along with the chapters some ideas for synchronous in class or online sessions as well as simulation experiments or homework assignments are detailed.

Chapter 1 Mobility
Short introduction of different mobility concepts
In-class discussion: which concept comes into mind first when thinking of mobility; which one will be the most important in the future or for a certain scenario

Chapter 2 Level calculation
Short introduction of level calculation

Chapter 3 Radio transmission
Part 1 Introduction of the concept of radio waves, the radio link (directional link, satellite link, mobile link) and first idea of multipath propagation
In-class discussion: which type of link will be useful in which scenario; what are the advantages and disadvantages of different satellite orbits; why isn't satellite telephony a mass market phenomenon
Part 2 Basics of antennas, antenna parameters, isotropic radiator, field regions, radiation density, normalized antenna pattern, directivity, gain, ideal dipole, effective aperture
In-class discussion: which characteristic may be suited for different scenarios; which antenna to use in a mobile, which to use in a base station, an earth station, a satellite; what is easier to measure: antenna input or output
Part 3 Introduction of link budget calculation and different standards
Part 4 Introduction of the mobile channel with multipath propagation and Doppler effect, free-space loss, calculation of impulse responses, introduction of propagation models
In-class discussion: what is the minimum of physical effects to take into account with respect to losses; how to decide which model to choose; how to get the parameters needed for a specific model

For chapter 3 some simulation exercises can be included.
One example in German (Mobilfunkkanal MFK) can be found here:
https://www.ei.tum.de/lnt/mitarbeiter/lehrbeauftragte/soeder/
You may also program yourself, e.g. MatLab model for a two-ray and a multiple ray model
Students can do some lab experiments getting used in choosing and interpreting models
Simulations may either be developed in a group exercise or be pre-programmed with a GUI and just used to learn about different models and how their responses, probability density distribution, power spectra etc. look like

Chapter 4 Introduction to frequency and code planning, hexagon model, cluster, carrier-to-interference, spreading and scrambling codes
In-class discussion: how useful is a hexagon model for real-life planning; which problems may occur in single frequency networks; what potential harm do scrambling codes cause

Chapter 5 Introduction of network architecture, based on GSM and UMTS, further explained for LTE and 5G which have fewer elements with more integrated functions

In-Class discussion: which features and components should be network specific; which parts of the network should be interoperable and able to deal with different systems; which interfaces are mandatory, which are optional, what do they simplfy

Chapter 6 Introduction to radio network planning and the use of modern planning tools
In-class activity: there is also an introduction to radio mobile, a publicly available planning tool
http://www.ve2dbe.com/english1.html
Radio mobile can be used for group work in class or at home, it can also be used as a tool for an homework assignment where each student is assigned a different planning area but all may work on the same tasks with respect to their individual region

Chapter 7 Introduction to basic network functions as location update, call setup, mobile originated and terminated call, handover, and call completion for different networks
In-class discussion: what are basic building blocks for the different protocols; how do the components from chapter 5 interact; what could be simplified if cross layer communication will be implemented

Chapter 8 Basic security aspects, especially authentication, authorization, and privacy
In-class discussion: what is the level of security in each system; which interfaces are protected against which attacks; how can a handover be made more secure

Chapter 9 Very short introduction to performance aspects

Chapter 10 Introduction to the concept of channel coding, automatic repeat request, forward error correction, basics of coding theory, block codes, parity check codes, convolutional codes, different diagrams to visualize codes, concatenated codes, interleaving
In-class discussion: what are advantages and drawbacks of ARQ and FEC, of using channel coding; how to cipher and decipher, designing codes and see how the work (this can be done be programming or using pre-programmed codes with different noise levels)

Example concept

Week	**Digital content**	**In-class** (other than described above)
1	Chapter 1, 2, 3-1	relate course to other courses in the study program assess prior knowledge prerequisites for the exam
2	Chapter 3-2	Lab-Experiment or demonstration with antennas Discussion of physical aspects
3	Chapter 3-3, 3-4	Discussion of mobility models and their choice
4 - 6	*Optional Lab – Specific documents for preparation*	*Lab, e.g. simulation of models, discussion of results* *The laboratory may need to take place in smaller groups and therefore may be planned in three weeks with only a third of the students in each week, then it may be in parallel to the homework assignments, so students acn use the time in the weeks when the have no lab*
7	Chapter 4	Group work: frequency planning, each group with a different scenario, discussion of approaches and results
8	Chapter 5	Students may prepare small reports of specific aspects of the different systems that are not detailed in the lecture notes
9	Chapter 6, Radio Mobile	Introduction to the program, getting used with small examples, preparation for the homework assignment
10	Chapter 7	Develop a specialized protocol for a certain feature, discuss what needs to be includes and what can be omitted
11	Chapter 8	What other aspects of security may be important today, how to protect the backbone network, what can the users do themselves to enhance security
12	Chapter 9, 10	Option for in depth discussion: provide additional simulation program or programming task
13		How to use the competences in relation to other topics, how do they relate to other concepts
14		*Exam preparation*
15		*Exam*

Notes from the design phase of the module:

Module Handbook:
Students gain knowledge about basics in radio propagation and antennas. They can describe the most important antenna parameters and can explain the physics behind the definition. Students can describe the physical effects in mobile channels and how they can be modeled. They can choose and use appropriate channel models for different scenarios. Students gain basic knowledge of mobile network planning and ate able to plan a full coverage network with the help of a planning tool. They can describe the mobile network components and the basic network functions as well as the basic security mechanisms.

Categories
gain knowledge:
- radio propagation – logical, psycho motoric
- antennas – logical
- mobile network planning –
- components of networks –
- channel models –

describe:
- antenna parameters – linguistic
- physical effects in mobile channels – spatial

explain:
- network functions
- security

choose:
- appropriate channel models

plan:
- a full coverage network with a tool – psycho motoric

Central questions:
Inquiry:
- what is the structure of propagation
- what are the causes of attenuation
- what is the mechanism of an antenna

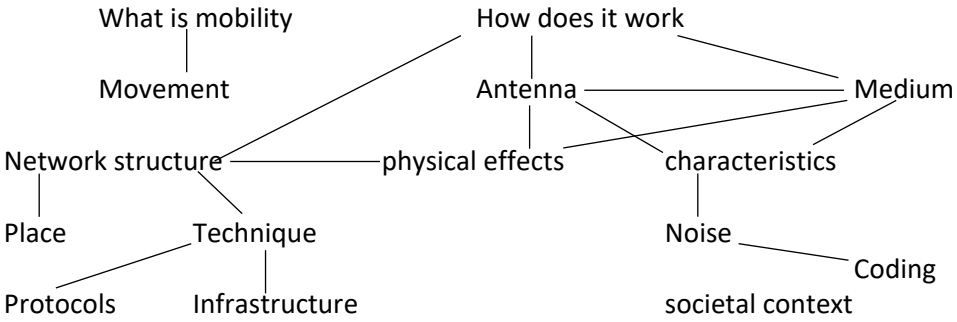
problem:
- how can an area be covered
- how can we provide safe and secure communication

Additional intended learning outcomes:
- What additional effects has mobility? The student should be able to reflect on different uses of mobility compared to fixed line communications and its impact on the planning of his/her day.
- How does mobile communication change societies? The students should be able to describe what impact mobile communication has in their daily life and how it works in the interaction with others.

Problem:
- Mobility and reception

Solution:

TEM waves	disadvantage	advantage
Analog	no parallel use	independence, basic signal
Digital	loss of accuracy	more efficient



First draft:
Introduction
History
Cellular networks
- Propagation -> physical effects, antenna
- Attenuation -> physical effects, free-space attenuation
- Multipath -> physical effects, obstacles
- Doppler -> physical effects, speed, direction
- Models including Rayleigh and Rice distribution
- Scarcity of frequency
- Mobility

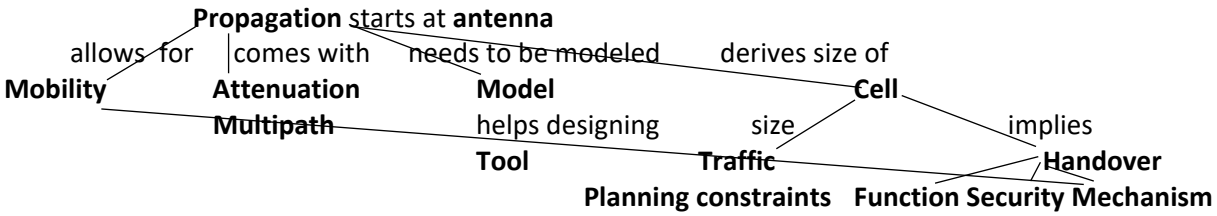
Network layout
- Hexagon model
- Sectorization
- Overlay
  - Network planning
  - Quality parameters
    - Latency
    - Security
    - Availability
    - Co-existence
    - Throughput

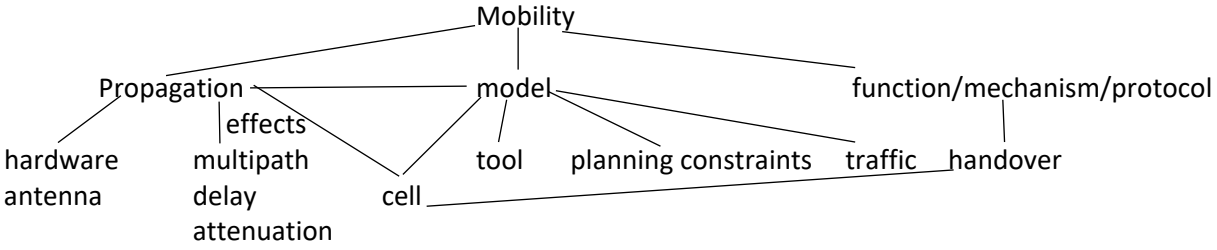
Mobility
- Handover

Capacity
- Traffic theory
- Multiple access schemes

-> Problems of noise, modulation (review from other module)
-> coding and interleaving
Systems
- GSM
- UMTS
- LTE, LTE-A
- 5G
- For further discussion, not detailed in lecture notes:
  - DECT, Bluetooth, IEEE 802.11, ZigBee,TETRA
- -> channel allocation and structure
- -> architecture,
- -> procedures/algorithms (authentication and mobility management)
- -> indoor requirements

Terminology: Propagation – antenna – mobility – model – tool – function – mechanism – security – planning constraints – system – multipath – cell – attenuation – handover – traffic





Story

Transmission is the underlying concept for the transfer of data / information. On recent decades technically supported communication started to be more and more mobile, i.e. independent from certain locations where transceivers have been available. To cope with mobility, the classical means of transmission and their description has to be broadened and extended to radio transmission to and from moving devices. Therefore, the classical models have to be extended / suited. This will lead to the introduction of statistics and probability into these models. The communication systems themselves have to be enriched with protocols and mechanisms to cope with the mobility and the unknown whereabouts of the devices. This lecture will provide the theoretical background of mobile communications and apply this to a hands-on experience of basic network planning.

Radio propagation –	transfer cable <-> air –	cell
Power law	antenna	impact on coverage
Multipath	description	constraints for planning
Attenuation		use of tools for cell planning
Appropriate model		backhaul planning
		Components for network interaction / protocols

Course rationale

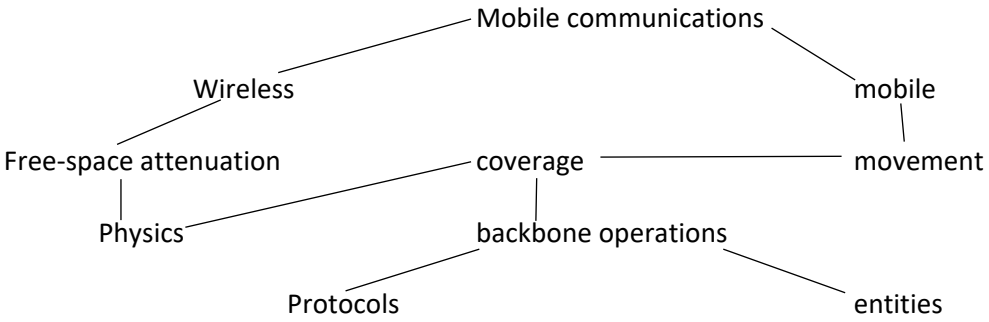
We all are used to mobile communication, anywhere at any time. This course will enable you to plan a wireless network and choose appropriate components. You will also gain knowledge in the interactions needed inside the network to deliver and transport data.

Students may be seen as a part if the workforce, as well as consuming the relevant services. They should be able to get the concept of mobile communication and its implementation. Understanding this will help to develop a critical view with respect to the use if wireless communication in society.

Cognition

Mobile communication is wireless communication with moving participants. Wireless communication uses the air as medium, therefore, it needs antennas to deliver and receive data from cable to air and vice versa. Air has a free-space attenuation like attenuation in cables, this does not depend on the material coefficients but the spatial dissemination of energy.

Mobile users can be anywhere, therefore, not only certain spots (as with cables) have to be covered. Thus, we need transmit stations instead of wall outlets. The stations need to be placed with respect to the coverage resulting from free-space loss and topology. The planning process is complex and will therefore be aided by tools. We need to provide the correct parameters to these tools. As we have so many points of contact, we need to provide special entities and protocol to the system to deal with mobility.



Scope

Introduction – overview - physics

a) Type of network: impact of mobility, impact on daily life
b) Antenna: parameters, physics, use of tool
c) Propagation: physics, causes, use of tool, models, derivation
d) Network components: name, function, evolution of systems
e) Network functions: basic functions, components involved, security

1) Introduction a) Impact of mobility
2) Propagation medium / antenna b) describe antenna
3) Propagation air c) describe propagation to derive model
4) Tool b) use of a planning tool
5) Backbone d) entities needed, evolution of components
6) Interworking of components e) how do entities interact
7) Security d-e) security

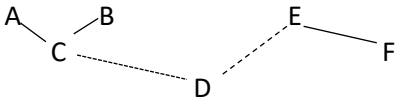
1) Demonstrate the impact of the type of network and build a base why the following is needed
2) To be able to intentionally send TEM waves and limit their unintended impact
3) Understand the constraints of air as a medium and the environment, how does the wave behave on its way from one antenna to another, what is alignment
4) Sum up how to describe propagation and how to make use of it while planning a network
5) Understand the path of the wave and the management needed in the distribution network
6) Interaction of entities and timing constraints

Intended learning outcomes:
The students can

1) describe the physics of radio propagation
   such as free-space attenuation, multipath propagation, and Doppler shift, and
   the impact of the environment (topology etc.)
   classify which of those is the main cause for an observed propagation result
2) name different antenna parameters and
   describe what they and the antenna can be used for and
   describe how they are derived from physical phenomena
3) use a radio propagation tool to plan the base station setup for coverage of a given area with
   respect to a given mobile communication standard
   avoid propagation holes as well as over-coverage with respect to health and economics
4) name the components of a network and
   describe their basic functions and interfaces and differences to fixed line networks
5) name some common channel models and
   explain how they have been derived and
   explain in which scenarios they could be used
6) describe the basic functions needed to deliver mobile calls, this includes
   describe which entities are involved
   describe the general order of the protocols
   describe prerequisites and restrictions
7) describe the security features of different communication systems and their evolution and time
   limitations
   rank which of a given set of networks has which grade of security (high – low)
8) reflect different usage scenarios of mobility and
   compare them to fixed-line communications with respect to the impact of their daily life
9) describe what impact mobile communication has on their interaction with others
10) name the main generations of mobile systems and describe their basic parameters and features
11) describe their concept of mobility and how it relates to their daily life

Units

A1) antenna parameters
A2) simple antenna design
B1) free-space attenuation
B2) multipath propagation
B3) Doppler shift
B4) channel models
C1) coverage
D1) introduction of a tool
E1) mobile systems
E2) network components
E3) network interfaces
F1) network functions related to cells
F2) security features
G1) mobility
H1) impact on our lives



B – G - A – C – D – E – F – H
D – C – B – G – A – E – F - H