

Data communication I

Lecture 10 – other types of networks

What else is there?

- Wireless networks
 - WLAN (Wireless LAN)
 - Cellular networks
 - Mobile wireless ad-hoc networks (MANETs)
 - Wireless sensor networks
- Optical networks
- Vehicular networks
- Real-time networks

Wireless networks

■ Advantages

- No wires
 - Lower cost
 - Mobility!!!

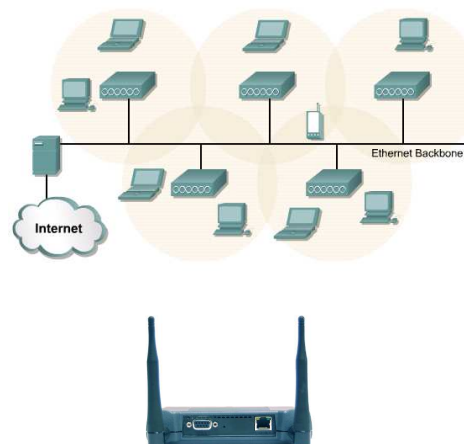
■ Drawbacks

- No wires
 - Higher bit error rates
 - Lower reliability
 - Lower data rates
- Battery lifetime might be an issue
- Mobility puts new demands on protocols
 - (e.g. to handle scalability and constantly changing topologies)

WLAN application areas

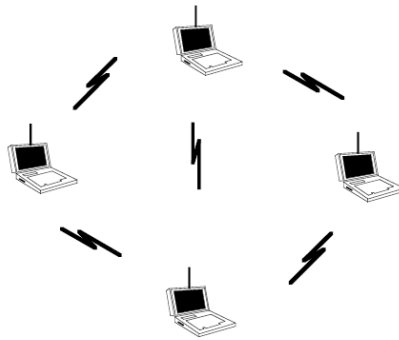
■ Nomadic access

- Backbone wired LAN (e.g. Ethernet)
 - Supports servers, networking devices etc.
- Mobile hosts (e.g. laptops) connect to the wired network through an access point



WLAN application areas

- Ad-hoc networking
 - Decentralized, peer-to-peer network
 - E.g. building a temporary wireless ad-hoc network of laptops for a business meeting

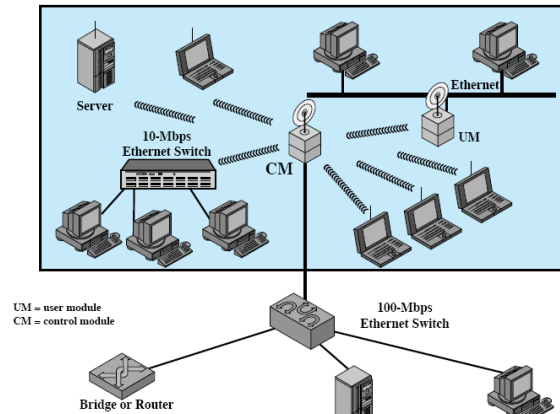


WLAN application areas

- LAN extensions
 - Backbone wired LAN (e.g. Ethernet)
 - Supports servers, networking devices etc.
 - WLAN attaches to backbone through access point
 - Router or switch/bridge functionality
 - Use e.g. to
 - connect the wireless control system of a factory floor to the company network
 - Interconnect LANs in buildings with large open areas where wiring is not feasible

WLAN application areas

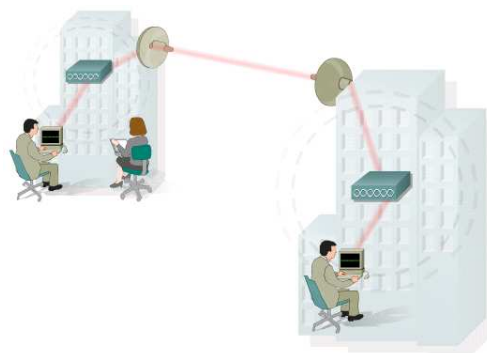
■ LAN extensions



WLAN application areas

■ Cross building interconnects

- Point-to-point wireless link
- Connecting devices have router or switch/bridge functionality



General requirements on WLANs

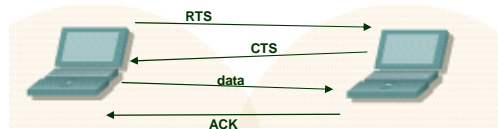
- Scalability
 - Support possibly hundreds of nodes
- Service area
 - Typically 100-300 m
- Power consumption is an issue for protocol designers
- Transmission robustness and security
 - Vulnerable to interference
 - Vulnerable to eavesdropping
- Dynamically reconfigurable protocols to handle nodes joining or leaving the network
- Handoff and roaming
 - Search for new access point when signal strength falls under threshold
 - Support seamless connection to new access point

The IEEE 802.11 protocol suit

- Part of the LAN protocol family (IEEE 802.x)
- Defines layer 1 and 2 protocols
- Two types of physical layer
 - Spread spectrum
 - Infrared
- Data link layer
 - Reliable data delivery
 - Medium Access Control

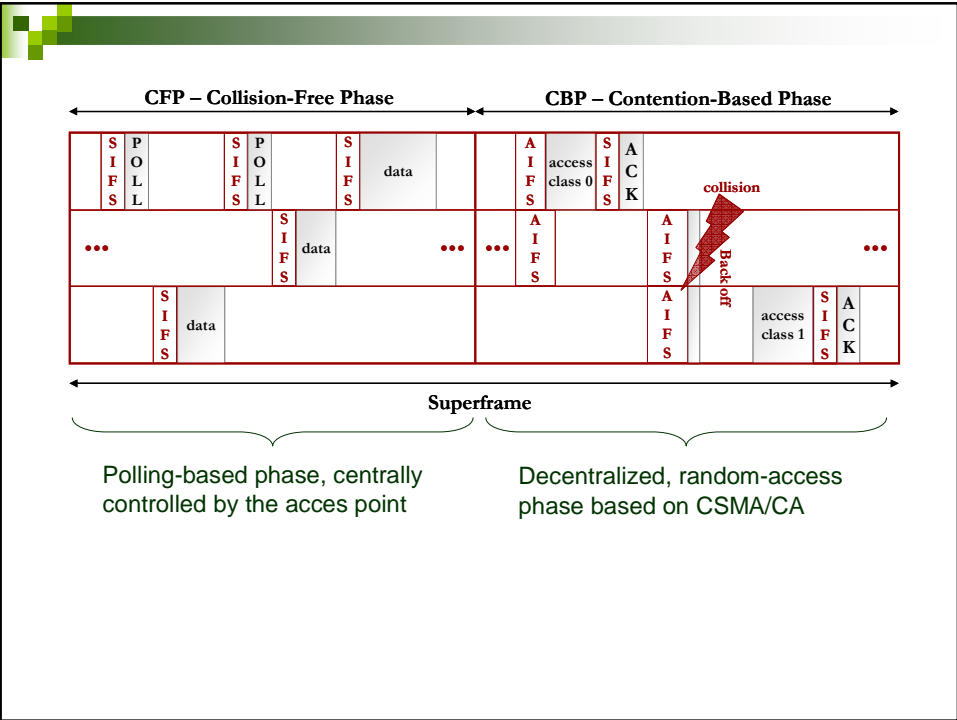
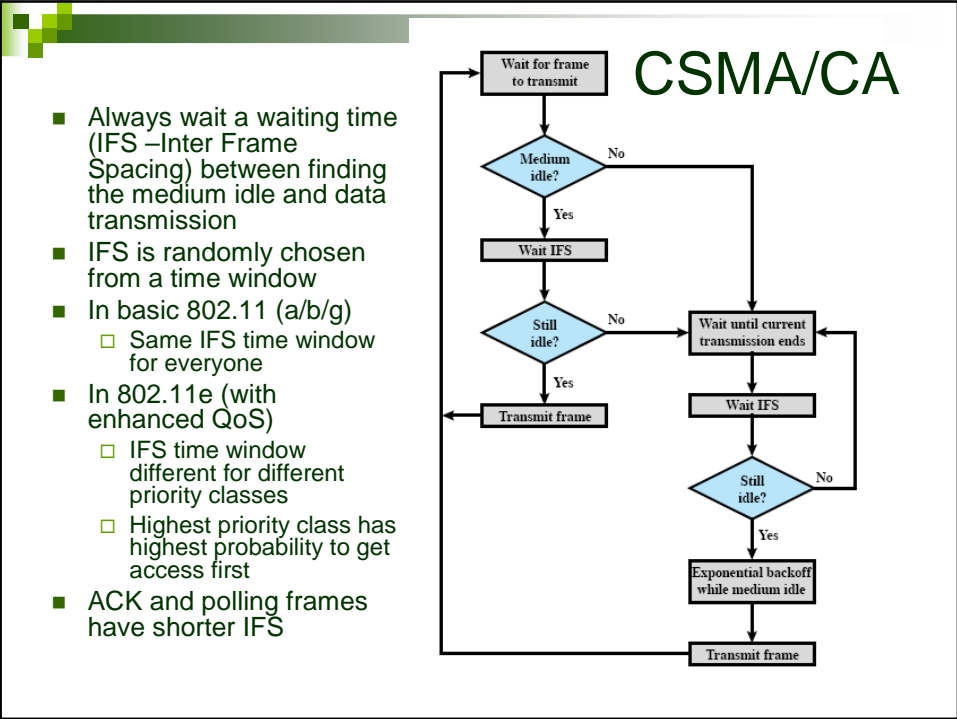
Reliable data delivery in WLAN

- Wireless channel always noisy and unreliable
- Solution:
 - ACK sent for each received frame
 - Until ACK is delivered, no other data transfer is allowed ("data-ACK-pairs") until time-out
 - Four-frame exchange
 - Ready-to-send (RTS) → clear-to-send (CTS) → data → ACK

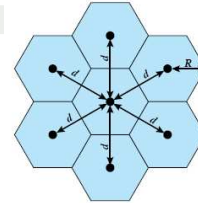


Medium Access Control in WLAN

- 2 MAC phases defined
 - Distributed coordination function (DCF)
 - Decentralized
 - Based on CSMA/CA
 - Point coordination function (PCF)
 - Centralized
 - Based on polling from the access point



Cellular networks



- Long-range wireless communication
 - E.g. mobile phones
- Cellular organization
 - Each cell has a base station using multiple low-power transmitters
 - Each cell is assigned a couple of frequency channels

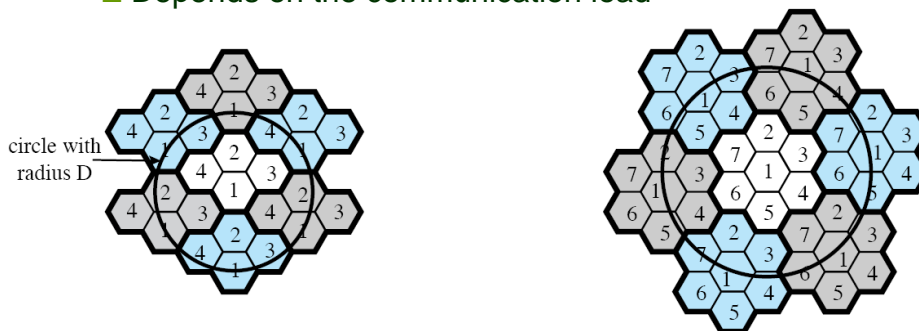
Frequency reuse

- Output power is limited so that the base station covers its cell
- but the signal should not disturb the communication within neighboring cells
- Is that possible?
 - Not really. Signal strength decreases with distance from base station, but will still be strong enough to interfere with neighboring base stations
- What to do?
 - Use different frequency band to communicate in neighboring cells
 - Reuse the same frequency band first in a cell that is far away

Frequency reuse

- Frequency division

- Not one, but up to 50 different frequency channels per cell
- Depends on the communication load



Cellular networks

- 2 types of channels between mobile node and base station

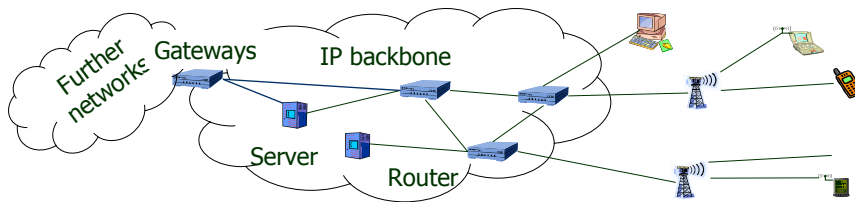
- Control channel for setting up and maintaining calls
- Data channel to carry (voice) data

- Handoff/handover

- Mobile node leaves cell during a call
- New base station is determined and takes over the call without interruption for the caller

Infrastructure-based wireless networks

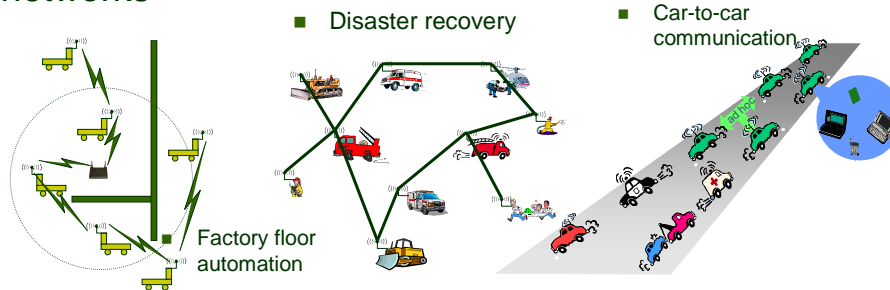
- Typical wireless network: Based on infrastructure
 - Access points connected to a wired backbone network
 - Mobile entities communicate wirelessly to these access points
 - Traffic between different mobile entities is relayed by through wired backbone
 - Mobility is supported by switching from one access point to another
 - Backbone infrastructure required for administrative tasks



Infrastructure-based wireless networks – Limits?

- What if ...
 - No infrastructure is available? – E.g., in disaster areas
 - It is too expensive/inconvenient to set up? – E.g., in remote, large construction sites
 - There is no time to set it up? – E.g., in military operations

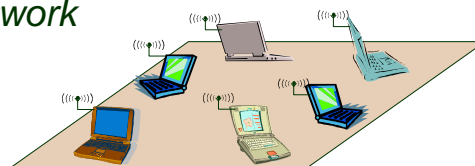
Possible applications for infrastructure-free networks



- Military networking: Tanks, soldiers, ...
 - Finding out empty parking lots in a city, without asking a server
 - Search-and-rescue in an avalanche
 - Personal area networking (watch, glasses, PDA, medical appliance, ...)
- Etc.

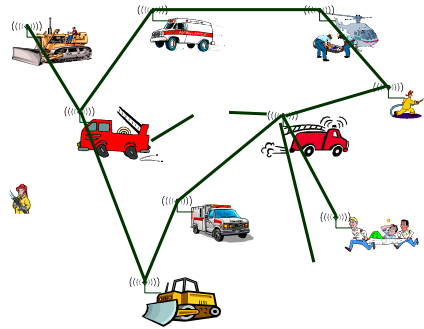
Wireless ad hoc networks

- Simplest example:
 - Laptops in a conference room – *single-hop ad hoc network*
- Possible challenges:
 - Limited power supply
 - Self-organization
 - Mobility
 - Scalability
 - Possibly large numbers of nodes to support
 - Limited transmission range
 - Multi-hop



Mobile ad-hoc networks (MANETs)

- Mobility poses difficult challenges
 - Constantly changing number of nodes, topology, link quality



Wireless Sensor Networks (WSN)

- interacting with environment
 - Network is embedded in environment
 - Nodes in the network are equipped with sensing and actuation to measure/influence environment
 - Nodes process information and communicate it wirelessly

WSN application examples

- Disaster relief operations
 - Drop sensor nodes from an aircraft over a wildfire
 - Each node measures temperature
 - Derive a “temperature map”
- Biodiversity mapping
 - Use sensor nodes to observe wildlife
- Intelligent buildings (or bridges)
 - Reduce energy wastage by proper humidity, ventilation, air conditioning control
 - Needs measurements about room occupancy, temperature, air flow, ...
 - Monitor mechanical stress after earthquakes



WSN application scenarios

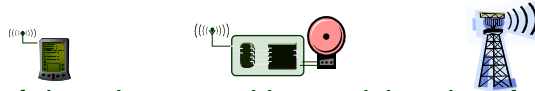
- Facility management
 - Intrusion detection into industrial sites
 - Control of leakages in chemical plants, ...
- Machine surveillance and preventive maintenance
 - Embed sensing/control functions into places no cable has gone before
 - E.g., tire pressure monitoring
- Precision agriculture
 - Bring out fertilizer/pesticides/irrigation only where needed
- Medicine and health care
 - Post-operative or intensive care
 - Long-term surveillance of chronically ill patients or the elderly



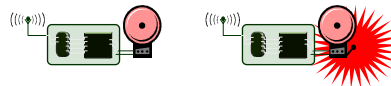
Participants in a WSN



- **Sources** of data: Measure data, report them “somewhere”
 - Typically equip with different kinds of actual sensors



- **Sinks** of data: Interested in receiving data from WSN
 - May be part of the WSN or external entity, PDA, gateway, ...



- **Actuators**: Control some device based on data

Some requirements of WSNs

- Scalability
- Maintainability
- Multi-hop capabilities
- Robustness
- Energy efficiency!!!

Energy aspects of WSNs

- Scavenge energy from available sources (e.g. solar energy)
- Design energy efficient protocols
- To think about:
 - Communication cost huge amounts of energy
 - Both sending and receiving
 - Idle state (listening) cost quite much energy
 - A sensor node in sleep mode draws almost no energy
 - Sleep mode ~ almost completely turned off but able to start up by itself at a given time

Energy-efficient protocol design

- Avoid communication! Avoid idle listening!
 - Protocols with a lot of communication overhead?
 - E.g. many ACKs, a long connection setup procedure, routing protocols with a large amount of routing updates etc.
 - Protocols that actively produce unnecessary data?
 - E.g., random access MAC protocols with many data collisions and retrails, insufficient error correction mechanisms, routing protocols with unnecessary flooding etc.

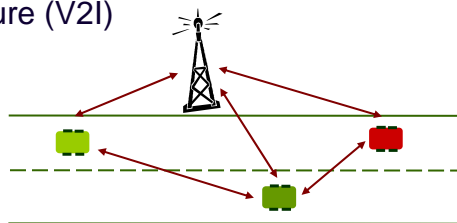
Some solutions

- Let the nodes sleep as much as possible
 - Wake up to synchronize, send or receive from time to time
 - Wake up according to predefined schedule
- Georouting
 - Flood only limited geographical areas where you know that the data is needed
- Have a second, low-power transmitter-receiver pair that listens for data traffic and wakes up the sensor node when necessary
- Data aggregation/fusion
 - If several nodes detected the same phenomenon, only forward one copy to the sink
 - Process data early in the network and only send on the result instead of all the indata
- Consider the power level of individual nodes when assigning them tasks

Vehicular networks

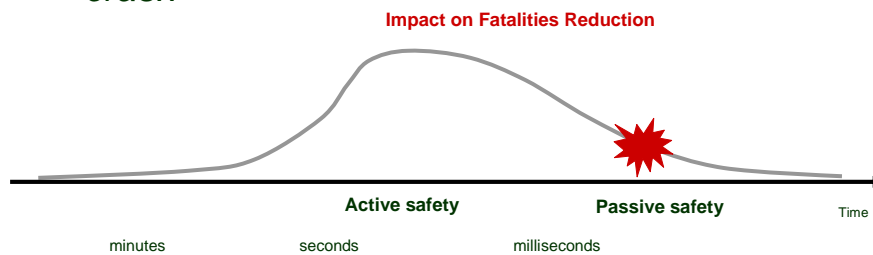
Inter-vehicle communication

- Vehicle-to-vehicle (V2V)
- Vehicle-to-Infrastructure (V2I)
 - Road Side Unit (RSU)
 - Static or semi-static
 - Sparsely spaced



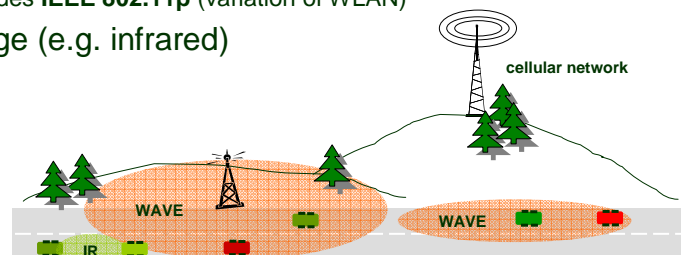
Potential of vehicular networks

- **Active safety:** *Prevention of accident or reduction of its impact before the crash*
- **Passive safety:** *Reduction of impact during the crash*



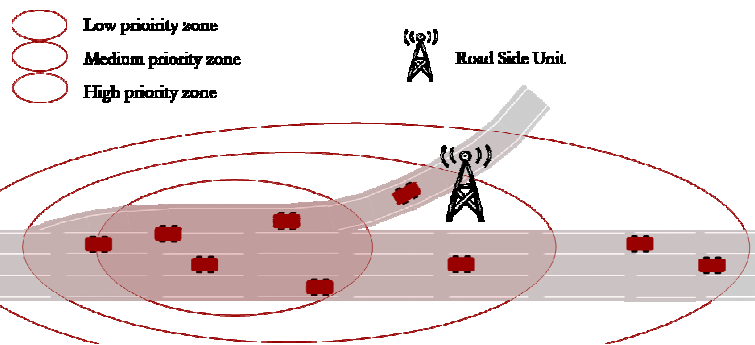
Wireless communication technologies

- Long range (e.g. cellular network)
- **Medium range**
 - Transmission radius: ~ 300-500 m
 - Dedicated frequency band (5.9 GHz range)
 - WAVE (Wireless Access for Vehicular Environments)
 - Standardized by IEEE
 - Includes **IEEE 802.11p** (variation of WLAN)
- Short range (e.g. infrared)



802.11p with position-based priorities

A vehicle's position (relative the "zone of hazard") determines period and deadline of its safety-critical data packets
→ "Shift" bandwidth from where its is not essential to where it is vital



Optical communication

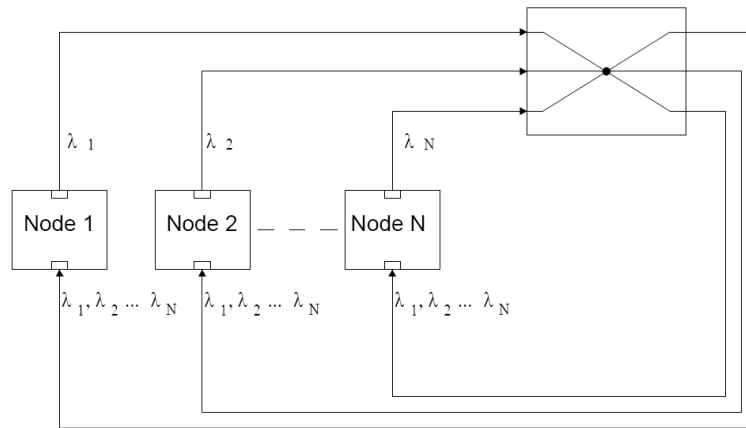


■ Optical switching

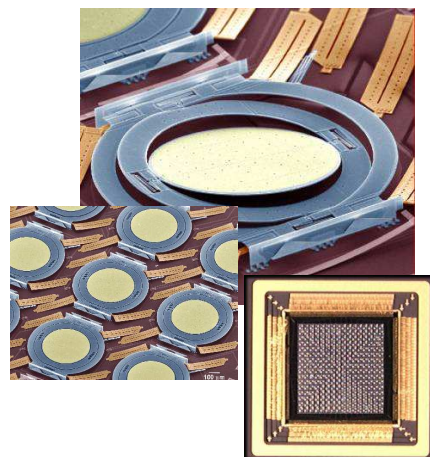
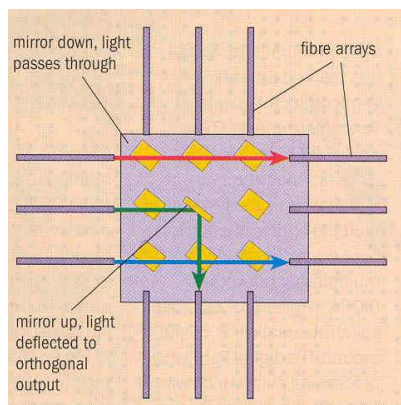
- Example: Passive Star Coupler (PSC)
 - Optical switching based on wavelength
 - Fixed transmitters, tunable receivers
 - Wavelength Division Multiplexing (WDM)
 - Several wavelengths can coexist in the network at the same time
 - Each attached receiver can listen to one transmitter at a time

Optical communication

■ Passive Star Coupler (PSC)



Optical Communication



MEMS – micro electro mechanical systems



Real-time communication

- What if it is absolutely essential that data arrives at its destination before a certain deadline (e.g. a car crash)?
 - Hard real-time requirements
- What if it is desirable but not really vital that data arrives before a certain deadline?
 - Soft real-time requirements
- Adaption needed on almost all communication layers
 - E.g. MAC protocols that guarantee access before a certain point in time
 - E.g. efficient error correction mechanisms so that retransmissions are avoided
 - E.g. routing protocols that guarantee to be up-to date
 - Etc.