Data communication I

Lecture 10 – other types of networks

What else is there?

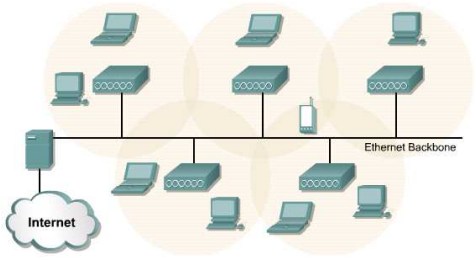
- Wireless networks
  - WLAN (Wireless LAN)
  - Cellular networks
  - Mobile wireless ad-hoc networks (MANETs)
  - Wireless sensor networks
- Optical networks
- Vehicular networks
- Real-time networks

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)

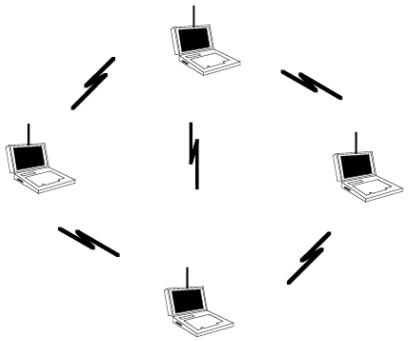
WLAN application areas

- 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

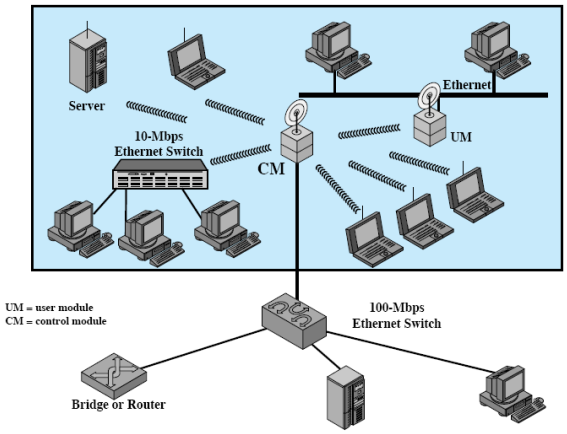


WLAN application areas

- 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

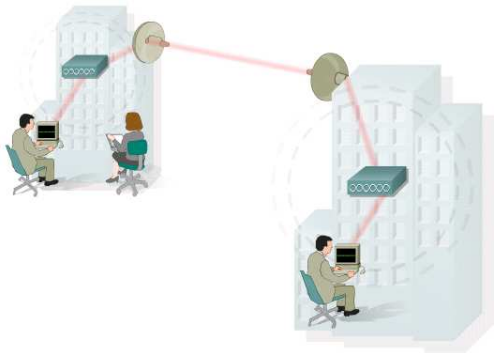
WLAN application areas

- 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

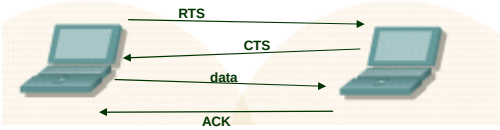
- Scalability
  - Support possibly hundreds of nodes
- Service area
  - Typically 100-300 m
- Power consumption is an issue for protocol designers
- Transmission robustness and security
  - Vulnerable to interference
  - Vulnerable to eavesdropping
- Dynamically reconfigurable protocols to handle nodes 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

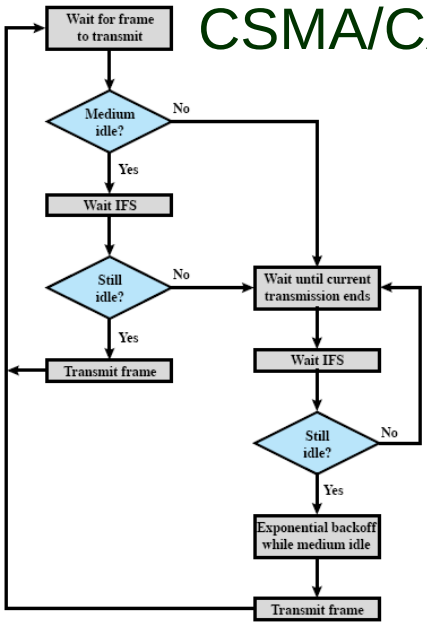


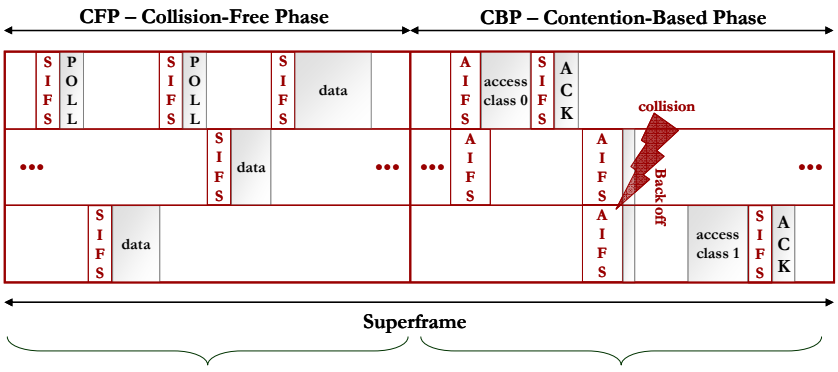
Medium Access Control in WLAN

- 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

CSMA/CA

- Always wait a waiting time (IFS –Inter Frame Spacing) between finding the medium idle and data transmission
- IFS is randomly chosen from a time window
- In basic 802.11 (a/b/g)
  - Same IFS time window for everyone
- In 802.11e (with enhanced QoS)
  - IFS time window different for different priority classes
  - Highest priority class has highest probability to get access first
- ACK and polling frames have shorter IFS

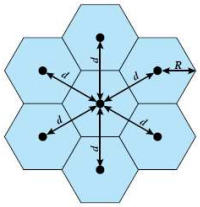




Polling-based phase, centrally controlled by the acces point

Decentralized, random-access phase based on CSMA/CA

Cellular networks



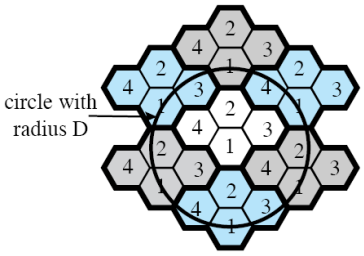
- Long-range wireless communication
  - E.g. mobile phones
- Cellular organization
  - Each cell has a base station using multiple low-power transmitters
  - Each cell is assigned a couple of frequency channels

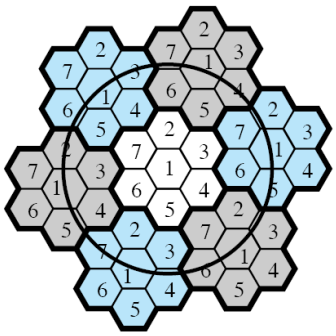
Frequency reuse

- Output power is limited so that the base station covers its cell
- but the signal should not disturbe 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



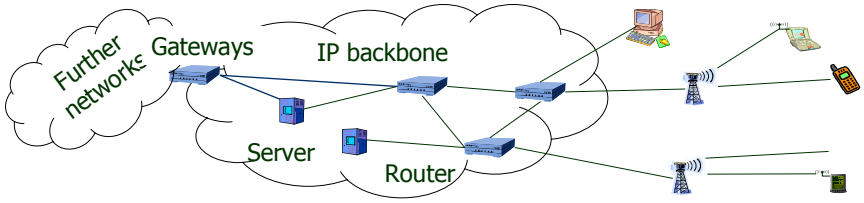


Cellular networks

- 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

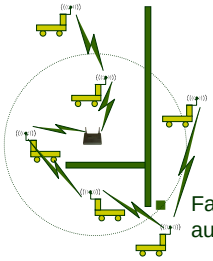
- Typical wireless network: Based on infrastructure
  - Access points connected to a wired backbone network
  - Mobile entities communicate wirelessly to these access points
  - Traffic between different mobile entities is relayed by through wired backbone
  - Mobility is supported by switching from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



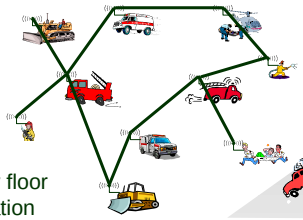
Infrastructure-based wireless networks – Limits?

- 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

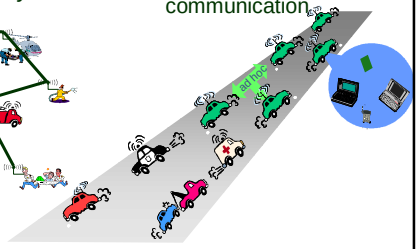
Possible applications for infrastructure-free networks



- Factory floor automation



- Disaster recovery



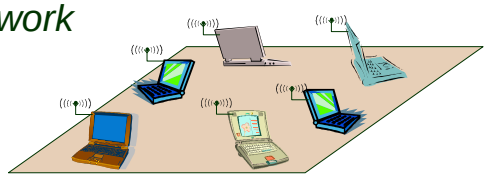
- Car-to-car communication

- 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.

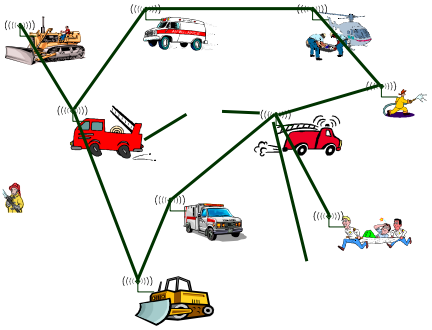
Wireless ad hoc networks

- 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)

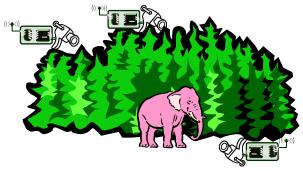
- Mobility poses difficult challanges
  - Constantly changing number of nodes, topology, link quality

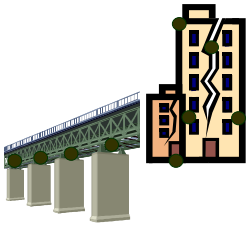


Wireless Sensor Networks (WSN)

- 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



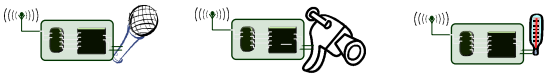


- Disaster relief operations
  - Drop sensor nodes from an aircraft over a wildfire
  - Each node measures temperature
  - Derive a “temperature map”
- Biodiversity mapping
  - Use sensor nodes to observe wildlife
- Intelligent buildings (or bridges)
  - Reduce energy wastage by proper humidity, ventilation,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

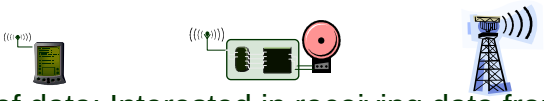
WSN application scenarios

- 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, unsufficient error correction mechanisms, routing protocols with unnecessary flooding etc.

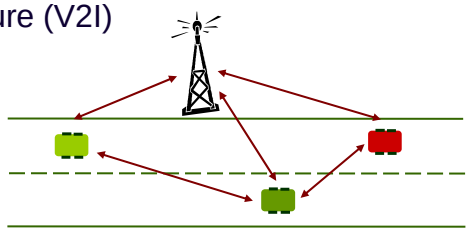
Some solutions

- 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

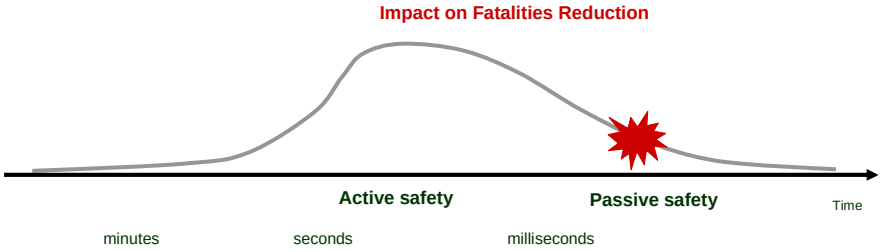
Inter-vehicle communication

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



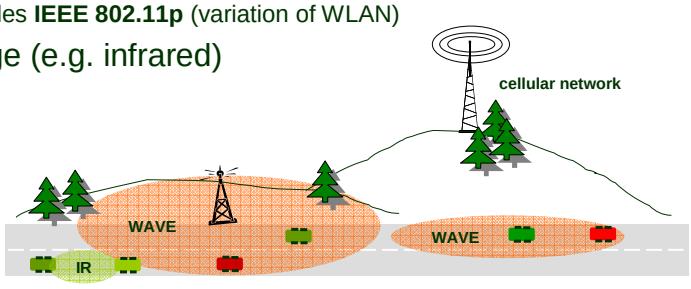
Potential of vehicular networks

- **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)

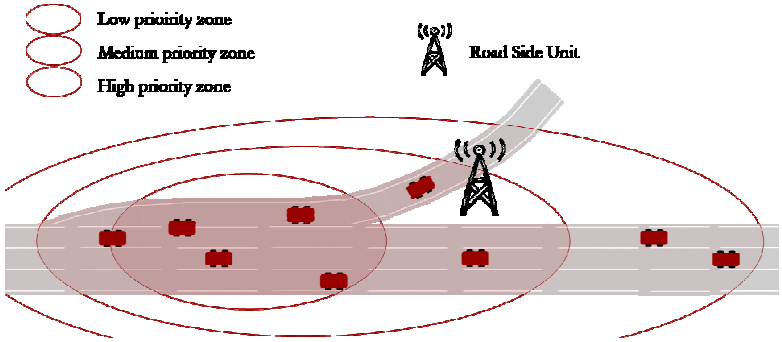


Ongoing research at HH

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

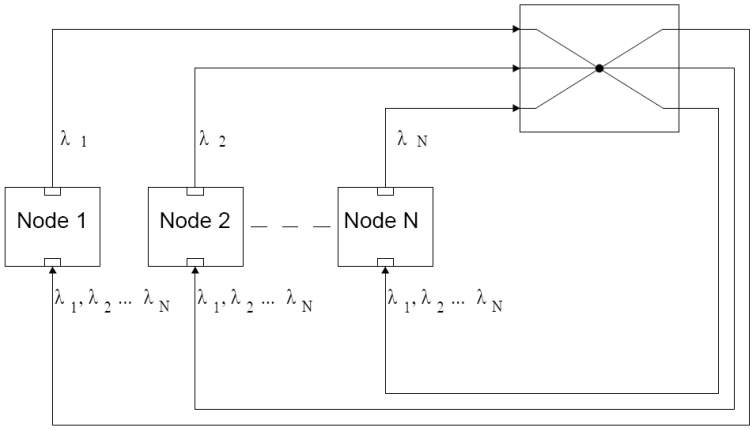


Optical communication

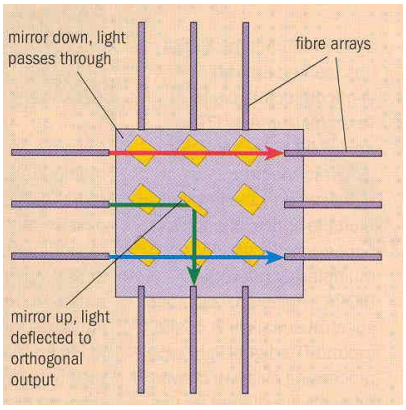
- Optical switching
  - Example: Passive Star Coupler (PSC)
    - Optical switching based on wavelength
    - Fixed transmitters, tunable receivers
    - Wavelenght Division Multiplexing (WDM)
      - Several wavelengths can coexist in the network at the same time
    - Each attached receiver can listen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

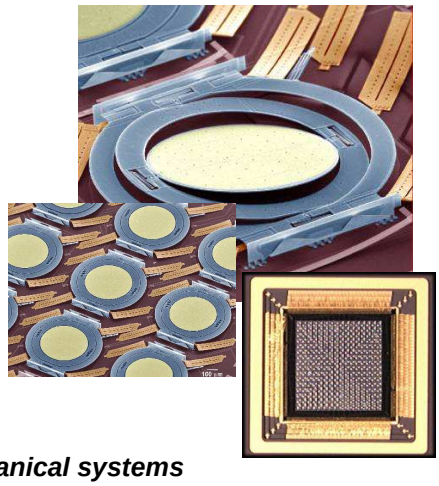
Optical communication

- 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 acces 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.