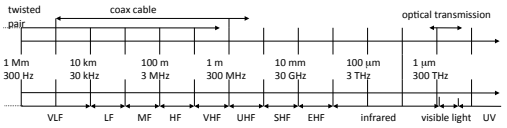
Networking

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

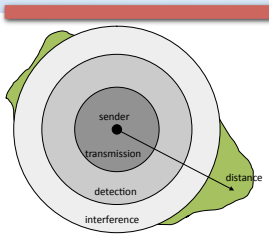
- Frequency and wave length
  - $\lambda = c/f$
  - wave length λ, speed of light $c \approx 3 \times 10^8$ m/s, frequency f



Frequencies

Examples	Europe	USA	Japan
Cellular phones	**GSM** 880-915, 925-960, 1710-1785, 1805-1880 **UMTS** 1920-1980, 2110-2170	**AMPS, TDMA, CDMA, GSM** 824-849, 869-894 **TDMA, CDMA, GSM, UMTS** 1850-1910, 1930-1990	**PDC, FOMA** 810-888, 893-958 **PDC** 1429-1453, 1477-1501 **FOMA** 1920-1980, 2110-2170
Cordless phones	**CT1+** 885-887, 930-932 **CT2** 864-868 **DECT** 1880-1900	**PACS** 1850-1910, 1930-1990 **PACS-UB** 1910-1930	**PHS** 1895-1918 **JCT** 245-380
Wireless LANs	**802.11b/g** 2412-2472	**802.11b/g** 2412-2462	**802.11b** 2412-2484 **802.11g** 2412-2472
Other RF systems	27, 128, 418, 433, 868	315, 915	426, 868

Signal Propagation

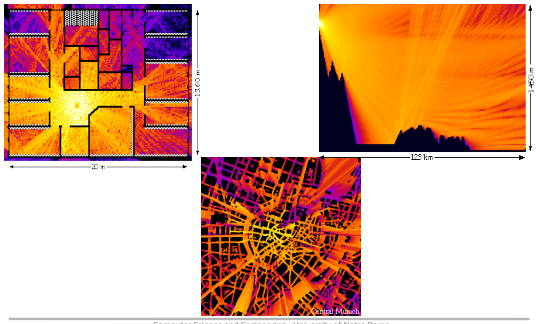


Signal Propagation

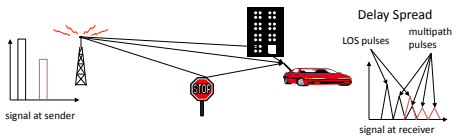
- Fundamental propagation behaviors:
  - ground wave (<2MHz): follow earth's surface, long distances (submarine communication, AM radio)
  - sky wave (2-30MHz): reflected at ionosphere, around the world (intl. broadcasts, amateur radio)
  - line-of-sight (>30MHz): LOS, straight line, waves are bent by atmosphere due to refraction (mobile phones, satellite, cordless)

shadowing reflection refraction scattering diffraction

Signal Propagation

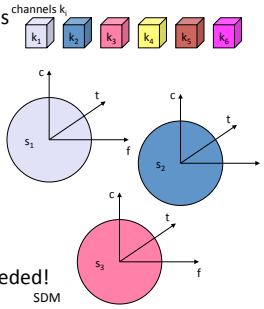


Multipath propagation

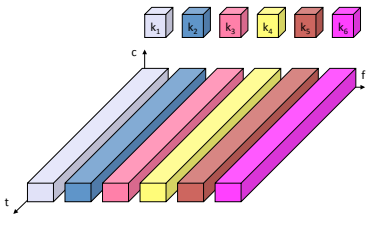


Multiplexing

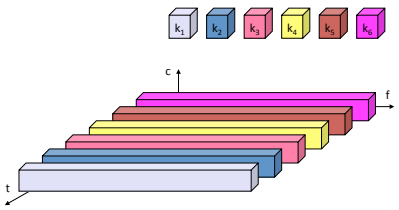
- Multiplexing in 4 dimensions
  - space (s_i)
  - time (t)
  - frequency (f)
  - code (c)
- Goal: multiple use of a shared medium
- Important: guard spaces needed!



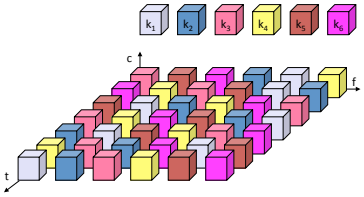
FDM: Frequency Division Multiplexing



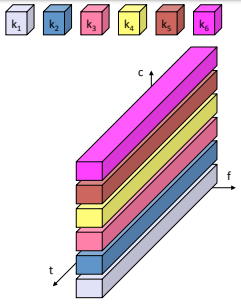
TDM: Time Division Multiplexing



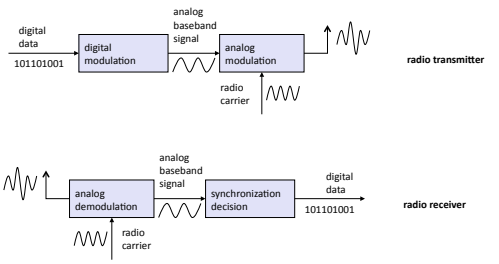
Time and Frequency Multiplexing



Code Division Multiplexing

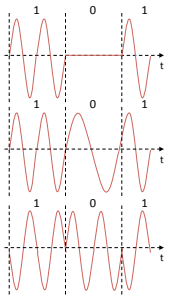


Modulation and Demodulation



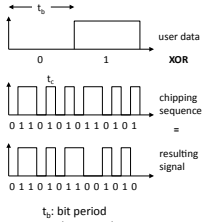
Digital Modulation

- Amplitude Shift Keying (ASK):
  - very simple
  - low bandwidth requirements
  - very susceptible to interference
- Frequency Shift Keying (FSK):
  - needs larger bandwidth
- Phase Shift Keying (PSK):
  - more complex
  - robust against interference



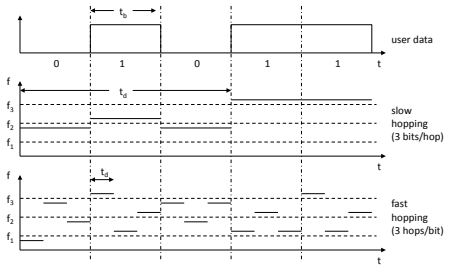
Direct Sequence Spread Spectrum (DSSS)

- XOR of the signal with pseudo-random number (chipping sequence)
  - many chips per bit (e.g., 128) result in higher bandwidth of the signal



t_b: bit period
t_c: chip period

Frequency Hopping Spread Spectrum (FHSS)



Wireless Technologies (IEEE)

WiFi

Local wireless networks
WLAN 802.11

802.11a → 802.11h
802.11i/e/…/n/…/z
802.11b → 802.11g

ZigBee

Personal wireless nets
WPAN 802.15

802.15.4 → 802.15.4a/b/c/d/e
802.15.5, .6 (WBAN)
802.15.2
802.15.3 → 802.15.3b/c
802.15.1
Bluetooth

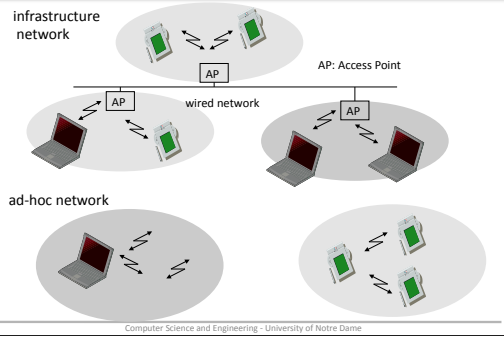
Wireless distribution networks
WMAN 802.16 (Broadband Wireless Access)

WiMAX

+ Mobility

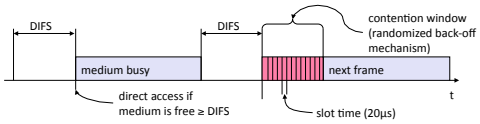
[802.20 (Mobile Broadband Wireless Access)]
802.16e (addition to .16 for mobile devices)

Infrastructure versus Ad-hoc Mode

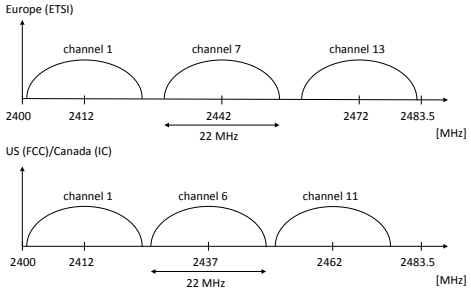


CSMA/CA

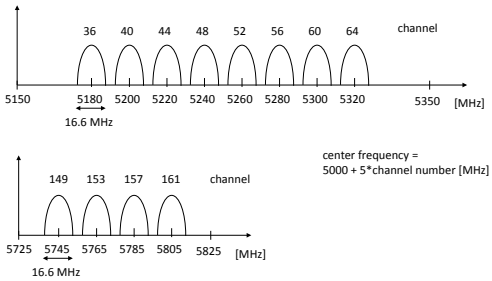
- Station ready to send starts sensing the medium (Carrier Sense based on CCA, Clear Channel Assessment)
- If the medium is free for the duration of an Inter-Frame Space (IFS), the station can start sending (IFS depends on service type)
- If the medium is busy, the station has to wait for a free IFS, then the station must additionally wait a random back-off time (collision avoidance, multiple of slot-time)
- If another station occupies the medium during the back-off time of the station, the back-off timer stops (fairness)



802.11b



802.11a

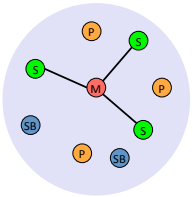


Bluetooth

- Basic idea
  - Universal radio interface for ad-hoc wireless connectivity
  - Interconnecting computer and peripherals, handheld devices, PDAs, cell phones – replacement of IrDA
  - Embedded in other devices, very cheap
  - Short range (10 m), low power consumption, license-free 2.45 GHz ISM
  - Voice and data transmission, approx. 1 Mbit/s data rate

Piconet

- Collection of devices connected in an ad hoc fashion
- One unit acts as master and the others as slaves for the lifetime of the piconet
- Master determines hopping pattern, slaves have to synchronize
- Each piconet has a unique hopping pattern
- Participation in a piconet = synchronization to hopping sequence
- Each piconet has one master and up to 7 simultaneous slaves (> 200 could be parked)

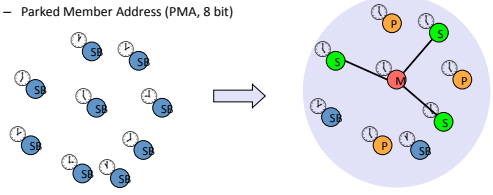


M=Master
S=Slave

P=Parked
SB=Standby

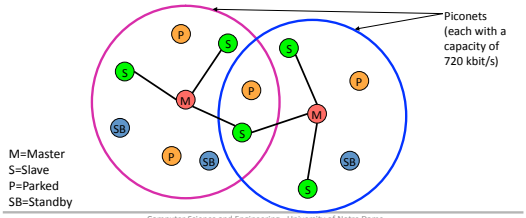
Piconet

- All devices in a piconet hop together
  - Master gives slaves its clock and device ID
    - Hopping pattern: determined by device ID (48 bit, unique worldwide)
    - Phase in hopping pattern determined by clock
- Addressing
  - Active Member Address (AMA, 3 bit)
  - Parked Member Address (PMA, 8 bit)

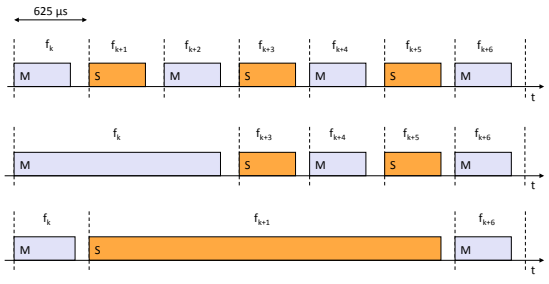


Scatternet

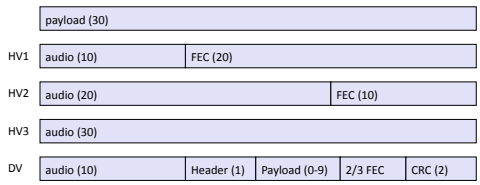
- Linking of multiple co-located piconets through the sharing of common master or slave devices
  - Devices can be slave in one piconet and master of another
- Communication between piconets
  - Devices jumping back and forth between the piconets



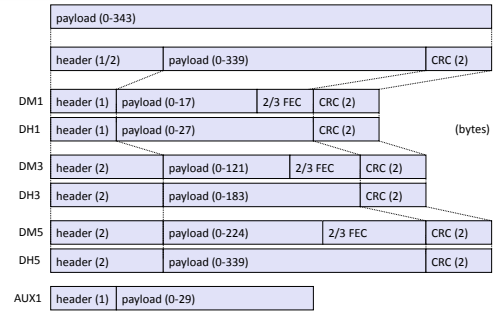
Communication



SCO Payload Types



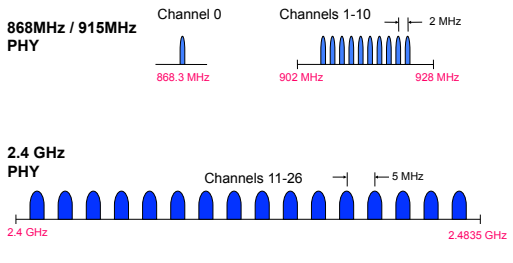
ACL Payload Types



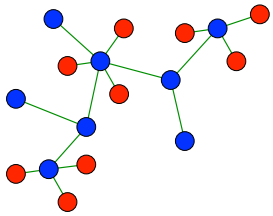
Bluetooth/Zigbee

- IEEE 802.15.1 – Bluetooth
- IEEE 802.15.4 – Zigbee
- Zigbee:
  - Low data rate solution with multi-month to multi-year battery life and very low complexity
  - Potential applications are sensors, interactive toys, smart badges, remote controls, and home automation
  - Data rates of 20-250 kbit/s, latency down to 15 ms
  - Master-Slave or Peer-to-Peer operation
  - Up to 254 devices or 64516 simpler nodes
  - Support for critical latency devices, such as joysticks
  - Power management to ensure low power consumption
  - 16 channels in the 2.4 GHz ISM band, 10 channels in the 915 MHz US ISM band and one channel in the European 868 MHz band

Zigbee



Zigbee



Clustered stars - for example, cluster nodes exist between rooms of a hotel and each room has a star network for control.

Full function device

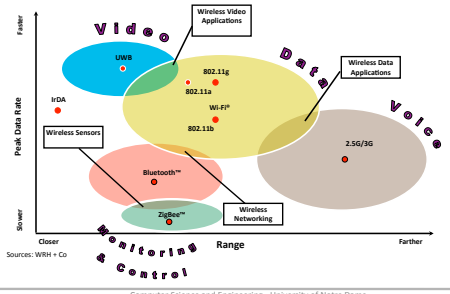
Reduced function device

Communications flow

Comparison of Wireless Technologies

Standard	Bandwidth	Power Consumption	Protocol Stack Size	Stronghold	Applications
Wi-Fi	Up to 54Mbps	400+mA TX, standby 20mA	100+KB	High data rate	Internet browsing, PC networking, file transfers
Bluetooth	1Mbps	40mA TX, standby 0.2mA	~100+KB	Interoperability, cable replacement	Wireless USB, handset, headset
ZigBee	250kbps	30mA TX, standby 356 µA	34KB /14KB	Long battery life, low cost	Remote control, battery-operated products, sensors

Comparison of Wireless Technologies



Bluetooth versus WiFi