Mobile Computing and the IoT
Wireless and Mobile Computing

Wireless Signals

George Roussos

g.roussos@dcs.bbk.ac.uk
Overview

• Signal characteristics
• Representing digital information with wireless
• Transmission and propagation
• Accessing the wireless medium
Signals

• physical representation of data
• function of time and location
• signal parameters: parameters representing the value of data
• classification
  – continuous time/discrete time
  – continuous values/discrete values
  – analog signal = continuous time and continuous values
  – digital signal = discrete time and discrete values
Signal parameters

• signal parameters of periodic signals:
  – period T,
  – frequency $f=1/T$,
  – amplitude $A$,
  – phase shift $\varphi$

• Example: A sine wave as special periodic signal:

$$s(t) = A_t \sin(2 \pi f_t t + \varphi_t)$$
Fourier representation of signals

\[ g(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2\pi n ft) + \sum_{n=1}^{\infty} b_n \cos(2\pi n ft) \]
Modulation and demodulation

- Digital data
- Digital modulation
- Analog baseband signal
- Analog modulation
- Radio carrier
- Radio transmitter

- Analog baseband signal
- Synchronization decision
- Digital data
- Radio receiver
• A set of rules according to which a sequence of bits is mapped to a signal
• Example: Manchester encoding

Source netlab.ulusofona.pt
Modulation

• Digital modulation
  – digital data is translated into an analog signal
  – different ways to achieve this
    • sine waveforms whose parameters are shaped (modulated) by the sequence of bits that is transmitted
  – different alternatives have differences in spectral efficiency, power efficiency, robustness
Digital modulation

• Modulation of digital signals known as Shift Keying
  – Amplitude Shift Keying (ASK)
  – Frequency Shift Keying (FSK)
  – Phase Shift Keying (PSK)
Example: EPC Gen2 RFID Example
Antennas: isotropic radiator

• 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
Antennas: radiation pattern

- Real antennas always have directive effects (vertically and/orhorizontally)
- Radiation pattern: measurement of radiation around an antenna
Antennas: simple dipoles

• Example: Radiation pattern of a simple dipole
Antennas: directed and sectorized

directed antenna

sectorized antenna
Example: Mobile phone antenna
### Signal propagation ranges

- **Transmission range**
  - communication possible
  - low error rate
- **Detection range**
  - detection of the signal possible
  - no communication possible
- **Interference range**
  - signal may not be detected
  - signal 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
Real world examples
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
  ➔ signal distortion depending on the phases of the different parts.
Example: Effect on GPS

Source: Bosch Sensortec
Observable error

Source: Oxford Technical Solutions oxts.com
Urban Canyons
GPS in Urban Canyons

Source: fmcsmart.forumotion.com/
GPS in multi-storey car parks

Source: fmcsmart.forumotion.com/
Media access

• Can we apply media access methods from fixed networks?

• Example CSMA/CD
  – **Carrier Sense Multiple Access with Collision Detection**
  – send as soon as the medium is free, listen into the medium if a collision occurs (original method in IEEE 802.3)

• Problems in wireless networks
  – signal strength decreases proportional to the square of the distance
  – the sender would apply CS and CD, but the collisions happen at the receiver
  – it might be the case that a sender cannot “hear” the collision, i.e., CD does not work
  – furthermore, CS might not work if, e.g., a terminal is “hidden”
Hidden and exposed terminals

- **Hidden terminals**
  - A sends to B, C cannot receive A
  - C wants to send to B, C senses a "free" medium (CS fails)
  - collision at B, A cannot receive the collision (CD fails)
  - A is "hidden" for C

- **Exposed terminals**
  - B sends to A, C wants to send to another terminal (not A or B)
  - C has to wait, CS signals a medium in use
  - but A is outside the radio range of C, therefore waiting is not necessary
  - C is "exposed" to B
Motivation - near and far terminals

- Terminals A and B send, C receives
  - signal strength decreases proportional to the square of the distance
  - the signal of terminal B therefore drowns out A’s signal
  - C cannot receive A

- If C for example was an arbiter for sending rights, terminal B would drown out terminal A already on the physical layer
- Also severe problem for CDMA-networks - precise power control needed!
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)
Summary

• Signal characteristics
• Signal modulation to represent information
• Signal processing pathway
• Role of antenna
• Propagation of wireless signals
• Wireless media access