Large-Scale Radio Propagation Introduction

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Practicalities

- **Lunches**
  - Offered at the UCL cafeteria
  - 2 tickets = 1 lunch (incl. 1 drink)
- **Social dinner**
  - On Wednesday evening
- **Evaluation**
  - On Friday

Cellular Telephone Systems

- **1G Advanced Mobile Phone Services (AMPS)**
  - Started in the US in 1983, going worldwide in the 1980s
  - Analog FM-modulated voice signals at 800 MHz
  - Still in use today in some US regions
- **2G … mostly voice**
  - In Europe, emergence of a unique standard (GSM) at 900 and 1800 MHz + SMS
  - In the US, competing incompatible standards in the 2-GHz band
    - IS-136 (similar to the Japanese system)
    - IS 95 (see future lecture)
    - GSM 1800 (but a different band than in Europe)

Cellular Telephone Systems (2)

- **2G evolutions: from voice to voice + data**
  - GSM with higher data rates ⇒ General Packet Radio Service (GPRS)
  - Enhanced Data rates for GSM Evolution (EDGE)
    - Up to 384 kbps, adaptive techniques
- **3G: voice + data, mobile web/data transmission**
  - IMT-2000, implemented as UMTS in Europe
    - Using CDMA
    - Long Term Evolution (LTE Rel. 8/9) of UMTS and WiMAX 1.0
    - Include MIMO and OFDMA (see Lectures 9-10 + 12-14)
- **Towards 4G and 5G: mobile voice + data**
  - From LTE Rel. 10

Cordless Phones

- The wireless link replaces the cord of home phones
- **CT-2**
  - Primarily for home use
  - Range may be extended beyond the home by base stations (telepoints), but this was rapidly abandoned (no handover, no routing)
- **DECT (Europe)**
  - Primarily designed for office buildings, multiple base stations at 1900 MHz
  - Handoff process
  - Now used in Europe for all CTs

Wireless LANs (a.k.a. WiFi)

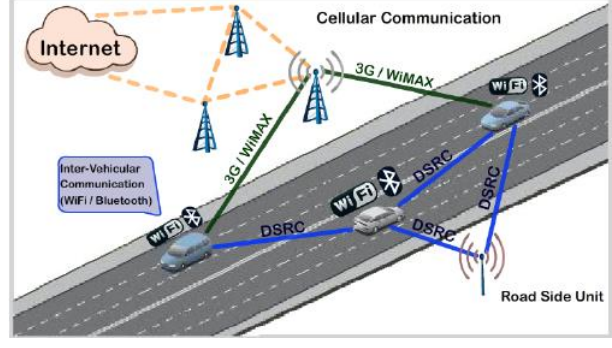
- High-speed data transmissions across small regions
  - Stationary or low-speed users
  - Concept of hot spots
- **1G**
  - Using unlicensed bands (900 MHz, 2.4 GHz and 5.8 GHz)
  - No standardization

Wireless LANs (2)

- **2G**
  - IEEE 802.11b (83./5 MHz BW @ 2.4GHz), rates up to 1.6 Mbps and range of 100 m
  - IEEE 802.11a (300 MHz BW @ 5 GHz), using multi-carrier modulation (OFDM)
  - European HYPERLAN (and version \2) similar to 802.11a
- **WLAN evolution**
  - 802.11n, using multiple antenna techniques (MIMO) and OFDM(A)
  - Increased data rate

Vehicular Networks

- **Based on IEEE 802.11**
  - VANET
  - 802.11p standard



Broadband Wireless Access

- Fixed access point (base station) and terminals
- **LMDS**
  - Using part of the 28-GHz to provide Internet access
- **MMDS and HIPERACCESS**
  - TV and telecommunication services at 2 GHz
- **WiMAX (IEEE 802.16)**
  - Competitor to WiFi, x-DSL and 3G/4G phones
  - From 2 to 11 GHz for non line-of-sight operations and up to 66 GHz for direct visibility links
  - 802.16e enables mobility (MIMO, OFDMA)
  - Lower cost than LTE ?

Satellite and High Altitude Platform Networks

- **Low Earth Orbit (LEO) satellites**
  - Constellations of satellites providing worldwide access
  - No success for communications and now used by US army
  - Positioning systems (GPS and Galileo)
- **HAPS**
  - Platform acts like a high base station
  - Supporting 3G/4G and/or WiMAX ?

Short-Range Radio Systems – IEEE 802.15

- **IEEE 802.15.1 - Bluetooth**
  - Connections between devices
- **IEEE 802.15.4 - ZigBee**
  - Low rate Personal Area Network (PAN)
  - Operates in the ISM bands
- **UWB**
  - Low power/low rate or high rate standard (IEEE 802.15.3)
  - Uses the spectrum between 3 and 10 GHz
  - Stringent spectrum mask

Why a Cellular Concept ?

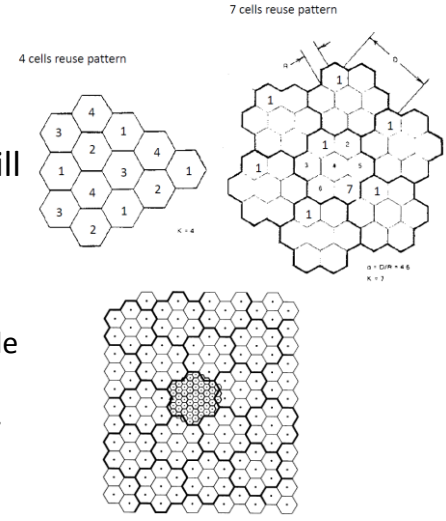
- How can users communicate at the same time over the wireless infrastructure ?
  - Use frequency
- But spectrum is a limited resource
  - Each frequency cannot just be used only once

⇒ frequency reuse

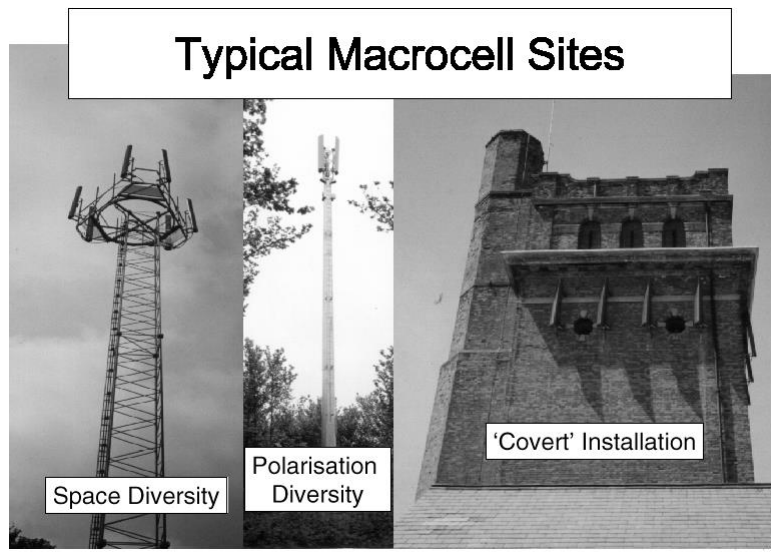
⇒ cellular concept

Cellular Networks

- Divide the area into cells
- Define a cluster, i.e. a reference pattern that will be repeated
  - A cluster is made of 4, 7, 12, 19, etc. cells
  - In each cluster, all available frequencies are allocated
  - Some cells may be further split to account for large demand
    - Frequency planning adapted



Base Station



Cellular Networks (2)

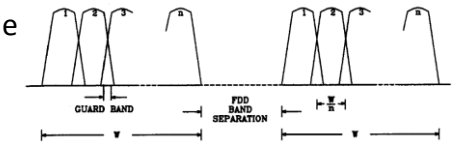
- In each cell, there is a **base station** (at the center)
- **Duplexing**
  - Uplink: from the user to the BS
  - Downlink : from the BS to the user
  - Up/down links on different frequency bands (FDD-frequency division duplexing)
- **Interference**
  - Interference due to the same frequency used in another cell: co-channel interference (CCI)
  - Directional BS antennas $\Rightarrow$ 3 sectors in each cell
  - Uplink power control to limit the mobile power to the minimum required and limit CCI

Handover and Multiple Access

- **Handover**
  - Procedure defining the transition of any user from one cell to a neighbouring cell
- Within a cell, how to separate users ?
  - Use frequency or time
  - Multiple Access: XDMA techniques
    - X must be an orthogonal resource
    - X = frequency, time, space, code, etc.

FDMA

- **Orthogonal resource = frequency**
  - Used in first generation mobile for analog FM transmission of speech (control: digital, FSK)
- Available bandwidth divided among users
  - FDD mode



  - May be used with TDD instead of FDD
- **Known "issues"**
  - Adjacent channel interference
  - The BS requires as many transceivers as mobile stations

TDMA

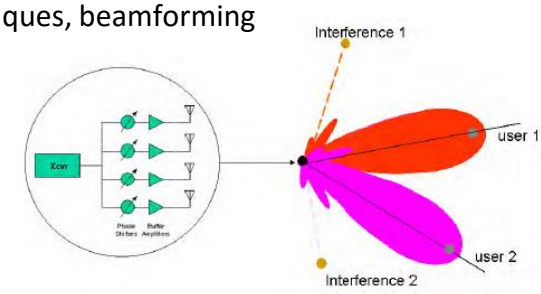
- **Orthogonal resource = time (slots)**
- All users access the whole BW only a fraction of time
  - Uplink: orthogonality must be maintained at the BS !
    - Timing advance owing to differentiated propagation delays
  - One carrier required
  - BS: one transceiver for all users
- **Known "issues"**
  - Burst structure with organized packets help the receiver
  - Additional bits required for sync, channel estimation, etc. (overhead)
  - Larger BW than FDMA (wireless channel might be more harmful)

CDMA

- **Orthogonal resource = code**
- All users access the whole BW all the time
  - They are separated by (quasi)-orthogonal codes
  - Spread spectrum technique
- **Known "issues"**
  - Codes are not fully orthogonal

SDMA (MU-MIMO)

- **Orthogonal resource = space (antenna)**
- Users are separated in the spatial domain by different beams
- MU-MIMO techniques, beamforming



Beamforming using 4 transmit antennas

- Use of massive MIMO

Block Diagram of a Communication System