TEKNILLINEN KORKEAKOULU
TEKNISKA HÖGSKOLAN
HELSINKI UNIVERSITY OF TECHNOLOGY

Cellular Network Planning and Optimization
Part I: Introduction

Jyri Hämäläinen,
Communications and Networking Department,
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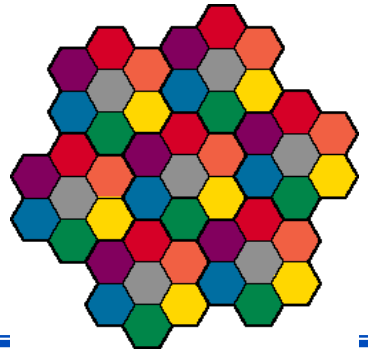
Outline

- Preliminaries
- Selection of technology examples
- Spectrum
- Way forward

Preliminaries

Cellular radio system

- Bandwidth is a scarce resource which needs to be divide among the users
- In practice all multiple access schemes introduce co-channel interference which limits the spatial reuse of the resources.
- Cellular radio concept (Bell Labs, 1943)
  - Service area of single base station is denoted as a cell



Same frequency can be reused in spatially separates cells
FDMA/TDMA

Objectives of radio network planning

1) To obtain sufficient *coverage* over the entire service area to ensure that high quality voice services and data services with low error rates can be offered to the subscribers.
2) To offer the subscriber traffic *network capacity* with sufficiently low *blocking* and call *dropping* rate.
3) To enable an *economical network implementation* when the service is established and a controlled network expansion during the life cycle of the network

Network planning from operator perspective

- For an operator good network planning =
  - Less money spend to infrastructure
  - More satisfied customers (good service quality)
  - Less need for adjustments
- For an operator network optimization =
  - Better return for investment
  - Less need for costly hardware updates
  - Less need for new sites (which are very expensive)

Viewpoints

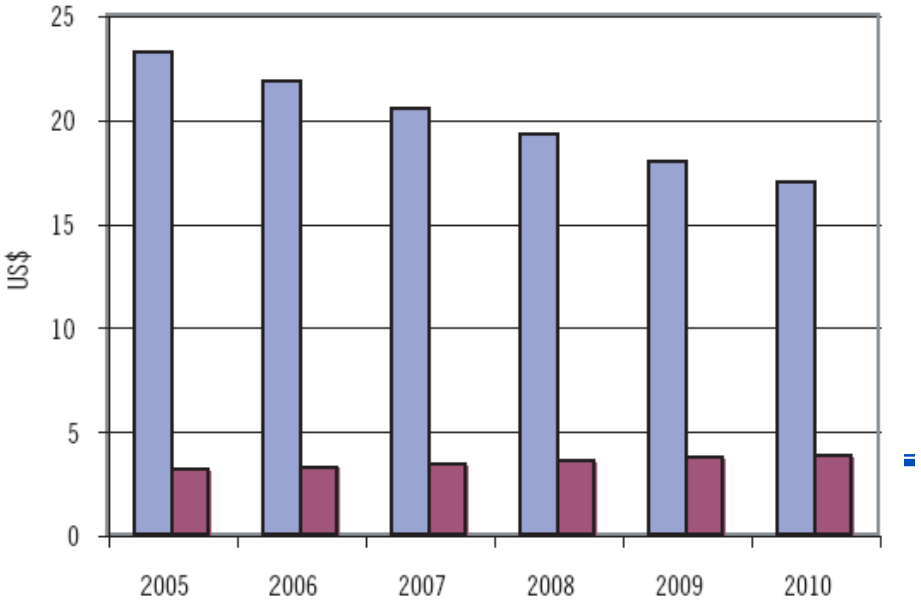
- Spectrum and network are valuable assets for cellular operators
  - Recall that there are also virtual operators i.e. operators that neither have spectrum nor network
- How do you select your operator?
  - Price is usually the driver
  - Connectivity is an issue only in rare cases
  - Availability and quality of voice services is quite good – exclude dense urban areas during peak traffic times.
  - Operator's brand is also important

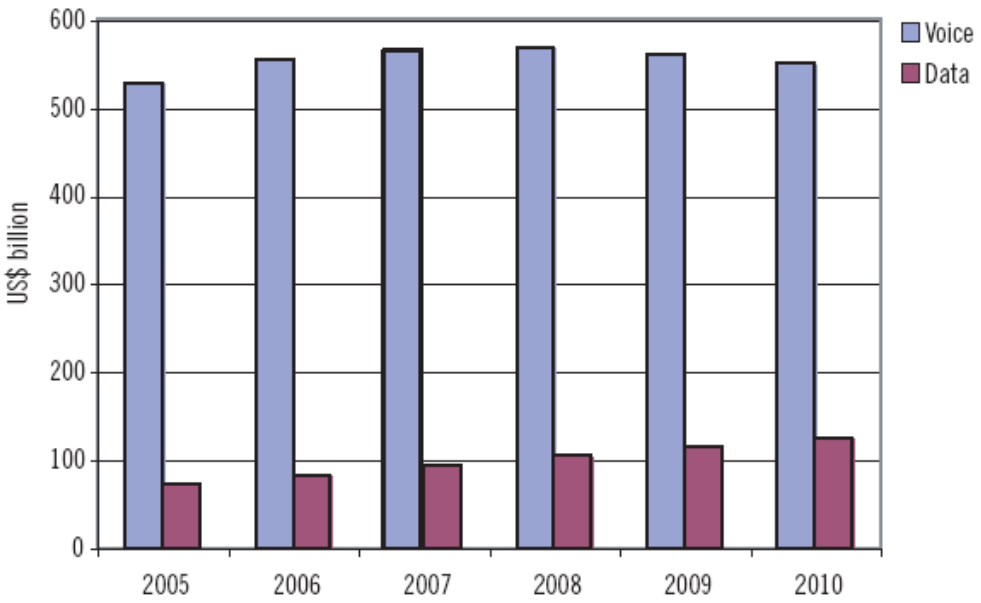
Services

- Services
  - Voice is still dominating
  - Data services gaining momentum due to introduction of 3G networks, breakthrough ongoing
- Most of the existing networks have been build for voice service
  - Coverage and network costs have been drivers in network planning
  - Usually minimum configuration used in network roll-outs
  - Capacity (= voice capacity) increased afterwards on need basis

ARPU development

- ARPU (= Average Revenue Per User)
  - The operator income from voice services is expected to decrease at the same time ARPU from data is increasing slowly
  - Operators have increasing cost pressure => network costs should be as low as possible





Future aspects

- 3.5G networks and beyond will be build for data services
  - Voice services provided through VoIP
- Network planning and optimization
  - Costs is increasingly important factor
  - Most of the operators want to use old sites (GSM) while introducing WCDMA, HSPA,,,=> increasing service coverage challenges
    - Higher carrier frequency, higher data rates etc
  - Network optimization important => operators want to take everything out from existing networks

Selection of technology examples

Role of technology

- There are some issues that are common in network planning independently from the applied technology
  - Environment and fading phenomena
  - Basic types of interference (co-channel, adjacent channel)
  - Traffic and service demands … but if technology can't support certain service then its demand is ignored
- Yet, the role of technology specific issues is increasing
  - In 'voice only' networks radio resources were more or less fixed and resource reuse ratio were low
  - The increasing demand data service, efficiency and higher user rates is driving towards networks where same radio resources are used in all (or almost all) cells.
  - While conventional planning is still important, the optimization of the networks is also vital.

Selection of focus technologies

- For this course we have selected some mobile communication technologies to serve as examples.
- To justify the selection we carry out a brief discussion on importance of the existing and future network technologies
  - Selected technologies should provide illustrative examples
  - Selected technologies should be widespread and/or they should be around once students of this course graduate
  - Some interesting technologies are left out due to lack of time
  - Selected technologies should present generations from 2G to latest 3G variants

First step: IMT-2000 Technologies

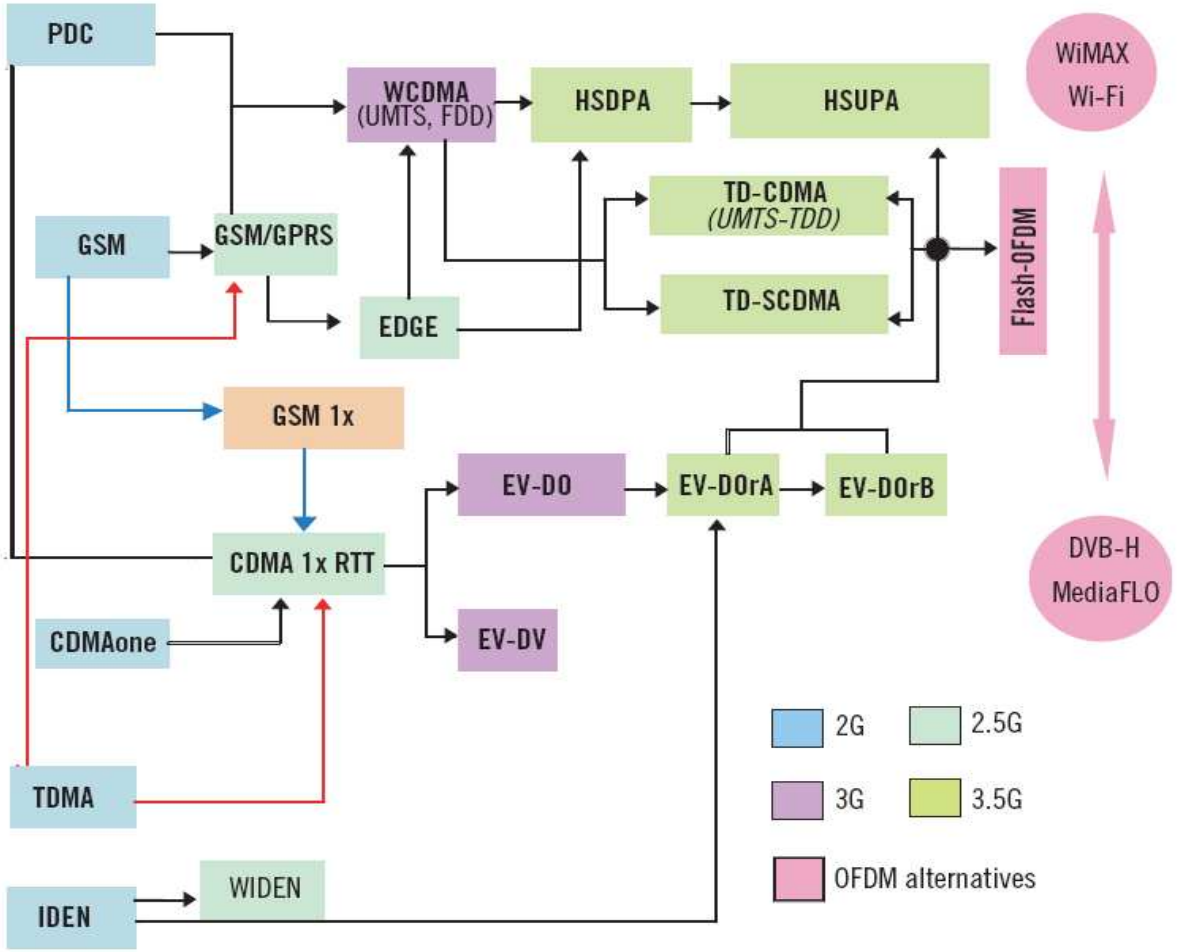
- **In GSM technology is dominating in 2G; it is clear choice for a 2G representative in our course**
- **3G cellular/broadband wireless technologies are included into IMT-2000 family**
  - **International Mobile Telecommunications-2000** (**IMT-2000**) is the global standard for third generation (3G) wireless communications as defined by the International Telecommunication Union (ITU). In 1999 ITU approved five radio interfaces for IMT-2000 as a part of the ITU-R M.1457 Recommendation and additionally approved a new standard in 2007 as the sixth IMT-2000 radio interface.
- IMT-2000 'label' is important for a wireless mobile technology because then it has an access to global IMT-2000 spectrum. The lack of this label may be a crucial obstacle for commercial use of the technology.

IMT-2000 Technologies

- IMT-DS Direct-Sequence
  - also known as **WCDMA** or UTRA-FDD, used in UMTS
- IMT-MC Multi-Carrier
  - also known as **CDMA2000**, the successor to 2G CDMA (IS-95)
- IMT-TD Time-Division
  - This comprises: TD-CDMA (Time Division - Code Division Multiple Access) and TD-SCDMA (Time Division - Synchronous Code Division Multiple Access). Both are standardized by 3GPP in UMTS like **UTRA TDD-HCR** (3.84 Mcps, 5 MHz bandwidth, TD-CDMA air interface) and UTRA TDD-LCR (1.28 Mcps, 1.6 MHz bandwidth, **TD-SCDMA** air interface).
- IMT-SC Single Carrier
  - also known as **EDGE**
- IMT-FT Frequency Time
  - also known as **DECT**
- IMT-OFDMA TDD WMAN
  - better known as **WiMAX**

Mobile network evolution paths

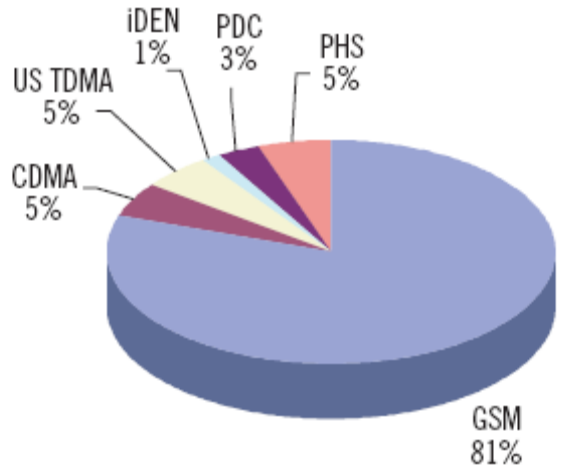
Figure 1.1: Different network evolution paths



The selection of 3G technologies seems bit tricky. Let's check how widespread different technologies are and what are future forecasts

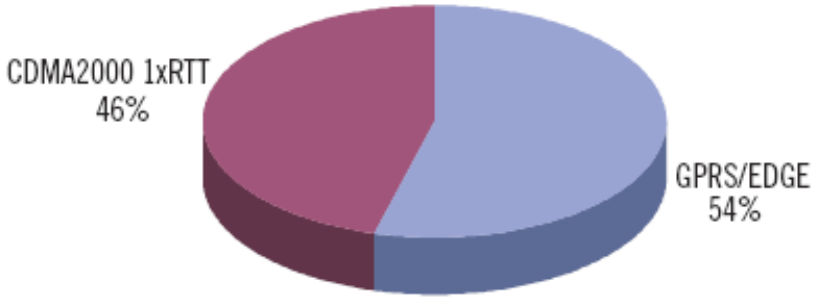
Technology shares

2G subscribers by technology

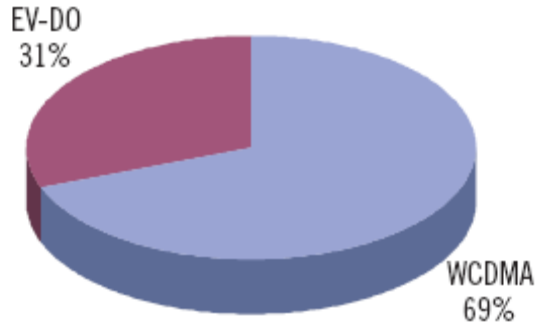


Subscriber forecast for 2010	
-2G/GSM	1135 million
-2.5G/GPRS/EDGE	541 million
-2.5G/CDMA1xRTT	271 million
-3G/WCDMA	365 million
-3G/EV-DO	88 million
-3.5G/HSPA	170 million
-3.5G/EV-DOrA,rB	40 million

2.5G subscribers by technology



3G subscribers by technology



Disclaimer: Technology shares as well as forecasts vary from source to source

Focus technologies: 2G

- 2G GSM and its evolution towards 2.5G GPRS and EDGE
  - GSM continues to be the most common voice technology
    - New roll-outs in emerging markets (India, China, Africa)
    - GSM capacity is still increased but in some markets new voice capacity is build on other technologies
  - EDGE continues to be important technology in near future (as well as its CDMA2000 competitor)
- In this course we
  - go through some basic elements on GSM/GPRS/EDGE network planning

Focus technologies: 3G/3G+

- 3G WCDMA and its evolution towards HSPA
  - 3G WCDMA provides a very good example of challenges in CDMA network planning.
  - Optimization of WCDMA network parameters important task also in future
  - HSPA important enhancement to WCDMA, data coverage challenges
- 3G LTE and mobile WiMAX (IEEE 802.16e)
  - Future OFDMA technologies, network planning and optimization aspects still widely unknown. First mobile WiMAX roll-outs ongoing, first LTE networks 2009-10
- In this course we
  - Put a lot of emphasis on WCDMA and HSPA
  - Scratch the future challenges related to 3G LTE and WiMAX
- If we have time then we also discuss on
  - Relay technologies
  - Other new network extensions

GSM/GPRS/EDGE

- GSM was originally designed for voice services
  - Macro-cell deployment was a baseline assumption
  - SMS was the first ‘killer application’ on data services due which the commercial potential of data applications were realized
  - Still today most of the voice capacity is build using GSM
- GPRS was created to extend GSM for packet data
  - Drawback was the lack of multimedia support and low bit rates in physical layer
  - The changes in core network due the GPRS are actually revolutionary
    - SGSN and GGSN provide packet switched connection to IP networks also in 3G
- Latest GSM evolution is called EDGE
  - In data rates EDGE is competitive even with WCDMA

WCDMA

- 3G/WCDMA
  - Designed for multimedia communications from the beginning
  - Provides more efficient means for image and video transfer
  - Variable bit rates up to 2 Mbps (Rel'99)
  - Multiplexing of services with different quality requirements into single connection
  - Quality requirements from 10% FER down to 10(-6) bit error rate
  - Support for asymmetric uplink and downlink traffic
  - Good spectral efficiency

Differences between WCDMA and GSM

	WCDMA	GSM
Carrier spacing	5MHz	200kHz
Frequency reuse	1/1	1/1-18
Power control	1.5kHz (‘fast’)	2Hz (‘slow’)
Quality control	RRM based	Mostly due frequency planning
Frequency diversity	Multi-path diversity	Frequency hopping
Multi-antenna transmission	Beam-forming and transmit diversity supported in standard	Simple non-standardized methods can be applied

HSPA (High Speed Packet Access)

- HSPA refers to two existing standards (HSDPA and HSUPA)
  - **High-Speed Downlink Packet Access** (**HSDPA**) allows networks based on UMTS/WCDMA to have higher data transfer speeds and capacity. Special characters:
    - Hybrid automatic repeat-request (HARQ)
    - Fast packet scheduling
    - Adaptive modulation and coding
  - As of May 2007, 102 HSDPA networks have commercially launched mobile broadband services in 55 countries
  - **High-Speed Uplink Packet Access (HSUPA)** is an uplink enhancement for UMTS/WCDMA
    - HSUPA contains similar enhancements as HSDPA: HARQ and packet scheduler.

Mobile WiMAX (IEEE 802.16e)

- The **IEEE 802.16 working group is focusing on broadband wireless access BWA) standards.**
  - **WiMAX refers to** "Worldwide Interoperability for Microwave Access" by an industry group called the WiMAX Forum.
  - IEEE 802.16e (also called as mobile WiMAX) is specifying a mobile BWA system. Characters
    - Scalable OFDMA that support channel bandwidths between 1.25 MHz and 20 MHz.
    - Hybrid automatic repeat-request (HARQ)
    - Fast packet scheduling
    - Adaptive modulation and coding
    - Packet switched network
  - First mobile WiMAX network roll-outs ongoing (USA/Sprint)

3G LTE (UMTS evolution)

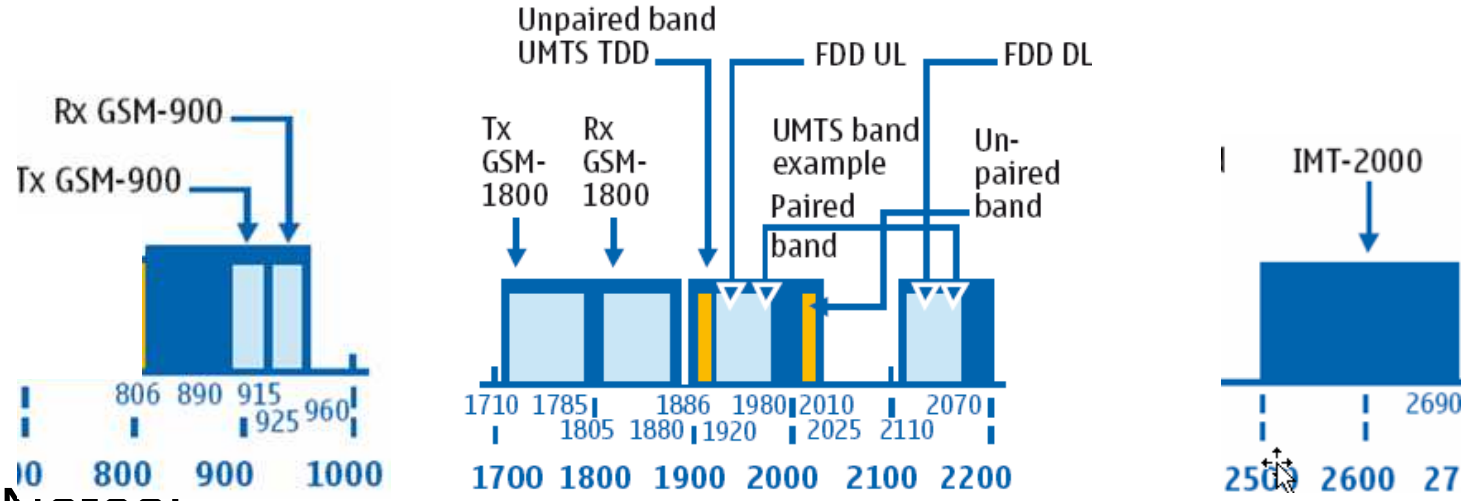
- **3GPP LTE** (Long Term Evolution) is a name given to a 3G/UMTS evolution to cope with future requirements.
  - It will result in the new release of the UMTS standard.
    - Scalable OFDMA from 1.25 MHz up to 20 MHz
    - Very high spectral efficiency
    - Hybrid automatic repeat-request (HARQ)
    - Fast packet scheduling
    - Adaptive modulation and coding
    - Packet switched network
  - LTE standard will be ready on 2008 and first products/networks are coming at 2009.

Spectrum

Background

- Spectrum is valuable property for network operator.
  - Spectrum is obtained through auction or ‘beauty contest’
- Spectrum is scarce
  - Not all operators can get spectrum although they would need it => spectrum efficiency of the technology is important
- There are global band allocations for IMT-2000 technologies
  - Global allocations are decided in World Radio congress (WRC) that usually takes place after each 4 years. Latest WRC were held on 2007.
  - National regulators may do their own decisions but most national regulators follow WRC decisions.

IMT-2000 Spectrum



Notes:

- IMT-2000 spectrum is in use in Europe, Asia, Africa, but in some regions (e.g. North America) spectrum allocation is different from the above figure.
- Spectrum is scarce and in some countries also expensive
- There are GSM spectrum on 900MHz and 1800MHz
- UMTS is operating on 1900-2200MHz spectrum

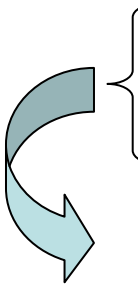
New IMT Spectrum

- New spectrum were granted by World Radio Congress (November 2007) for present and future IMT systems.
  - An important new band is on 3.4-3.6 GHz frequency (200MHz)
  - Also some bands were granted on lower frequencies, round 800 MHz. Amount of new spectrum depends on the region.
  - These new band allocations ensure the growth opportunity for wireless mobile business (we have jobs also in future).

Way forward

Next steps

- Next lectures
  - Planning aspects that are common to all cellular networks
  - GSM/GPRS/EDGE network planning: A brief introduction
  - WCDMA/HSPA network planning and optimization. This topic form the core of this course.
  - LTE and WiMAX planning aspects
  - Future trends



If we have time