Mobile Networks

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T-110.5121 Mobile Cloud Computing

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Lecture Contents

- Target: provide an overview of the operation of mobile networks – in particular 3G cellular

- Cellular network
  - Challenges arising in cellular communication
  - Basic structure and architecture
  - Key mechanisms: mobility management, call formation, handover
- Data transfer in cellular networks
  - GPRS, UMTS, LTE
- Issues relevant for mobile cloud computing
  - Energy efficiency

Challenges in Mobile Environments

- Limitations of the Wireless Network
  - packet loss due to transmission errors
  - variable capacity links
  - limited communication bandwidth
  - Broadcast nature of the communications
- Limitations Imposed by Mobility
  - To form connection to a user
  - To maintain connection while the user moves
- Limitations of the Handheld device
  - short battery lifetime
  - limited capacities

History



ARP NMT → GSM (2G) 1993 → GPRS (2.5G) 2001 → 3G 1999 → LTE 2009

Analog: ARP, NMT

Digital: GSM (2G), GPRS (2.5G), 3G, LTE

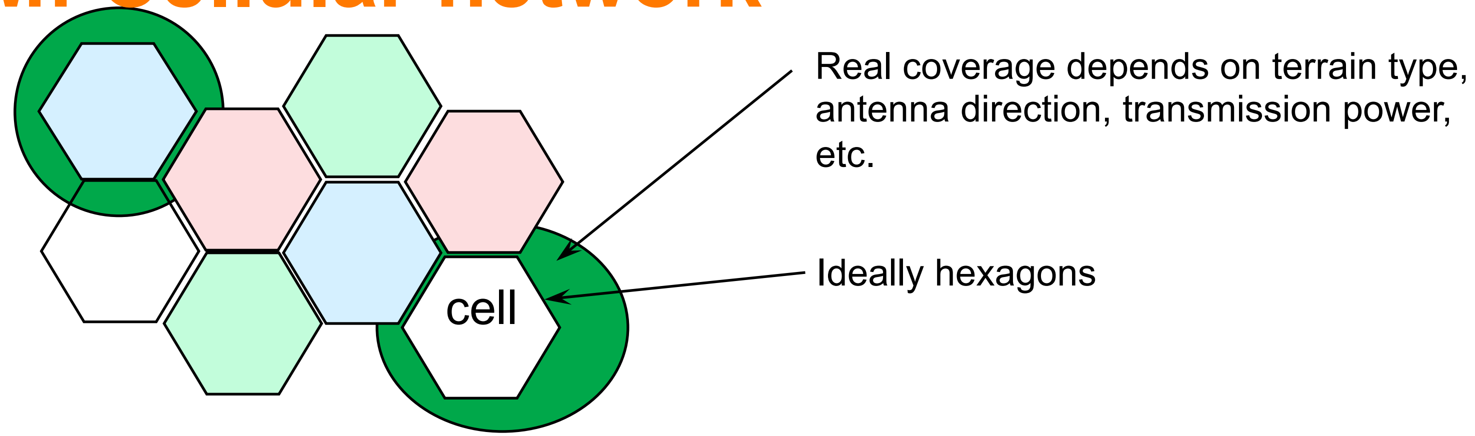
Faster data rates; towards global standards; smaller, lighter, smarter, …, terminals

Basic structure and operation of GSM network

Partly adapted from:
Computer Networking: A Top Down Approach
5th edition.
Jim Kurose, Keith Ross
Addison-Wesley, April 2009.

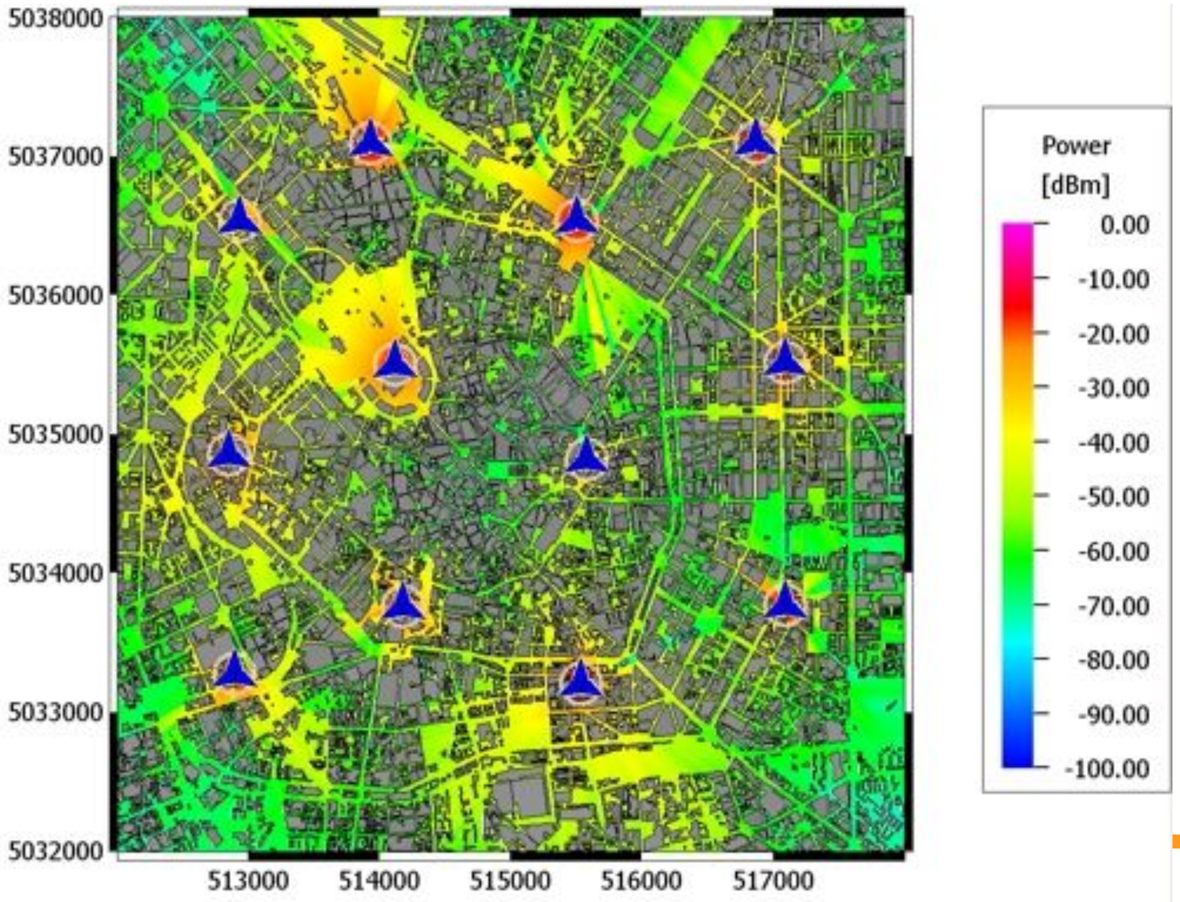
Aalto University
School of Science

GSM: Cellular network

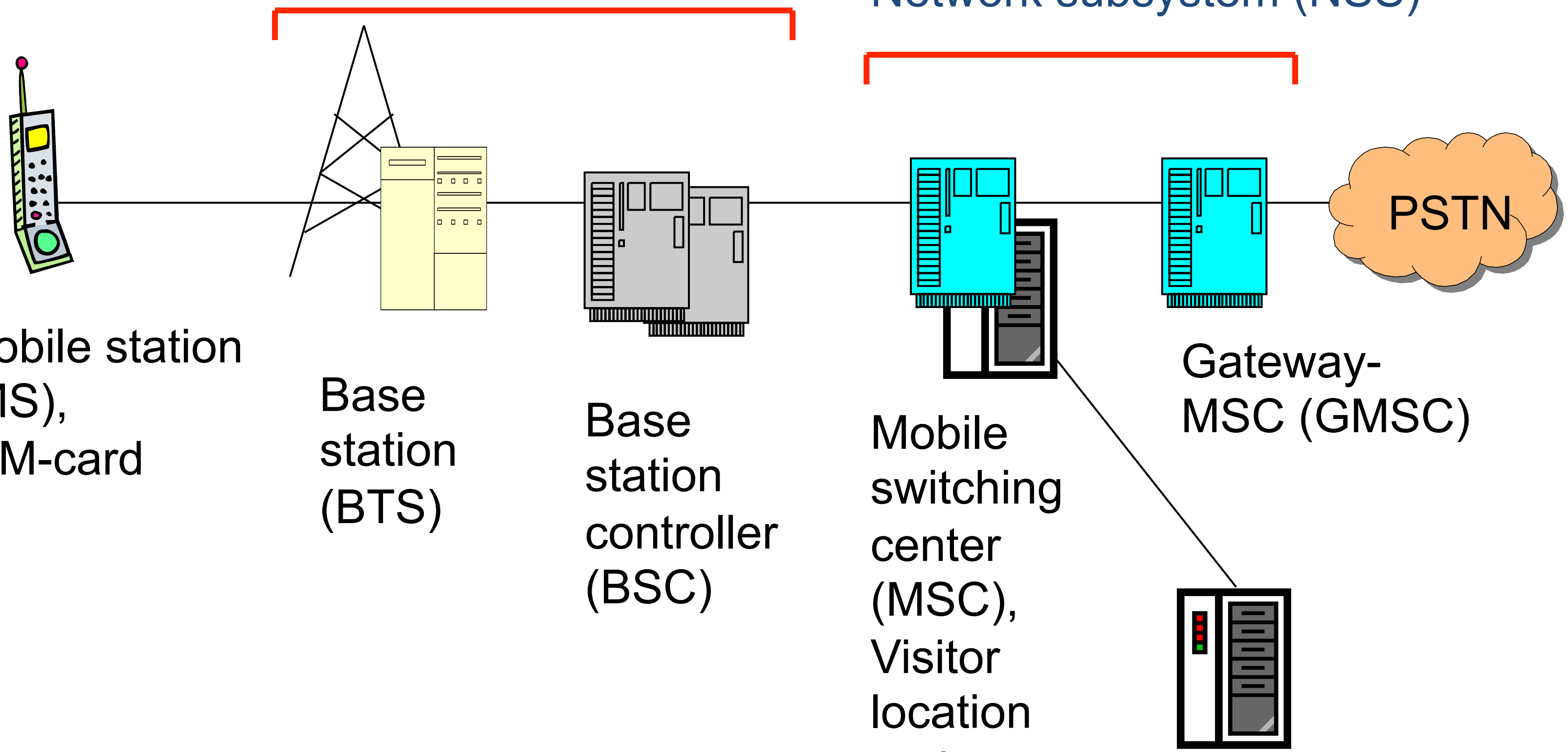


- Region is divided into cells. Each cell has its own frequency (in 2G)
- Different frequencies in neighboring cells, reuse of frequences further away
- Cell sizes wary: 50 m - 35 km
  - Picocells inside buildings, microcells e.g. for a street, macrocells on the countryside. Now coming nanocells for indidual homes.
- Planning of cellular network is an optimization problem
  - Limited number of frequencies available
  - Cover geographical area (remote area problem)
  - Enough capacity (city problem)
  - Minimize cost

Example of cell coverage



GSM Architecture



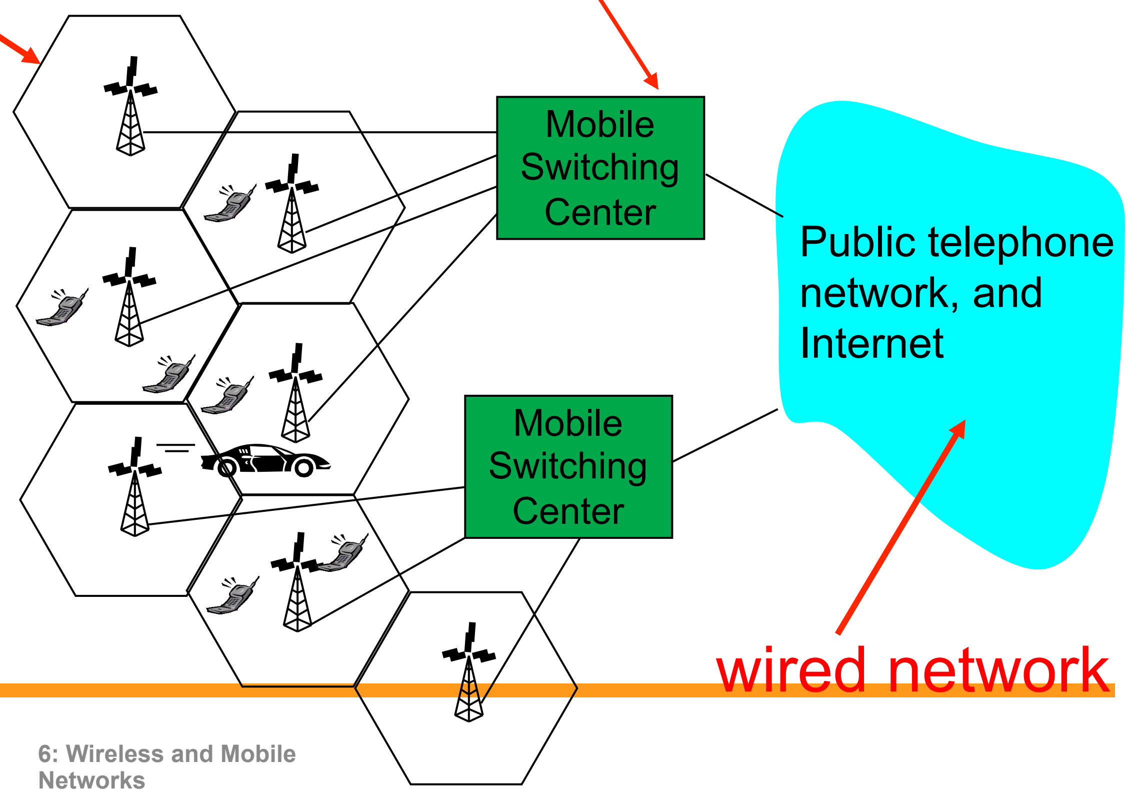
Components of cellular network architecture

MSC

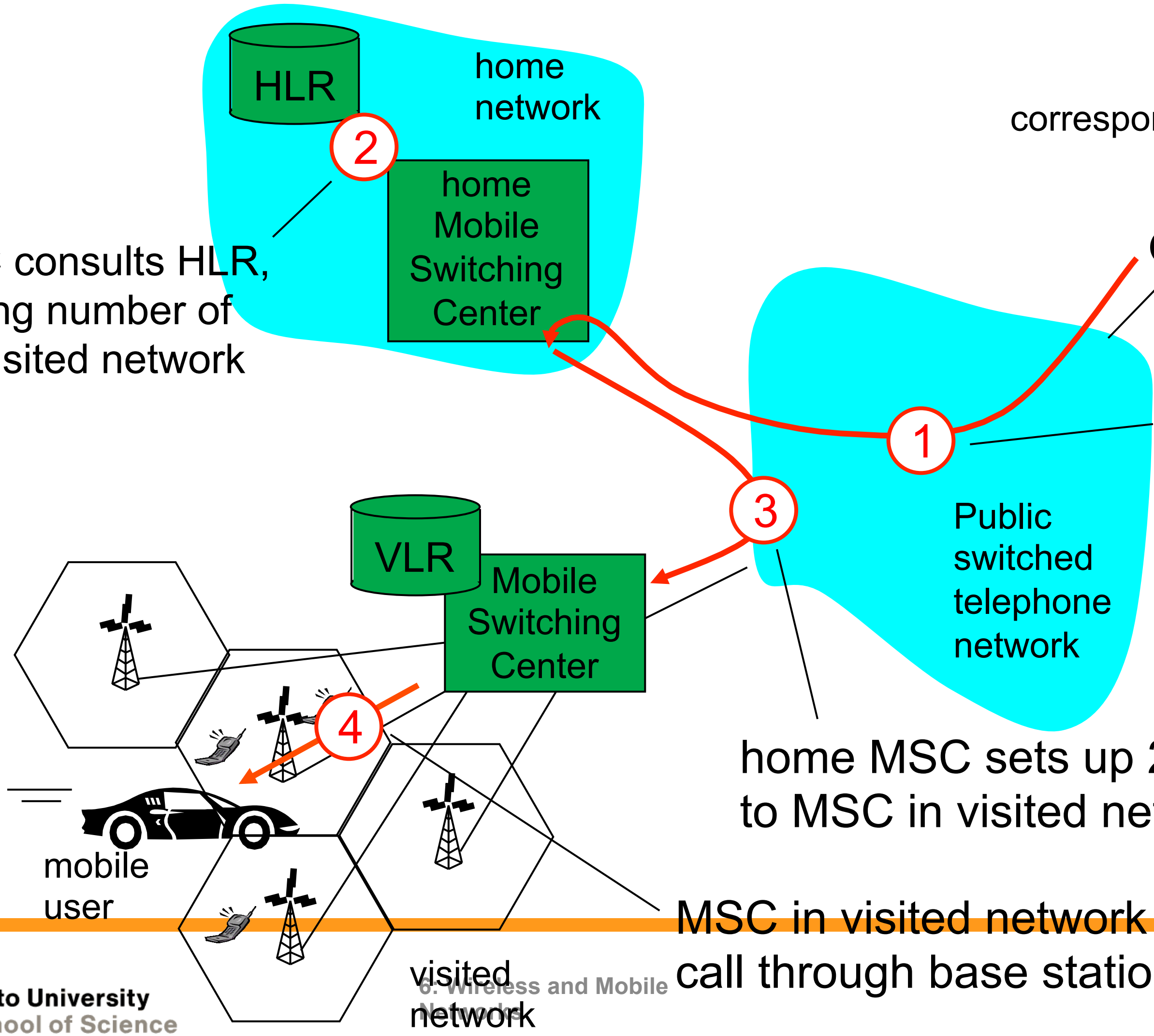
- connects cells to wide area net
- manages call setup
- handles mobility

cell

- covers geographical region
- *base station* (BS) analogous to 802.11 AP
- *mobile users* attach to network through BS
- *air-interface:* physical and link layer protocol between mobile and BS



GSM: indirect routing to mobile



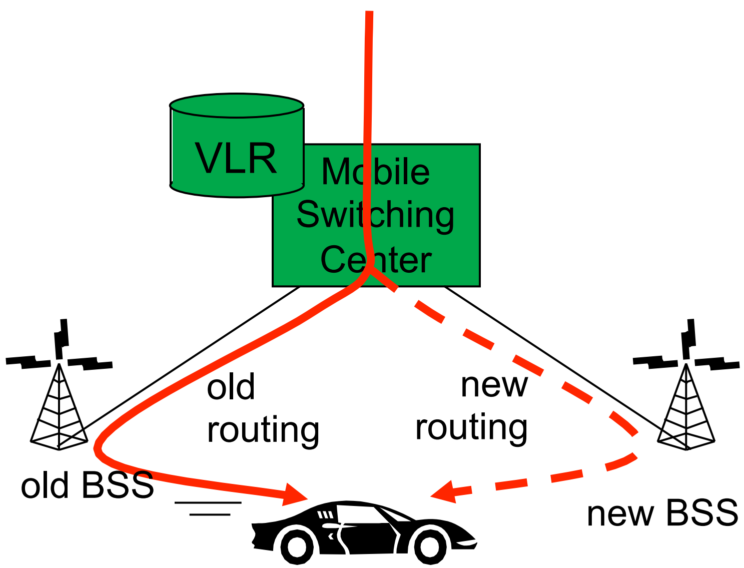
home MSC consults HLR, gets roaming number of mobile in visited network

call routed to home network

home MSC sets up 2nd leg of call to MSC in visited network

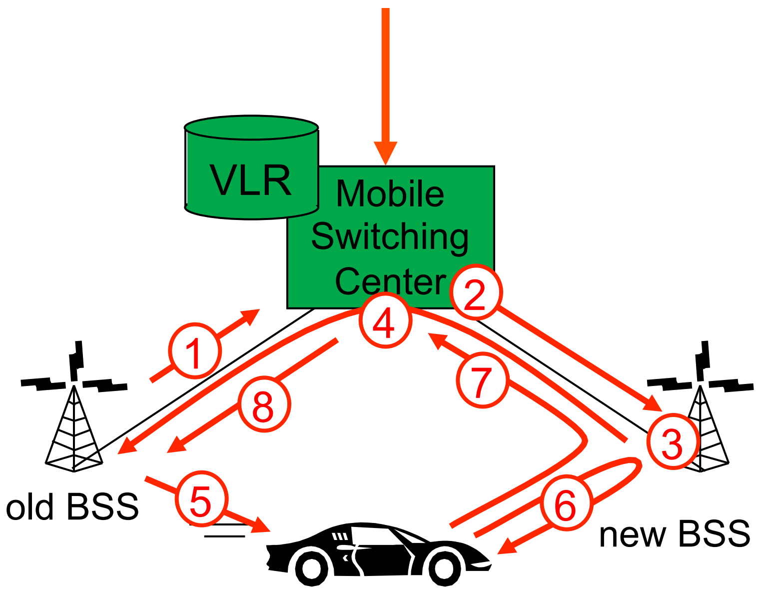
MSC in visited network completes call through base station to mobile

GSM: handoff with common MSC



- Handoff goal: route call via new base station (without interruption)
- reasons for handoff:
  - stronger signal to/from new BSS (continuing connectivity, less battery drain)
  - load balance: free up channel in current BSS
  - GSM doesn't mandate why to perform handoff (policy), only how (mechanism)
- handoff initiated by old BSS

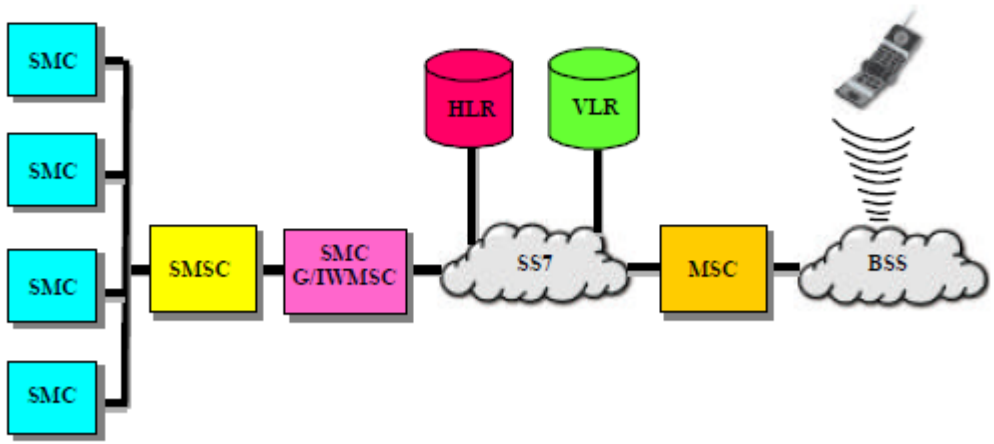
GSM: handoff with common MSC



1. old BSS informs MSC of impending handoff, provides list of 1^+ new BSSs
2. MSC sets up path (allocates resources) to new BSS
3. new BSS allocates radio channel for use by mobile
4. new BSS signals MSC, old BSS: ready
5. old BSS tells mobile: perform handoff to new BSS
6. mobile, new BSS signal to activate new channel
7. mobile signals via new BSS to MSC: handoff complete. MSC reroutes call

8 MSC-old-BSS resources released

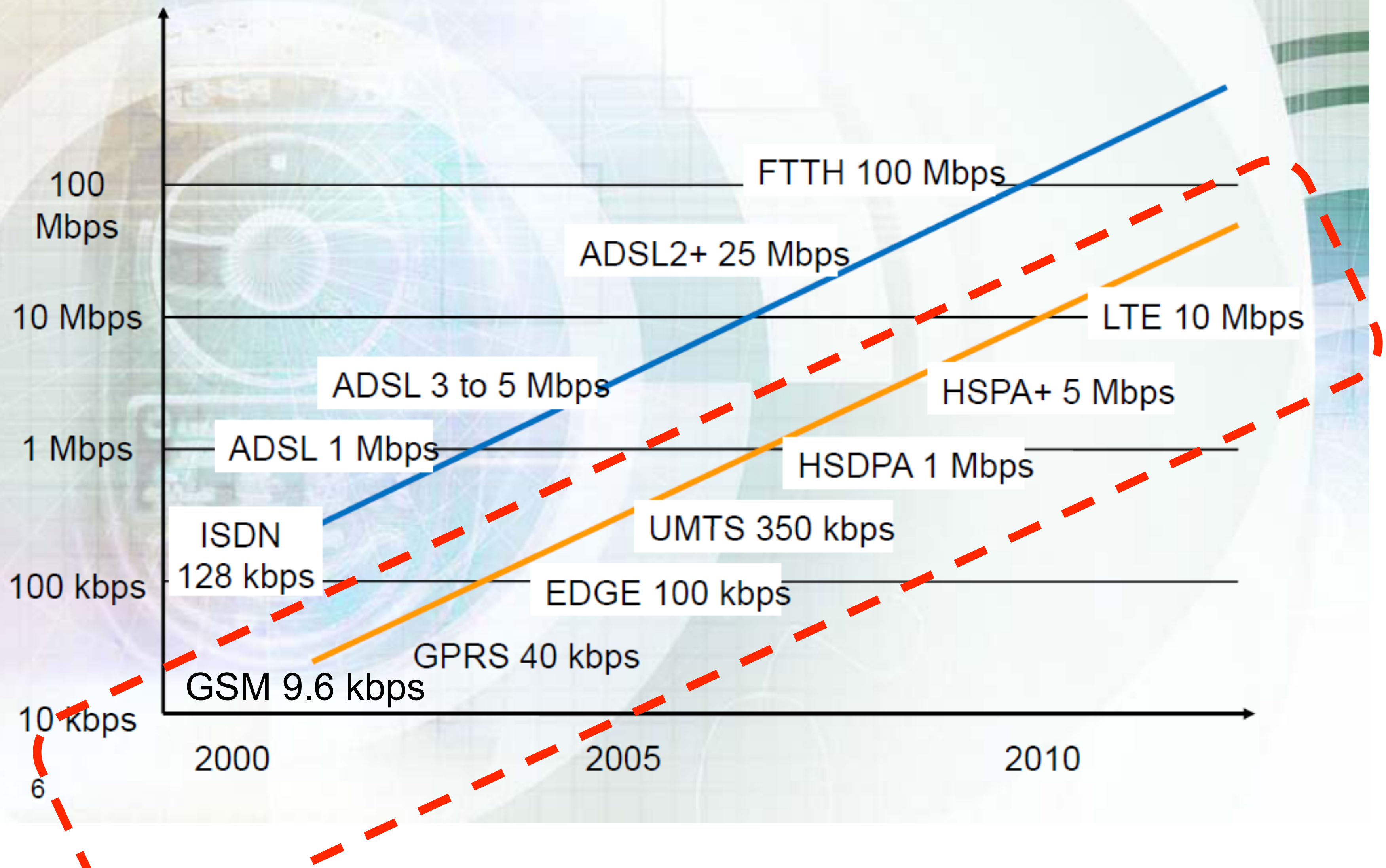
SMS text messaging service



- SMC (short message center) stores and forwards the text messages
- Detection of phone location in the same way as in call formation

Mobile data

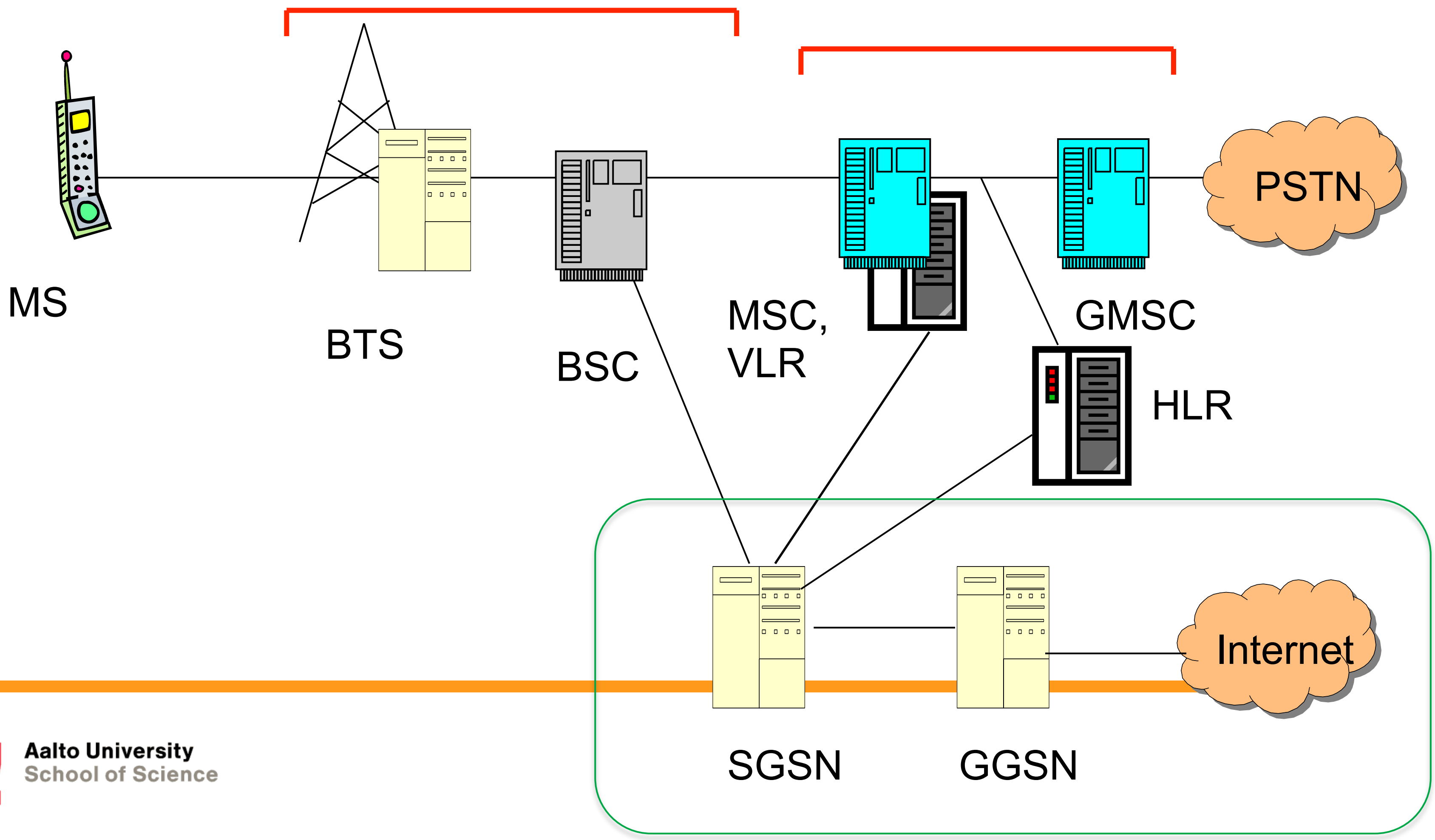
Wireline and Wireless Advances



Targets for cellular data transfer

- High bit rate
- Low latency
- Efficient use of resources when transferring data (which in many cases is bursty)
- Billing based on amount of data (instead of time connected)
- Small resource requirements for mobile and small energy consumption

GPRS

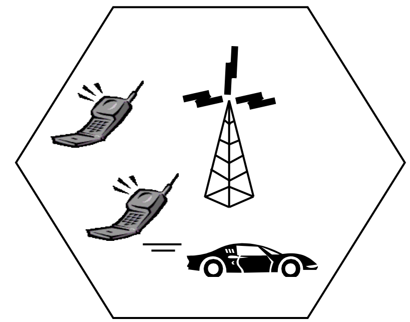


New GPRS elements

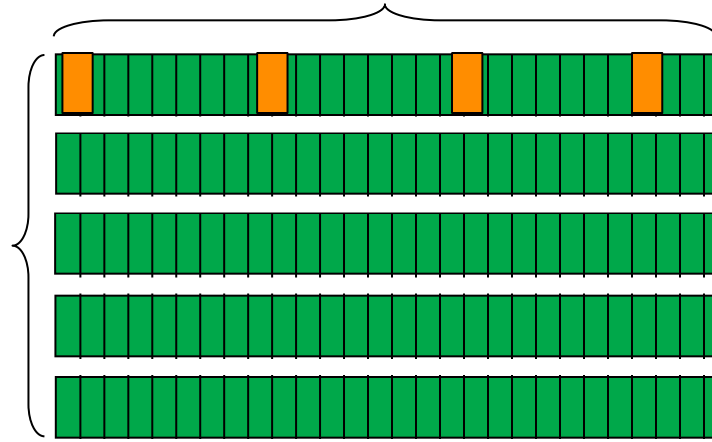
- Serving GPRS Support Node (SGSN) is a router
  - Keeps track of mobile location
  - Forwards the traffic
  - Handles billing
  - Identifies mobile and executes other management activities
- Gateway GPRS Support Node (GGSN)
  - Forwards traffic to other networks, in particular IP-packets to Internet
  - Allocates IP address to mobile
    - IP address does not change even if user moves
- Utilizes the GSM mechanisms such as VLR ja HLR

GSM radio interface

Speed: 9.6 kbps



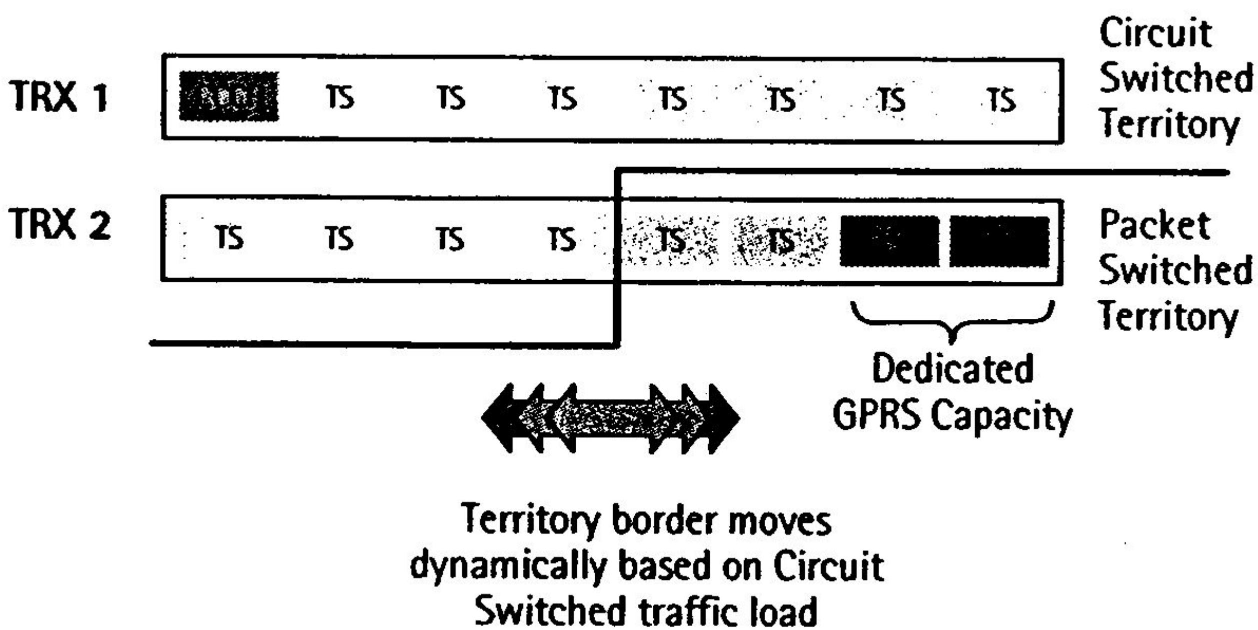
- Combination of FDMA (Frequency Division Multiple Access, taajuusjako) ja TDMA (Time Division Multiple Access)
- Each cell has fixed frequency
- Each call uses negotiated timeslots



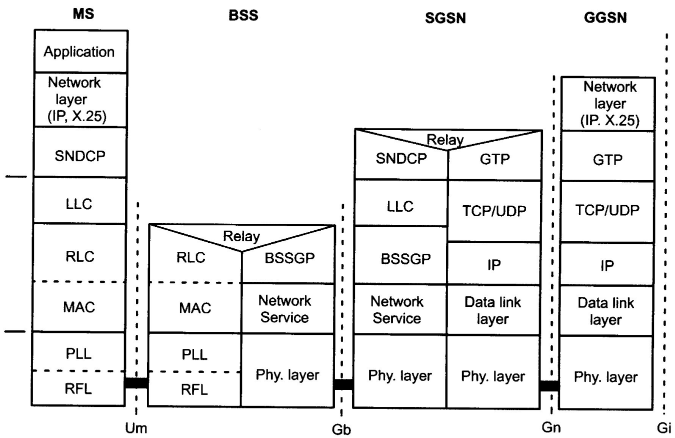
- Problem for fast data transfer: more timeslots would be needed but only for the duration of the databurst

GPRS: Dynamic allocation of time slots -> more speed

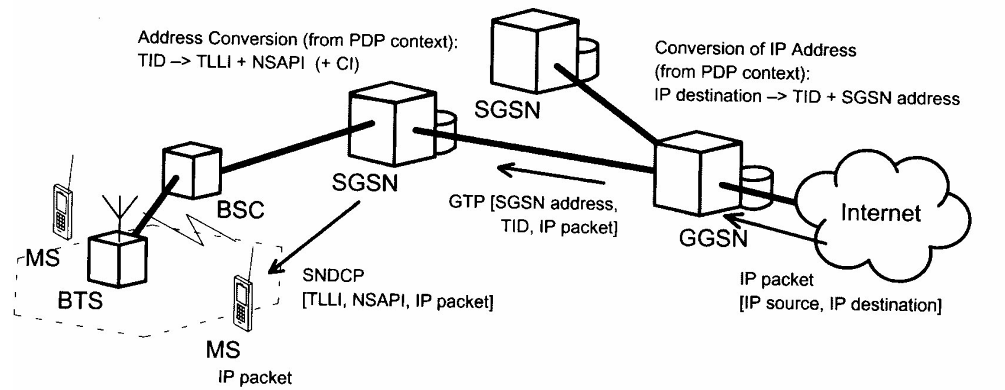
- Takes a number of free timeslots into use when there are packets in the queue (e.g. 50 kbit/s with 4 timeslots)
- Dynamic allocation and freeing of timeslots
  - Voice has priority



Mobile and IP: Routing in GPRS (example)

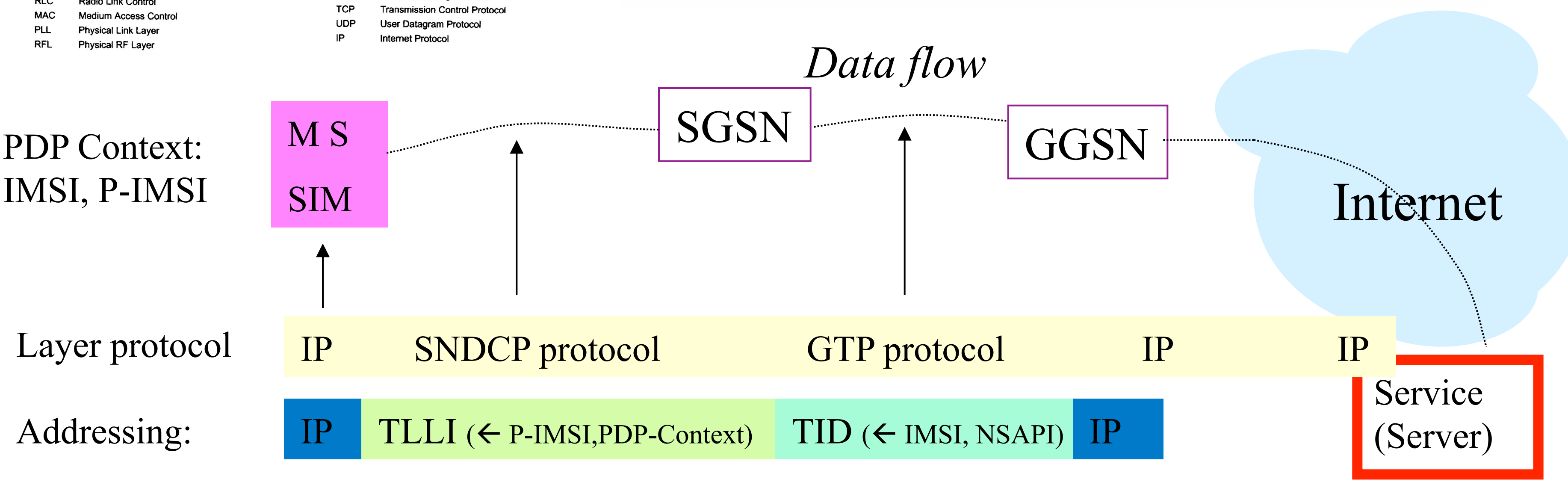


SNDCP	Subnetwork Dependent Convergence Protocol
LLC	Logical Link Control
RLC	Radio Link Control
MAC	Medium Access Control
PLL	Physical Link Layer
RFL	Physical RF Layer
BSSGP	BSS GPRS Application Protocol
GTP	GPRS Tunneling Protocol
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
IP	Internet Protocol



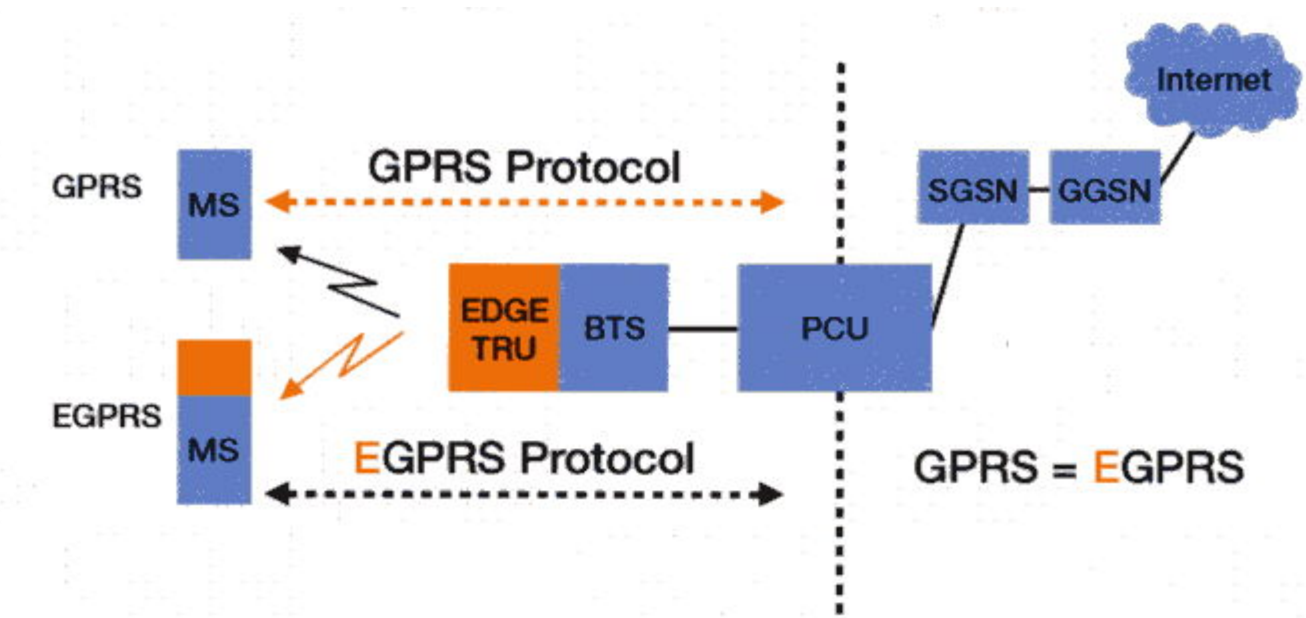
Adresses:

IP Destination address	
TID	Tunnel Identifier
SGSN Address	IP Address of SGSN
TLLI	Temporary Logical Link Identity
NSAPI	Network Layer Service Access Point Identifier
CI	Cell Identifier

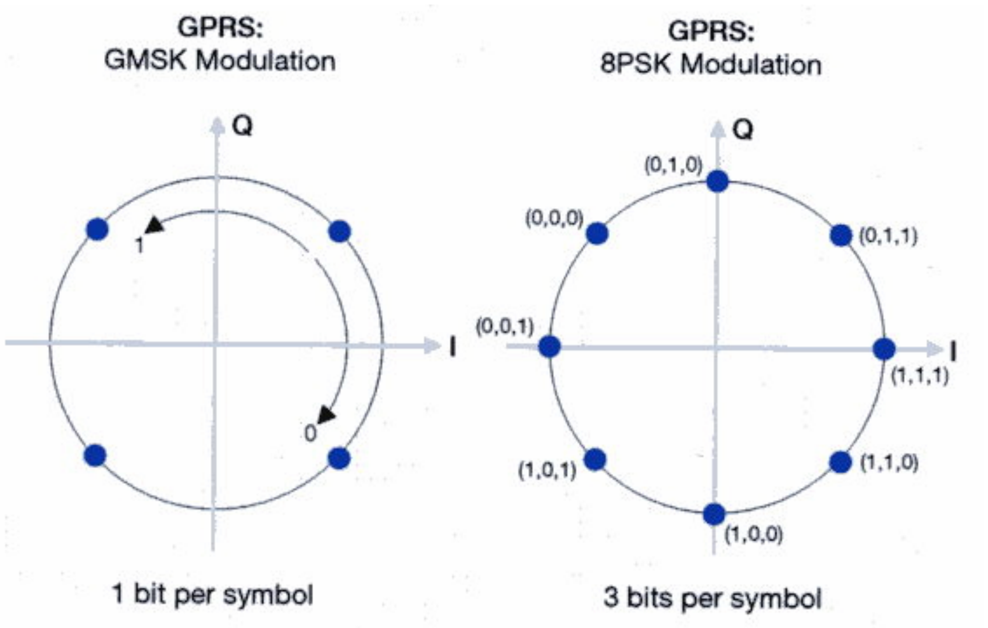


EDGE

- Enhanced Data rate for GSM Evolution
- Like GPRS but faster with new modulation
  - 40 kbps -> 115 kbps
  - Data rates depend on context (other users, distance from basestation)

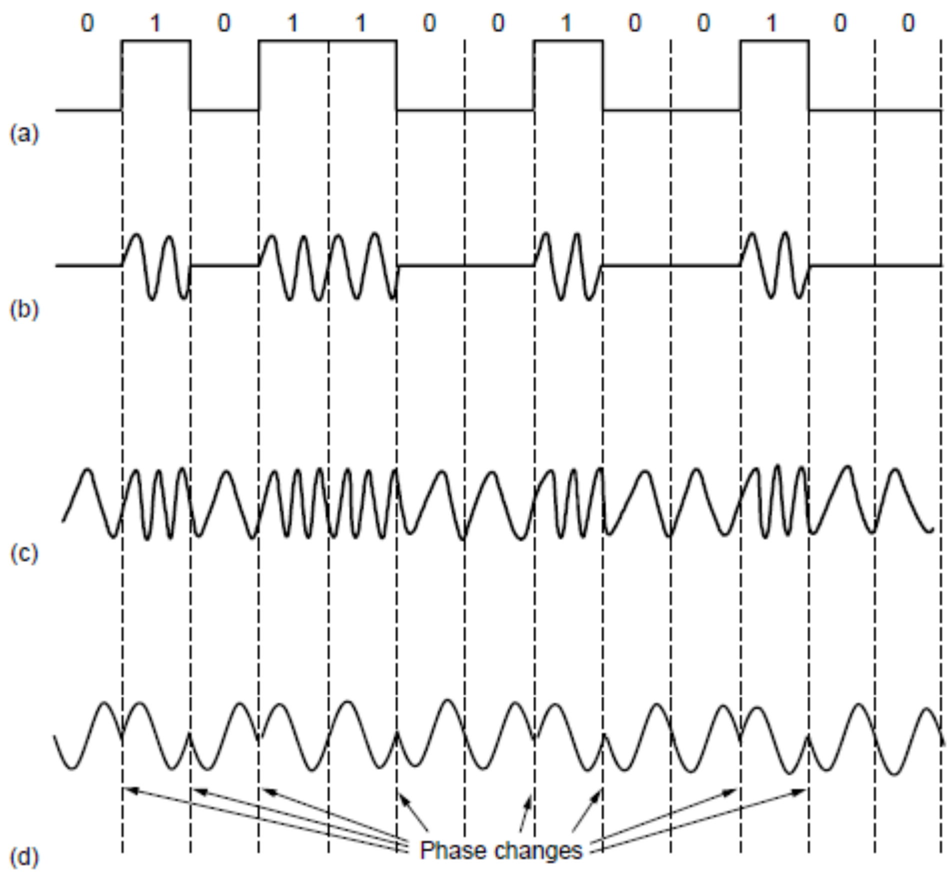


Modulation change



- 1 bit per symbol -> 3 bits per symbol

Passband Transmission (1)



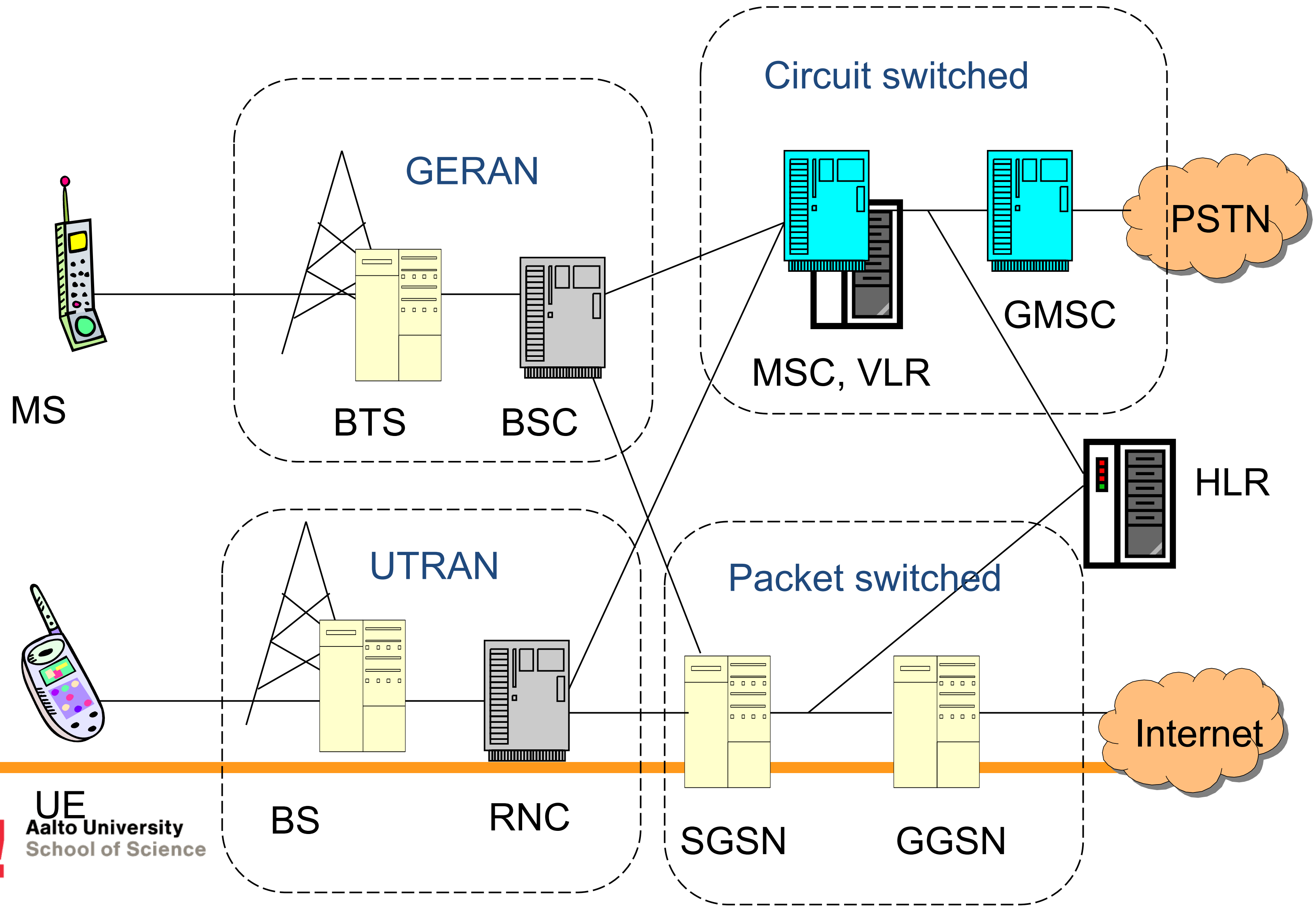
How big phase change is done?

(a) A binary signal. (b) Amplitude shift keying.
(c) Frequency shift keying. (d) Phase shift keying.

UMTS (3G)

- Universal Mobile Telecommunications System
  - Also known as 3G
- Still higher data rates than in GSM/GPRS/EDGE
    - Data transfer with 2 Mb/s
    - In practice often much less
- More efficient utilization of radio resources with WCDMA technology

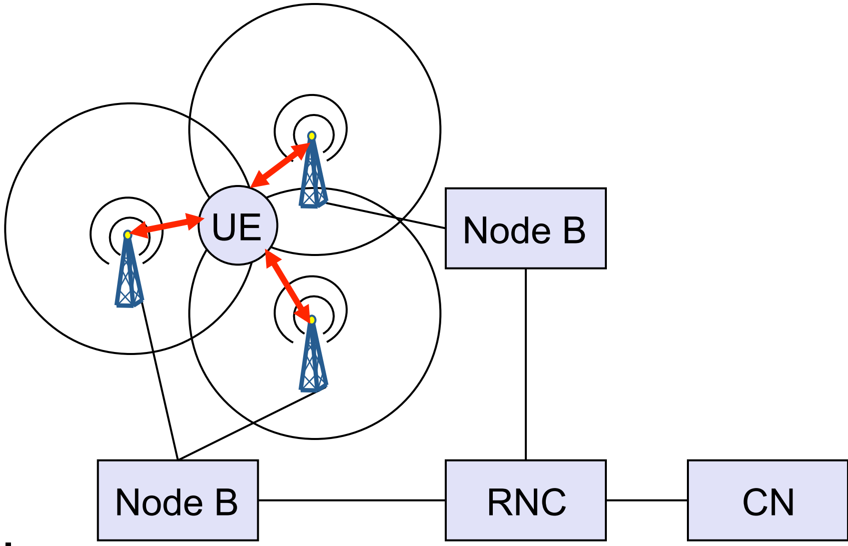
UMTS



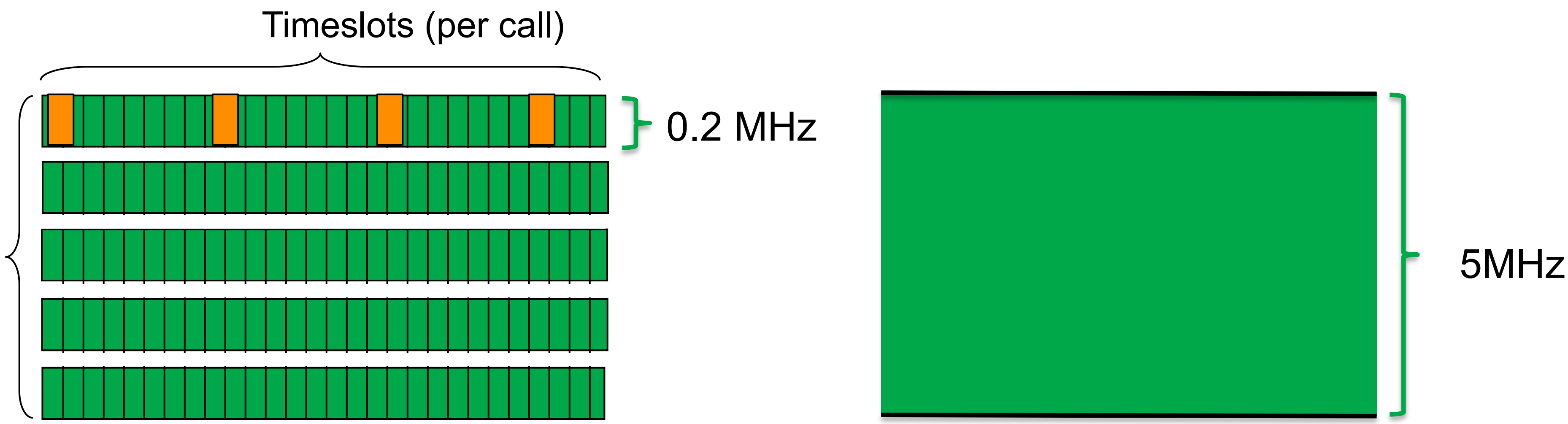
Circuit switched
GERAN
PSTN
GMSC
MSC, VLR
MS
BTS
BSC
HLR
UTRAN
Packet switched
Internet
UE
BS
RNC
SGSN
GGSN

UMTS radio interface

- CDMA, Code Division Multiple Access
- All base stations use the same frequency
- Each user has his own code
- When codes are properly selected multiple transmissions at the same time at the same frequency are possiblem
- One bit is coded into multiple symbols which the receiver of the proper code is able to detect from background noise



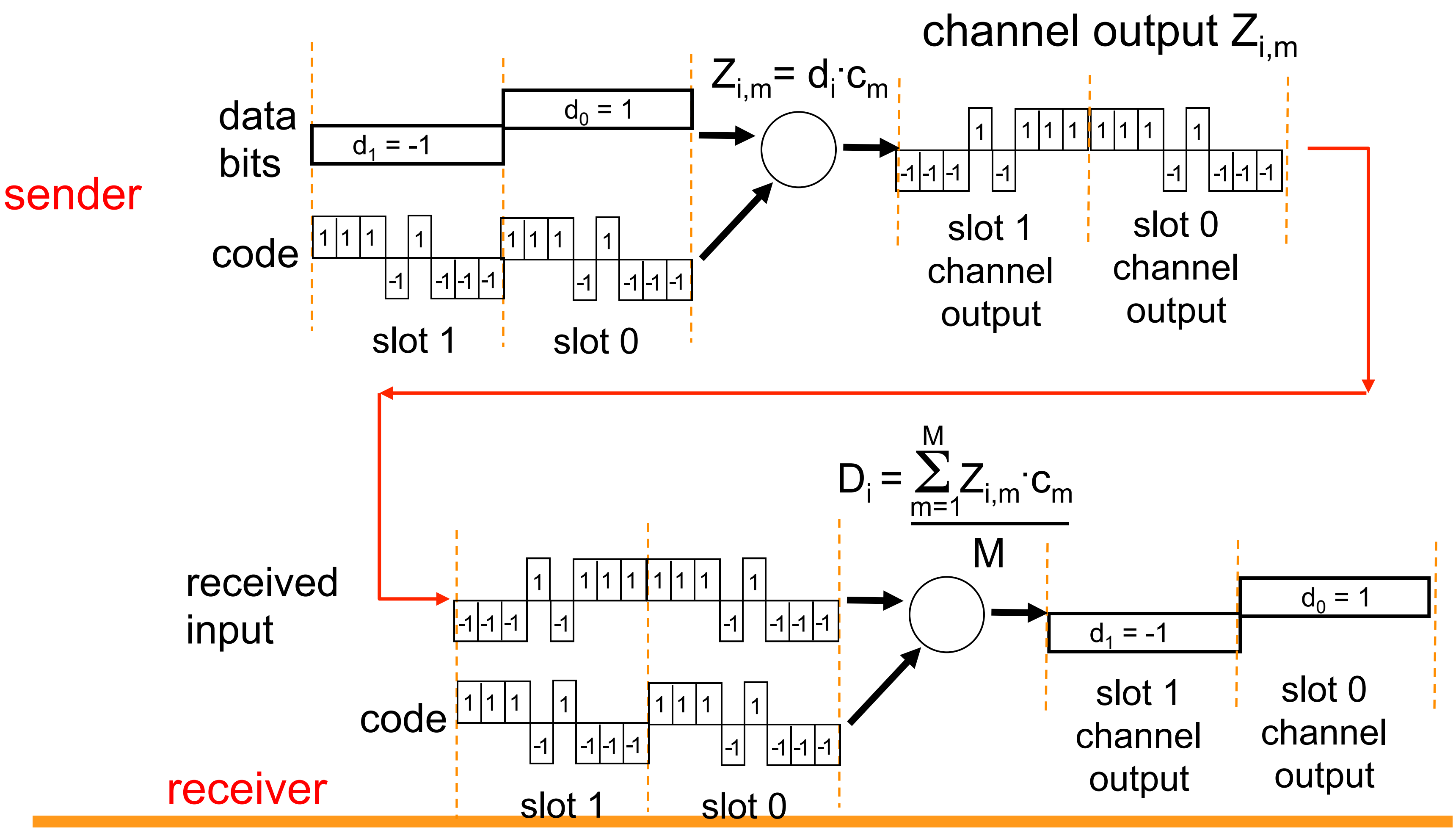
GSM vs. UMTS radio interface



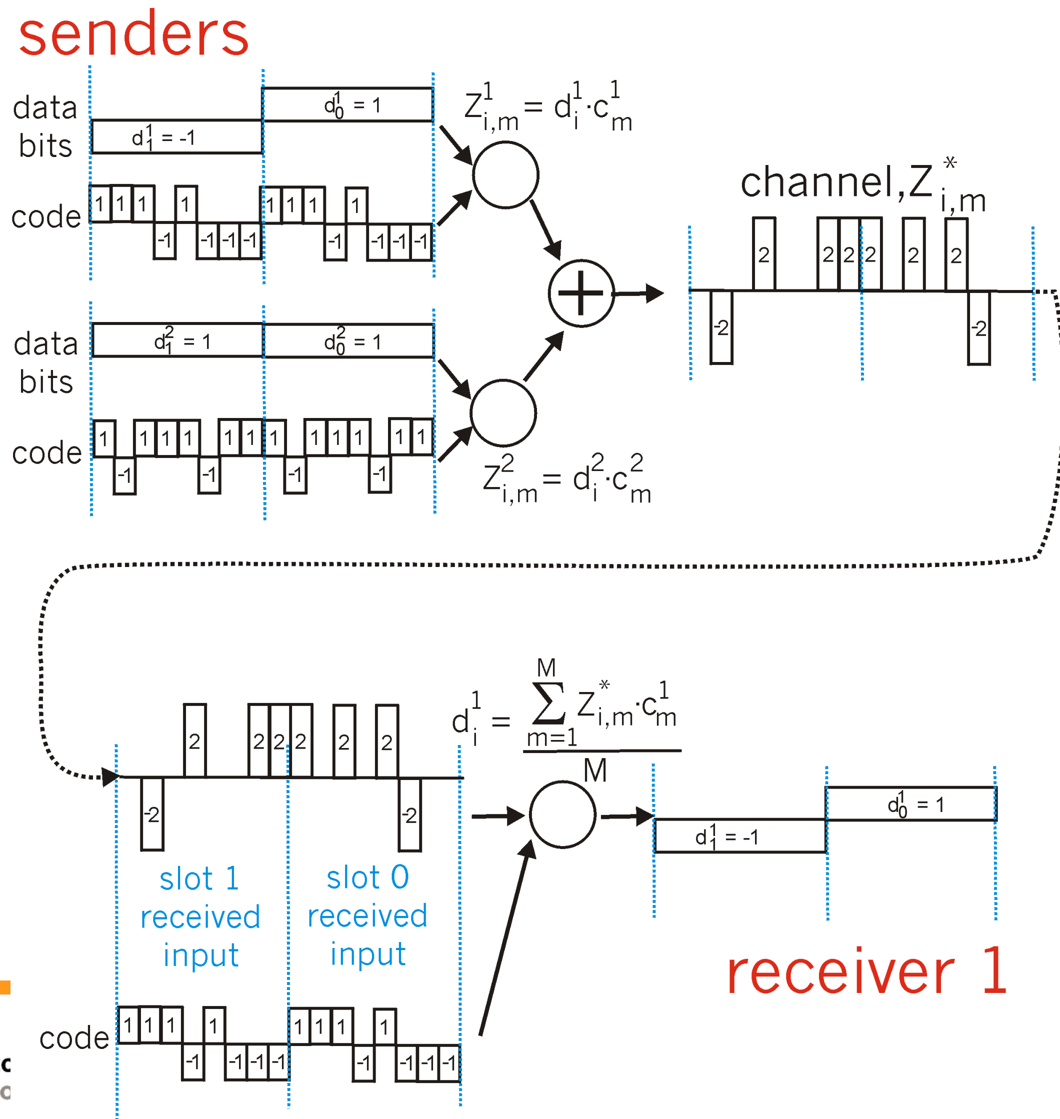
GSM
Each person at a different time
Each base station (in a region)
with a different frequency

UMTS
Everybody at the same time
Wide channel => high bitrate
(Nyquist formula)

CDMA Encode/Decode



CDMA: two-sender interference

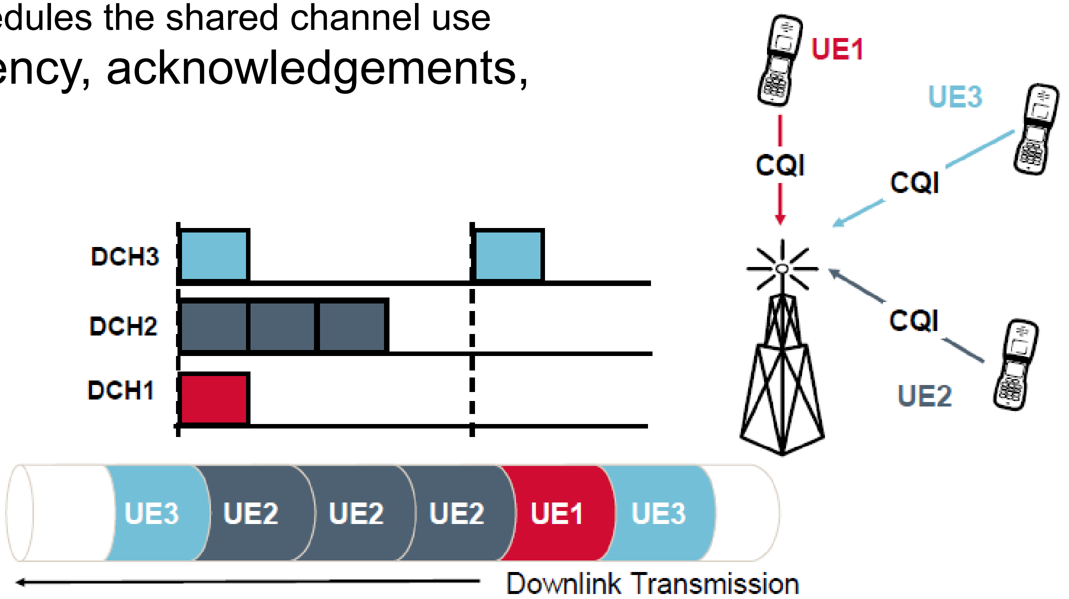


CDMA – Why it makes sense?

- Symbol speed (chip rate) 3.84 Mchip/s
- Number of available code 512, if 512 symbols are used to transfer a bit
  - Then bitrate1.7 kbit/s (too slow even for voice)
- Faster speeds by having smaller number of symbols per bit
  - 256 symbols -> 5.51 kbit/s (voice)
  - 8 symbols -> 384 kbit/s
- The smaller the symbol the less simulateous users
  - 8 symbols/bit => 7 users
  - 256 symbols/bit => 255 users
- The systems adjusts the allocation of symbols based on user number and data transfer needs

HSDPA (3.5G)

- High Speed Downlink Packet Access
- 1.8, 3.6, 7.2 and 14.4 Mbit/s (42 & 84 Mbit/s with HSPA+)
- A step back to time division
  - In UMTS each user has his own code
  - In HSDPA a number of users have the same code but traffic is divided in different time points
    - High Speed Downlink Shared Channel
    - The system dynamically schedules the shared channel use
  - Other improvements in latency, acknowledgements, modulation, etc

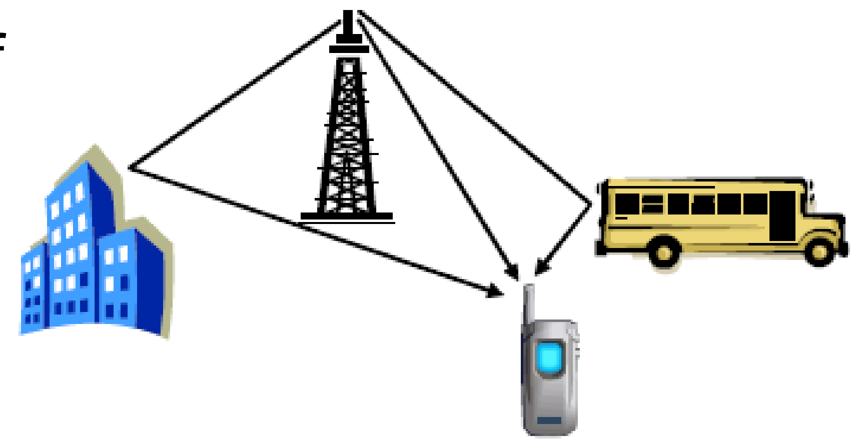


LTE

- Only packet data (Voice ->VoIP)
- Less network elements (RNC level removed)
- Applies many new radio and antenna techniques (OFDM, MIMO)
- First test networks in use
  - No phones, only data dongles (in Finland, phones also in US, Korea, and some other countries)

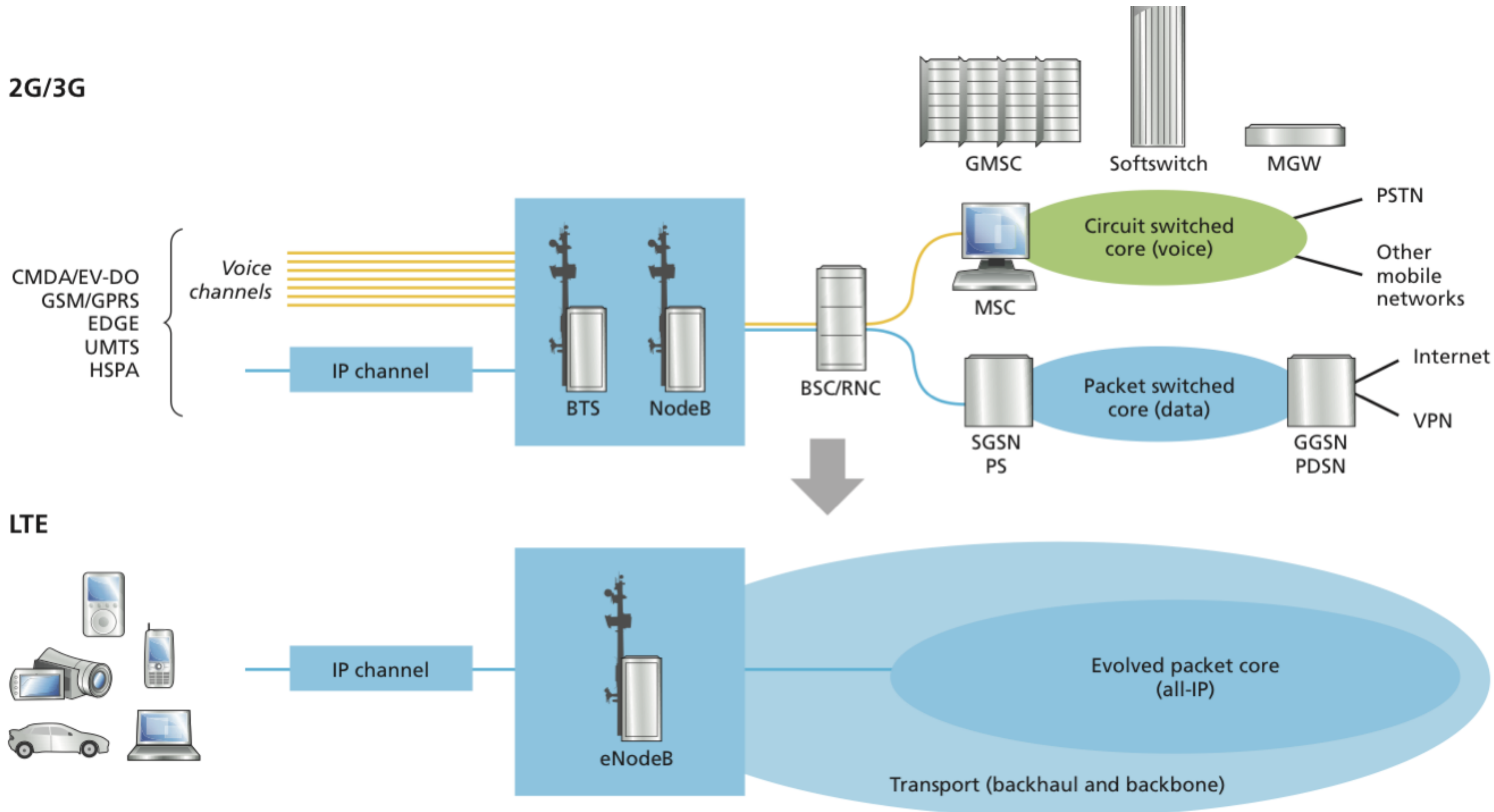
LTE **radio interface**

- Increasing the chip rate in WCDMA is difficult because of multipath propagation (signals reaching phone through different paths come at different times)
- Based OFDMA (Orthogonal Frequency-Division Multiple Access) teknology
  - Whole channel distributed to narrow subchannels
  - Multiple subchannels used in parallel for faster bitrate
  - Different users transfer data at different times



- Multipath propagation

LTE Architecture



LTE Throughput in Test Network

Base station located at **X**.

L1 Throughput
Max: 154 Mbps
Mean: 78 Mbps
Min: 16 Mbps

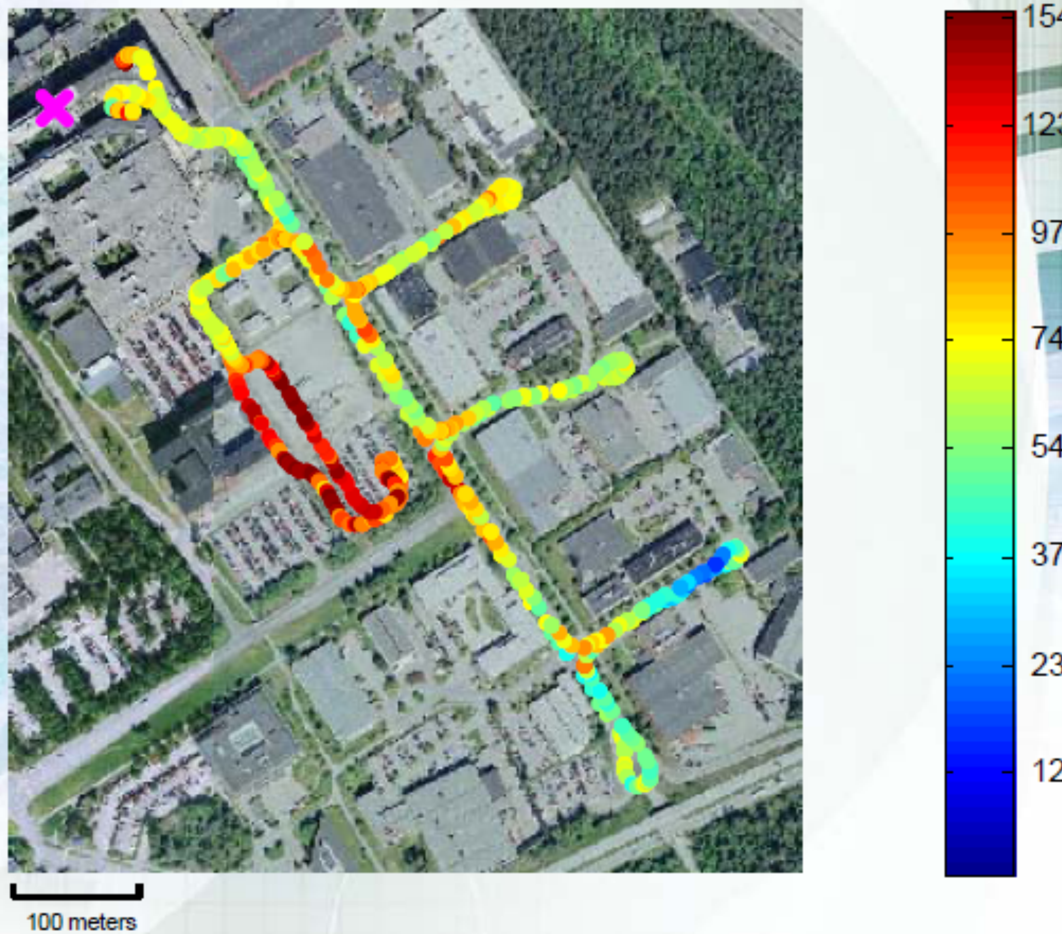
User Speed
Max: 45 km/h
Mean: 16 km/h
Min: 0 km/h

Sub-urban area with line-of-sight: less than 40% of the samples

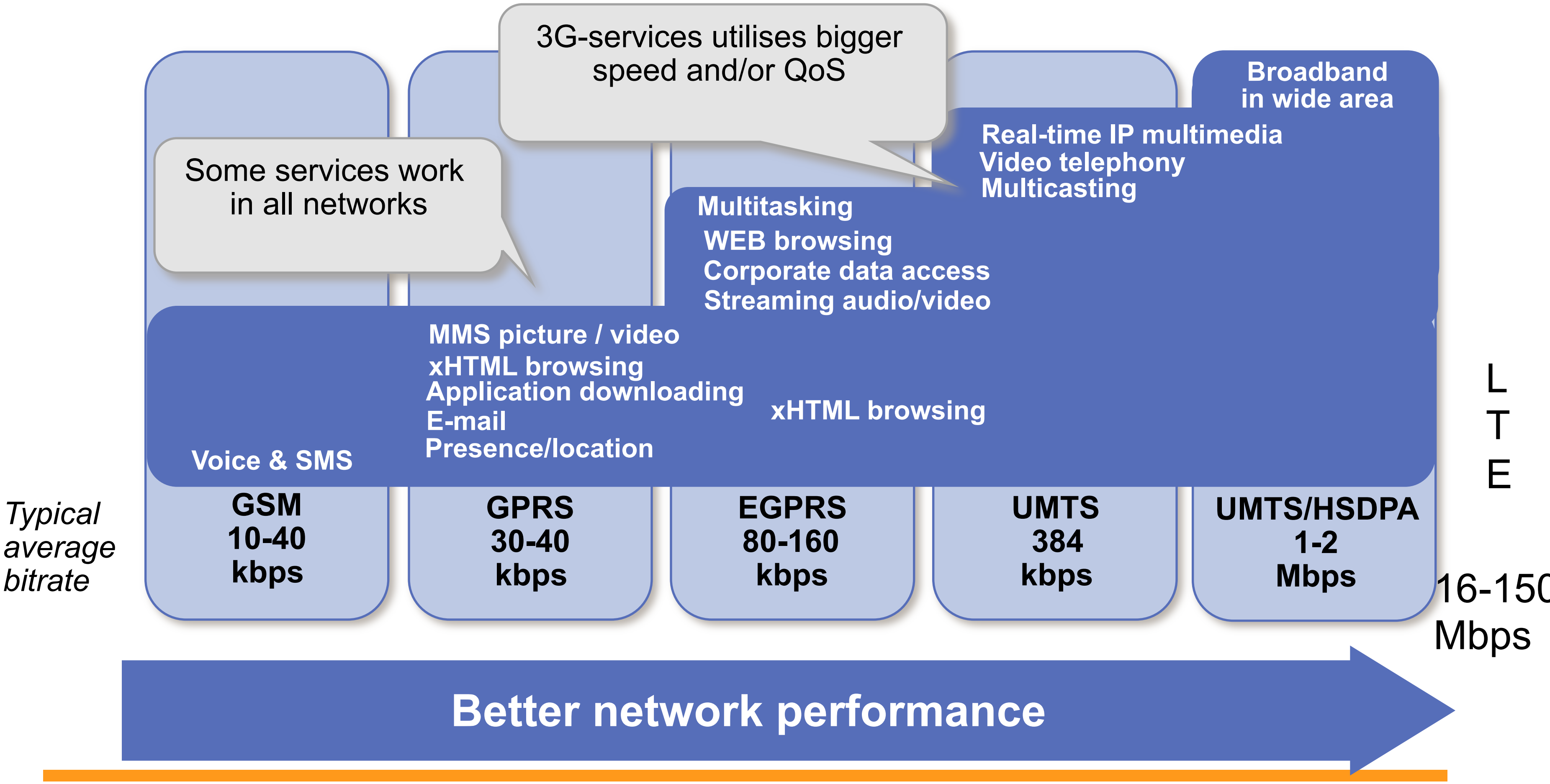
Heights of surrounding buildings: 15-25 m

20 MHz Channel

2X2 MIMO



New services with UMTS



Remember that there are other radios than cellular

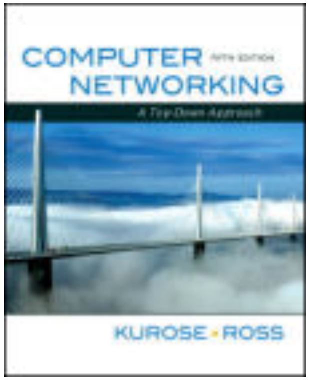
- WLAN
- Bluetooth
  - Bluetooth low energy (BLE)
- RFID
  - Near field communication

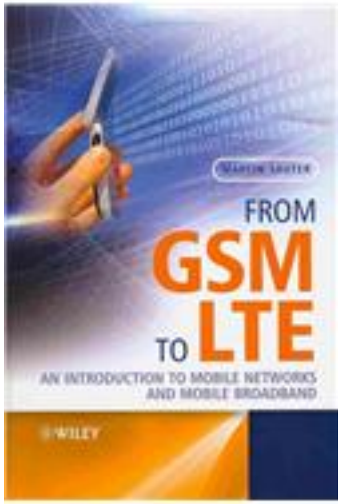
Present now or near future in mobile phones

- WiMax
- ZigBee

To Read More

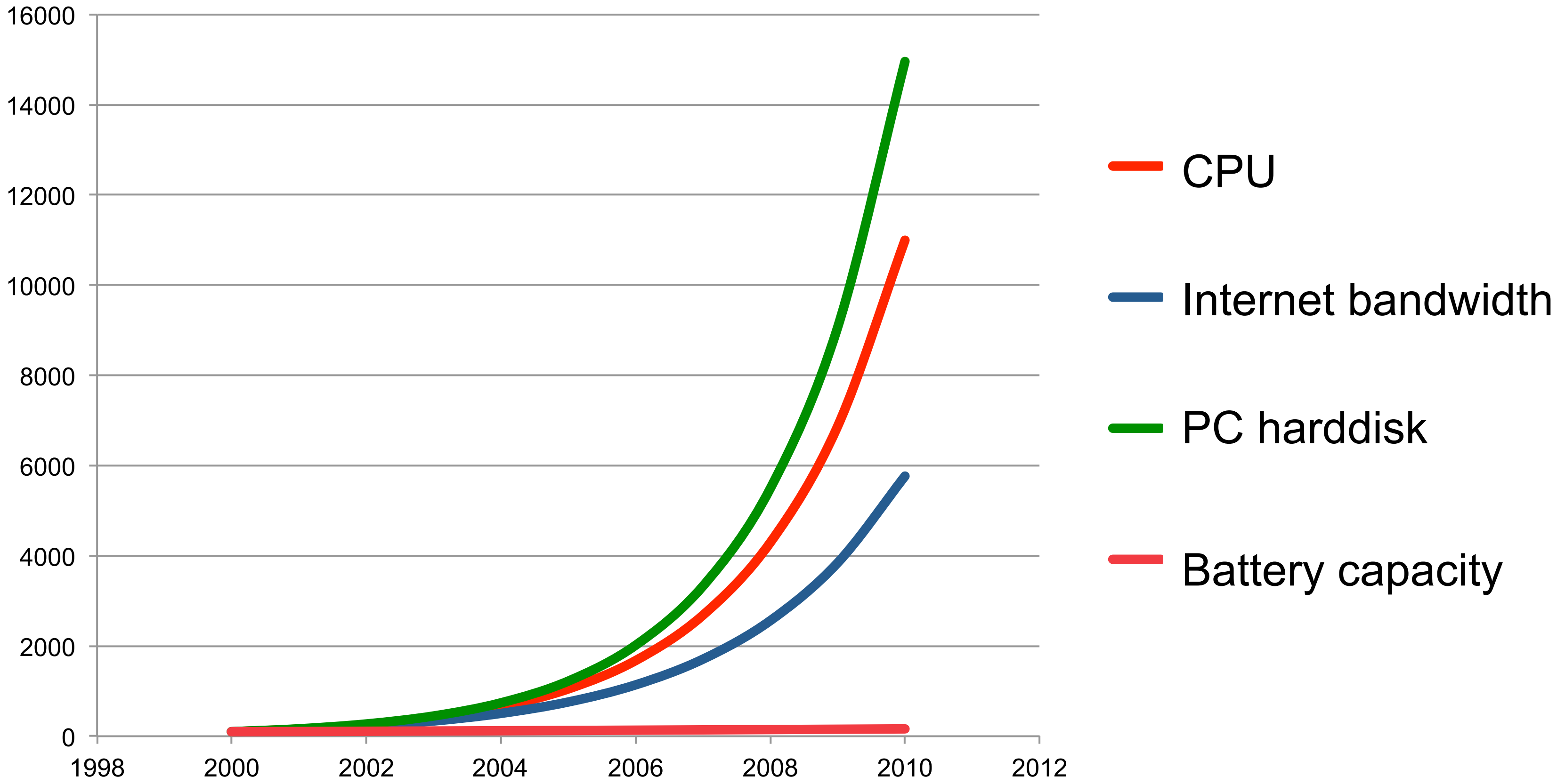
- *Computer Networking: A Top Down Approach Featuring the Internet (5th ed.)*, J.F. Kurose and K.W. Ross, Addison-Wesley Longman
  - 6.2 CDMA
  - 6.4 Cellular internet access
  - 6.7 Managing mobility in cellular networks
- *From GSM to LTE,* Martin Sauter, John Wiley & Sons Inc
- Courses at electrical engineering department at Aalto





Energy efficiency

High exponential growth of most resources – except battery capacity



Power consumption of streaming in 3G phone

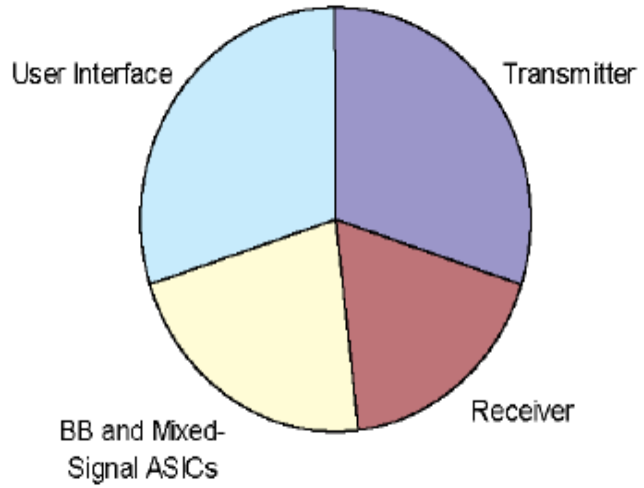
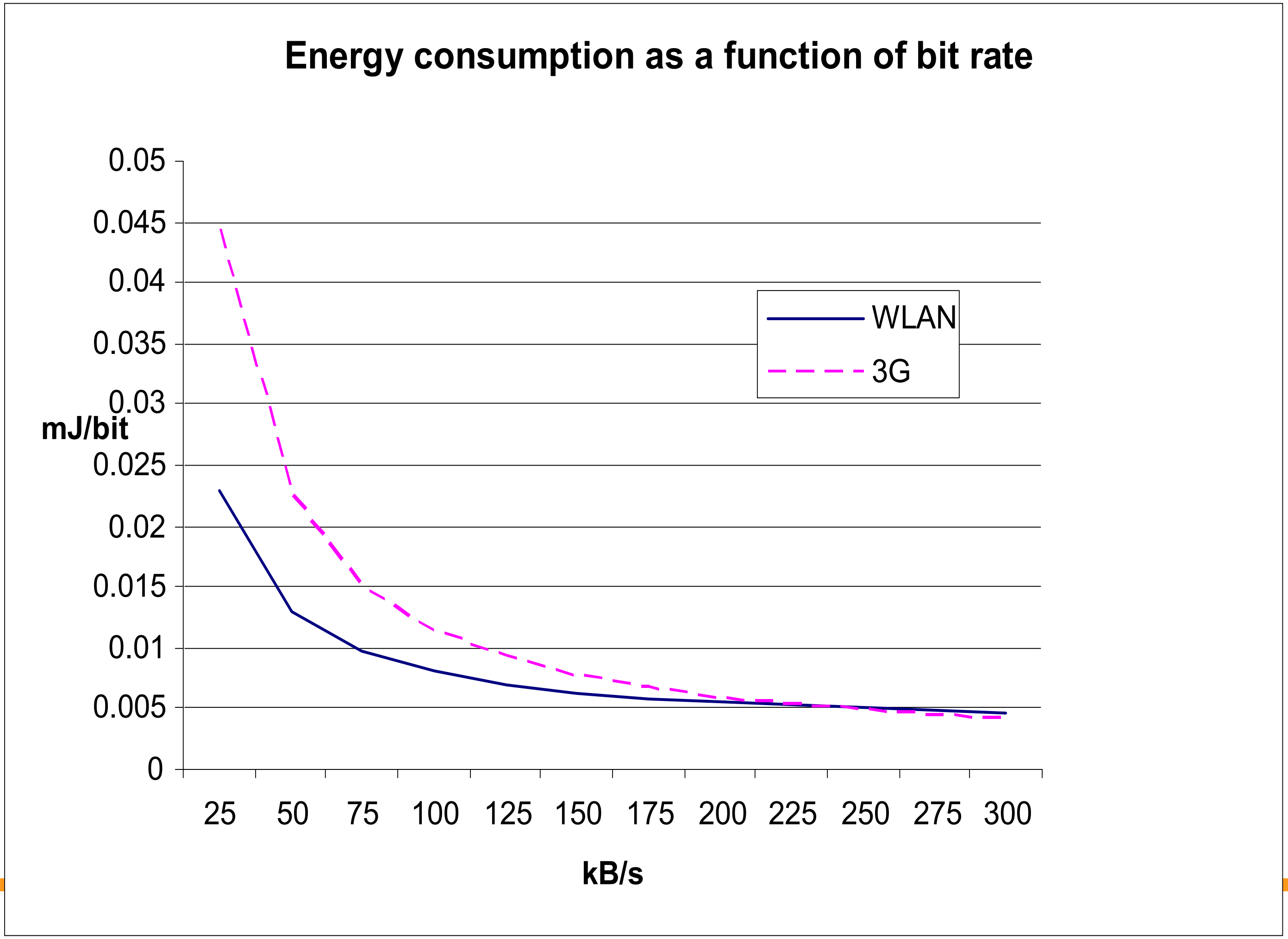


Figure 1.3.7: Power consumption break down in video streaming in a 3G phone.

Neuvo, Y., "Cellular phones as embedded systems," *Solid-State Circuits Conference, 2004. Digest of Technical Papers. ISSCC. 2004 IEEE International* , vol., no., pp. 32-37 Vol.1, 15-19 Feb. 2004

Higher bit rate -> more energy-efficient

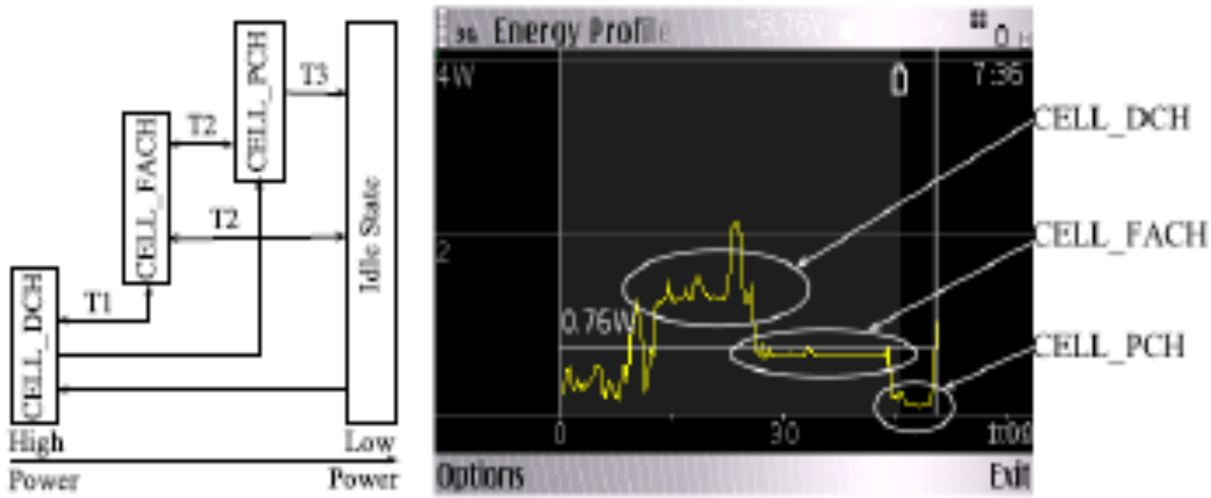


Communication
Same average bitrate different traffic pattern

0.99W

0.53W

3G Energy Consumption (Tail energy p



(a) WCDMA 3G States (b) Power Consumption with Nokia E-71

Figure 1: 3G States and Power Consumption

- Data transfer in DCH (dedicated channel) state
- After data transfer is complete it takes seconds to return to idle state. The actual depends on your cellular operator (e.g. Elisa 2s+2s, some US operator 12.5s)