UNIK4230: Mobile Communications

Spring Semester, 2015

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Tentative lecture schedule- UNIK4230

Spring Semester, 2015

Uke:	Dato:	Tema:
4	**22.01.2015**	**Introduction**
5	29.01.2015	*No lecture*
6	**05.02.2015**	**Network Architecture and functionality**
7	**12.02.2015**	**Propagation characteristics of wireless channels**
8	19.02.2015	*No lecture, Winter holidays*
9	**26.02.2015**	**Combating effects of fading in mobile systems**
10	05.03.2015	*No lecture*
11	**12.03.2015**	**Cells and cellular traffic**
12	**19.03.2015**	**Multiple access**
13	**26.03.2015**	**Mobile Broadband**
14	02.04.2015	*No lecture, Easter week*
15	**09.04.2015**	**Student seminar; presentations**
16	16.04.2015	*No lecture*
17	**23.04.2015**	**Guest lecture, topic to be defined**
18	**30.04.2015**	**Management of radio spectrum**
19	07.05.2015	*No lecture*
20	14.05.2015	*No lecture, Ascension day*
21	**21.05.2015**	**Small cells and Heterogeneous networks**
22	**28.05.2015**	**Repetion, walk through and exam guidance**
23	04.06.2015	*No lecture*
24	**11.06.2015**	**Examination (oral)**

Reference literature & examination

- **Lecture slides** (will be uploaded before lectures):
  - http://cwi.unik.no/wiki/UNIK4230
- **Video streaming**:
  - mms://lux.unik.no/401
- **Video**s available after the lecture for replay:
  - http://lux.unik.no/UNIK4230-AK/UNIK-2015*mmdd*.wmv

- Book
  - P. M. Shankar, ´´*Introduction to Wireless Systems*``, 2002, Wiley.
    - Syllabus: chapter 2, 3, 4, 5 & 6
    - Do you need a copy of the chapters?
  - Harri Holma and Antti Toskala , *"LTE for UMTS. Evolution to LTE-Advanced"*. 2nd Edition.

- Articles
  - Will be provided during lectures (when necessary)
- Examination type:
  - Oral examination (based on lecture slides, chapters of the course book, articles provided during lectures); if book chapter discusses more, contents in the lecture slide will limit the syllabus; however, lecture slides may contain more topics than the book chapter. In that case, follow the extra topics only from the slides and the articles (if given).
- Assignments
  - Presentation on selected topics

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Introduction

Date: 22.01.2015

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Importance of Telecommunication

Telekom er viktigere enn strøm og vei

Jeg ble veldig overrasket da jeg forsto for første gang at telekommunikasjon er viktigere enn strøm og vei. Vi kan klare oss uten strøm og vei, men telekom kan vi ikke klare oss uten.

-**Torstein Olsen**, direktør i Post- og teletilsynet informerte

-Source: dn.no. Publisert: 13.01.2012 - 16:40 Oppdatert

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Importance of Telecommunication

- Mobile Communications industry contributes to between 3.7 percent and 6.2 percent of GDP in the Telenor markets in Bangladesh, Pakistan, Thailand, Serbia and Ukraine.

- An increase of 10 percent in mobile penetration will boost the annual economic growth rate of a developing country by 1.2 percent.

according to a study by Deloitte for Telenor in Bangladesh, Pakistan, Thailand, Serbia and Ukraine in 2008

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Agenda

- What is mobile communication?
- History and trends
- Elements in mobile communication systems
- Basic functionality

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- What is mobile communication?
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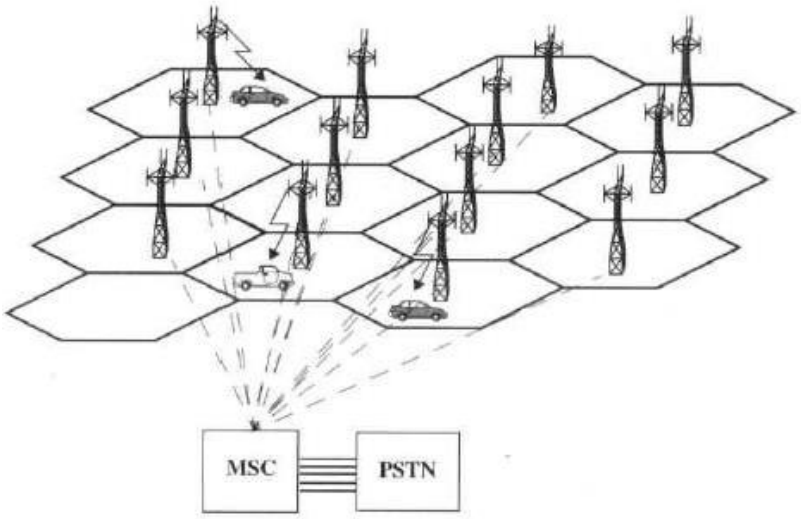
What is mobile communication?

- Mobile communication system allows communication to and from handheld devices during movement
- The system can handle a large number of users and provides almost a continuous coverage in a large geographical area
- Base station provides an area coverage
- The system has underlying infrastructure that provides communication to/from other type of communication networks



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Mobile Communication

- Mobile Device is most personalized device
- Voice, SMS
- Data/Internet
- Emergency (police, ambulance, fire)
- Payment
- M2M communication
- Entertainment (music, gaming)
- Social Network and life

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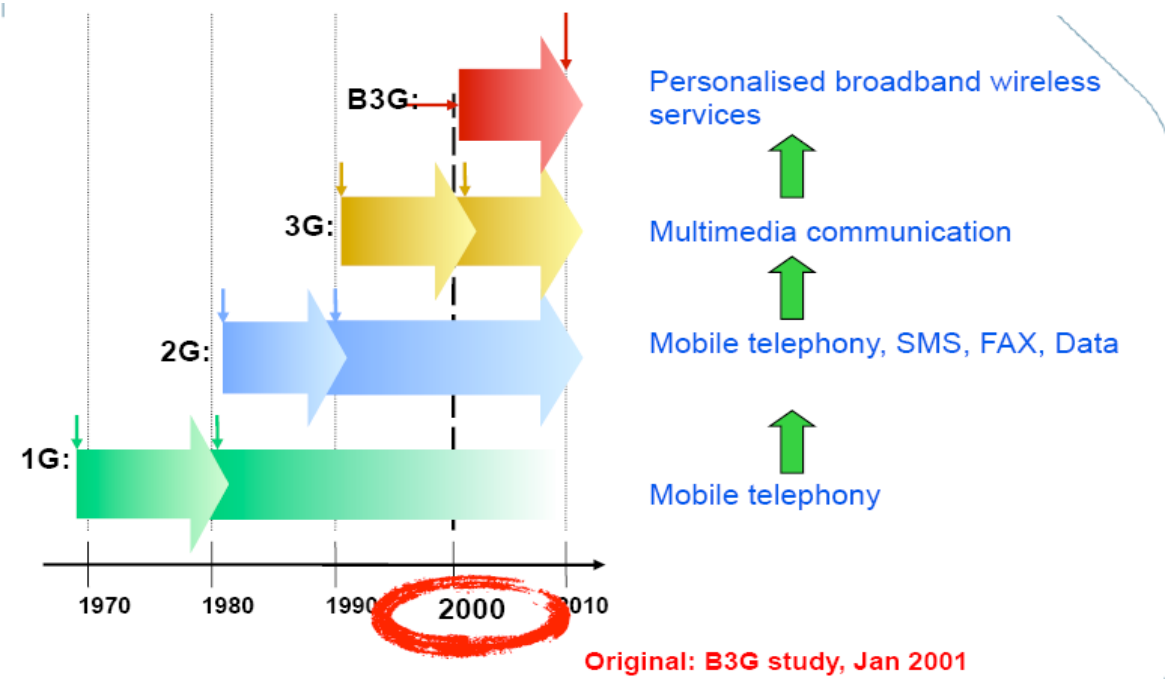
Generations in Mobile Communication



Original: B3G study, Jan 2001

1G – 1980s

Analog communication

Only voice

e.g NMT-450, AMPS

2G – 1990s

Digital communication

Mostly voice service, data service limited and low speed

e.g. GSM

3G – 2000s

Simultaneous voice and data

peak data rate at least 200 kbps (IMT-2000 specs.)

Latest UMTS release HSPA+ (Evolved HSPA): upto 84Mbit/s (DL), upto 22 Mbit/s (UL) -> 3.75G?

4G – 2010s

50-100 Mbit/s for high mobility communication

Mobile broadband

Next: LTE-A: 1 Gbit/s for low mobility

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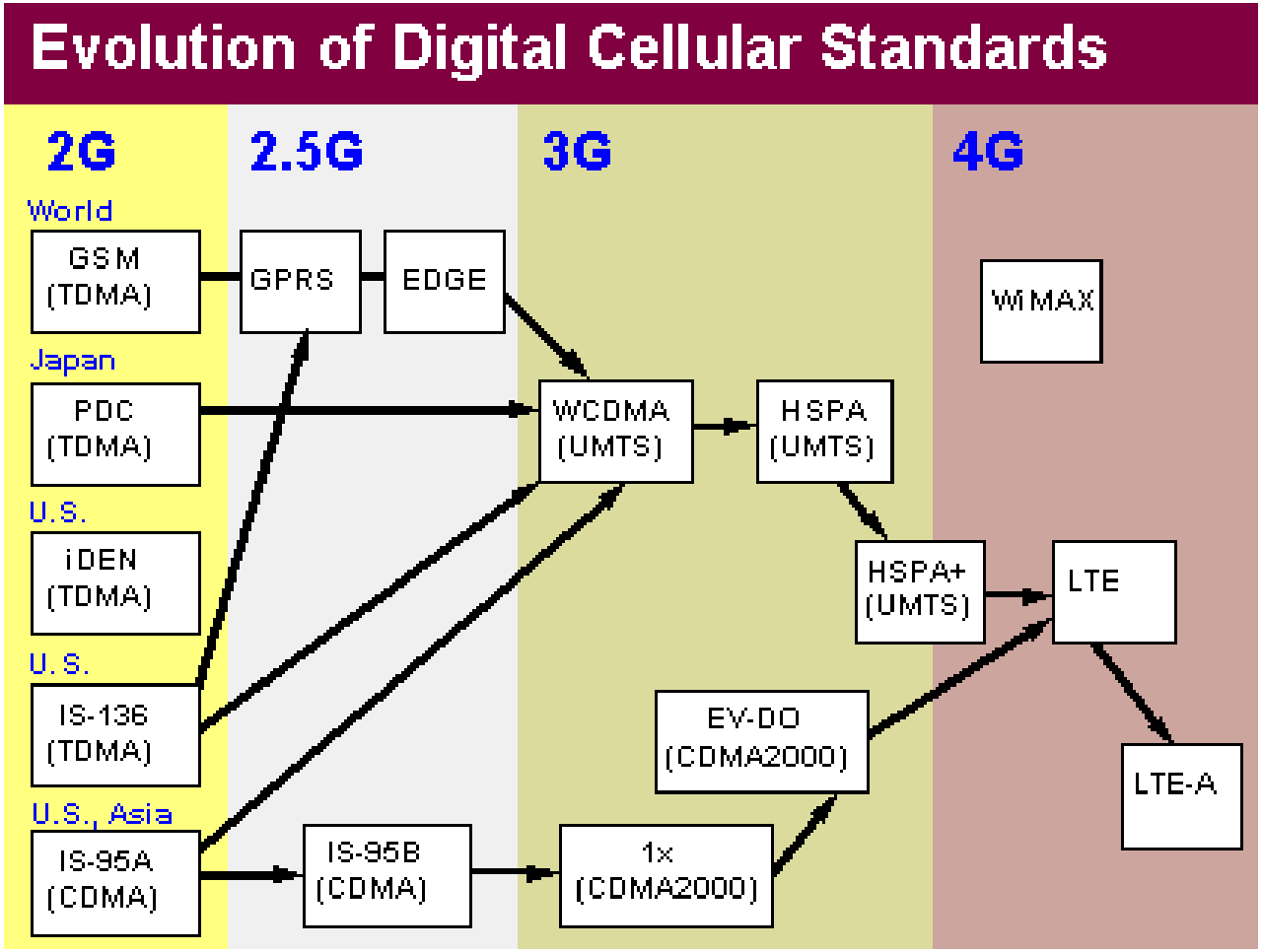
Generations in Mobile Communications



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Frequency band, technologies & operators Norway (www.ncom.no, 11.09.2014)

	Frequency band	Total available bandwidth	Use/expected use in Norway	Operators
450 MHz	452.5-457.5 462.5-467.5	2 x 4 MHz	CDMA2000	ICE
800 MHz	791-821 832-862	2 x 30 MHz	LTE	ICE Netcom Telenor
900 MHz	880-915 925-960	2 x 35 MHz	GSM, UMTS	ICE Netcom Telenor
1800 MHz	1710-1785 1805-1880	2 x 75 MHz	GSM, LTE	Telenor Netcom ICE
2100 MHz	1920-1980 2110-2170	2 x 60 MHz	UMTS	Netcom Telenor Mobile Norway
2600 MHz	2500-2570 2620-2690	2 x 70 MHz	LTE	Telenor Netcom Cloudberry Mobile

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- Basic functionality

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"Orienteringshefte" for mobiltelefon i 1970

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History: Bell lab was testing mobile radio telephone in 1924

© Bell Labs

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History

- According to Bell Labs, on June 17, 1946, the first mobile telephone call was placed in St. Louis, Missouri from a telephone set installed in an automobile.

- In 1947 AT&T introduced **Mobile Telephone Service** (MTS). Extended to 100 towns and highway corridors by 1948.
  - Only 5,000 customers placing about 30,000 calls each week. Calls were set up manually by an operator and the user had to depress a button on the handset to talk and release the button to listen.
  - 3 radio channels were available and hence 3 persons in any given city could make mobile telephone calls at one time

- In 1965 AT&T introduced **Improved Mobile Telephone Service** (IMTS).
  - more simultaneous calls in a given geographic area, customer dialing, eliminating manual call set by an operator, and reduced the size and weight of the subscriber equipment

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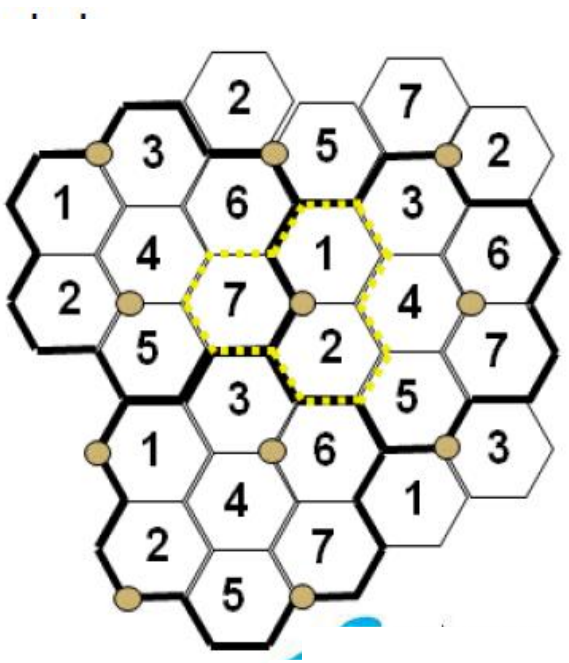
History: Cellular principle

- In December 1947, Douglas H. Ring and W. Rae Young of Bell Labs, proposed hexagonal cells for mobile phones in vehicles.
- No technology was available to implement those until 1960
- There were no continuity of services between several cells in that early implementation
- The concept of *frequency reuse* and *handoff* was introduced later in 1970's.



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History- NMT

- NMT was first tested in Stockholm between 1975-1979
- In October 1981, Nordic countries (Norway, Sweden, Denmark, Finland, Iceland) opened NMT network with automatic roaming between countries
- In Norway 250-300 BTS were expected to provide land coverage
- Initially capacity was 35000 subscriber that could be increased to 140000
- The first mobile phone weighed about 17 kg and cost was 35000 kr!

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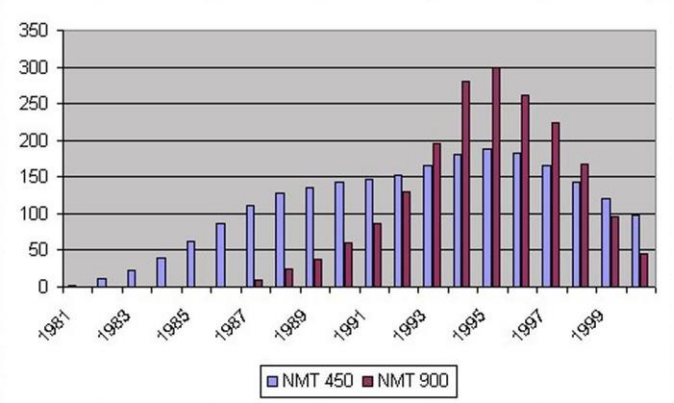
History- NMT

- In 1984 NMT started facing capacity problem
- In 1986 NMT-450 had 87000 subscription in Norway
- To increase capacity, NMT later rolled out NMT 900 MHz band
- In 1995, two years after the start of GSM, NMT subscriber number peaked and there were 488 000 NMT subscribers in Norway
- Finally NMT were taken out of service in 2005, a month after 3G network was opened in Norway



History- GSM

- In 1982, the Conference of European Posts and Telegraphs (CEPT) formed an Groupe Spécial Mobile (GSM) study group to develop a pan-European public land mobile system
- In 1987, 15 representatives from 13 European countries signed a memorandum of understanding to develop and deploy a common cellular telephone system
- In 1990, the Phase I of the GSM specifications for voice and Short Messaging Services (SMS) were published by ETSI
- In 1991, First commercial network launched by Radiolinja (Elisa Finland)

1991: Radiolinja (now Elisa) the first GSM Network in Finland. Mr. Harri Holkeri, then prime minister of Finland made the first GSM call.

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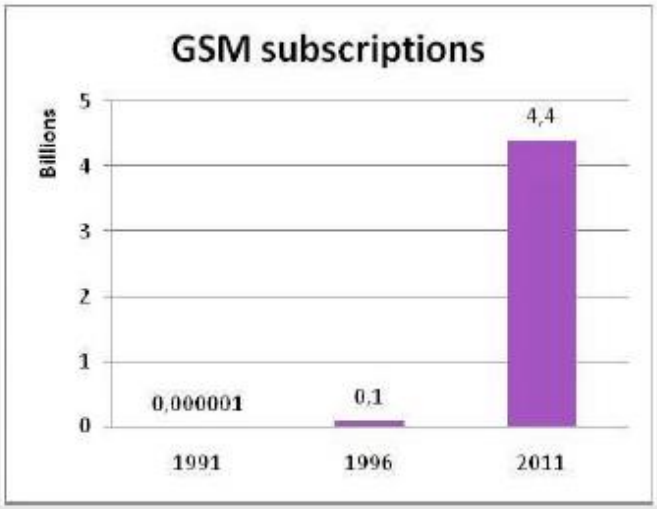
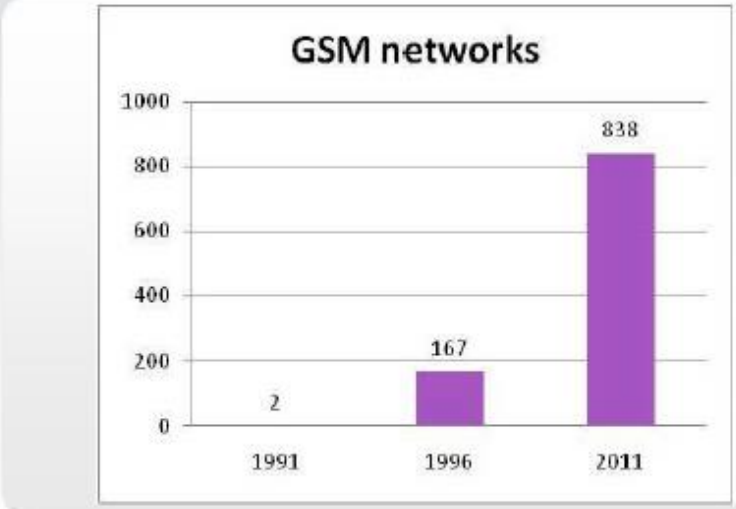
History- GSM

- 1993: Tele-Mobil (Telenor Mobil) and NetCom GSM opens their networks in Norway
- 1998: GSM 1800 starts operation to increase the network capacity in cities in Norway
- 2001: GPRS service started by Telenor Mobil
- 2004: EDGE Service started in Norway





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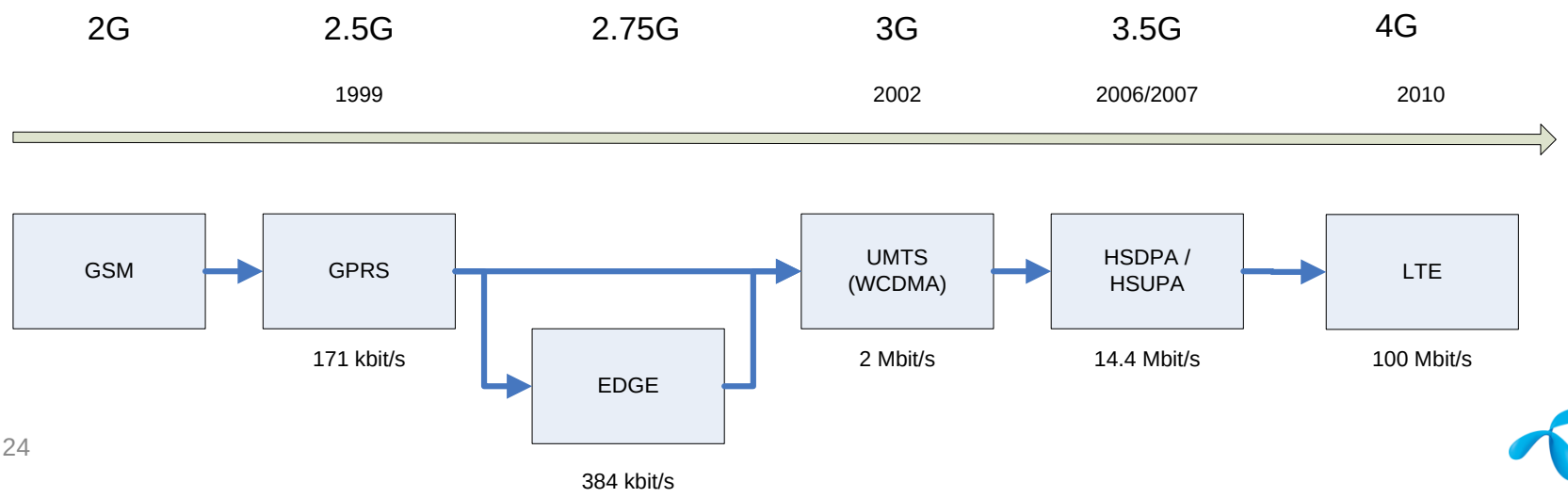
3G systems - UMTS

- The first operational 3G networks in Europe were launched in 2003 based on the UMTS-standard (Universal Mobile Telecommunications System)
- Main differences from 2G:
  - Global standard
  - Higher datarates (opp til 2 Mbit/s defined, typisk 384 kbit/s in the first phase)
  - Support for multimedia
  - Improved security (e.g. the network must also autheticate to the mobile)
- Coordinated with 2G, not replacing but supplementing
- Commercial start i Norway in 2004

Development of 3G/UMTS

- A continuous development of the 3G-standards (3.5G)
  - HSDPA – High Speed Downlink Packet Access
    - Theoretical data rate: 14.4 Mbit/s
  - HSUPA – High Speed Uplink Downlink Access
    - Teoretisk datarate opp til 5,76 Mbit/s
  - HSPA+ - (Evolved HSPA):
    - Up to 84Mbit/s (DL) and 22 Mbit/s (UL) -> 3.75G?



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4G – LTE and LTE-Advanced

- The latest addition to the ‘mobile family’
- Launched in 2010
- Base version:
  - Theoretical data rate: up to 326 Mb/s
- Introduces multiple antenna concepts
- Flexible bandwidths
- Only packet switched (PS), based on IP

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Regulation & standardization

- National & International regulators decide to use different frequency band for different applications. The most important regulatory bodies are:
  - Post & Telecommunication Authority, regulatory authority in Norway
  - CEPT (Conference of European Post and Telecommunications Administrations)
  - ITU-R (International Telecommunication Union – Radio Communication), international regulatory authority arrange WRC (World Radio Communication Conference)

- Standard organizations develop and adopt international standards for telecommunication systems, most important bodies are:
  - ETSI (European Telecommunication Standard Institute), developed GSM standards
  - ITU-T (International Telecommunication Union Standardization Sector), part of the ITU standardization
  - 3GPP (3rd Generation Partnership Project), cooperation between regional standardization body of Europe, North America and Asia; responsible for all standardization of GSM, 3G and LTE.

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Where we are today

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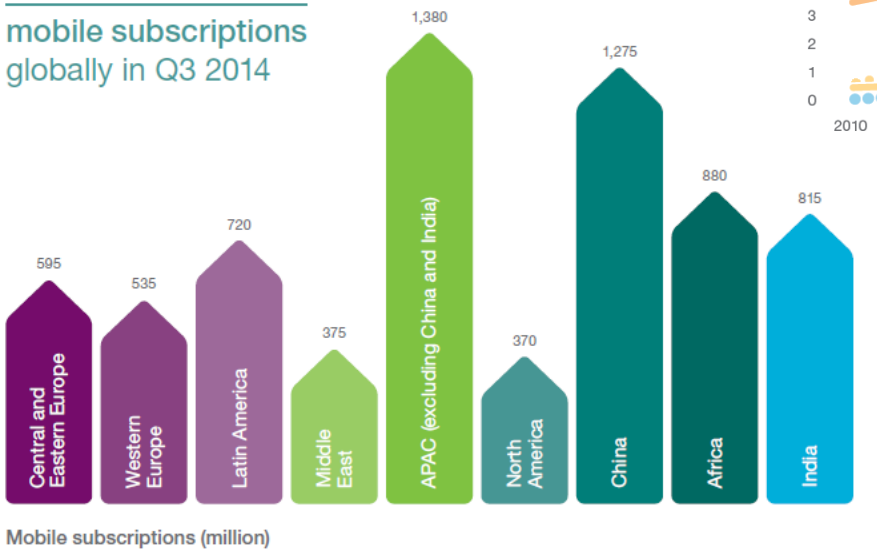
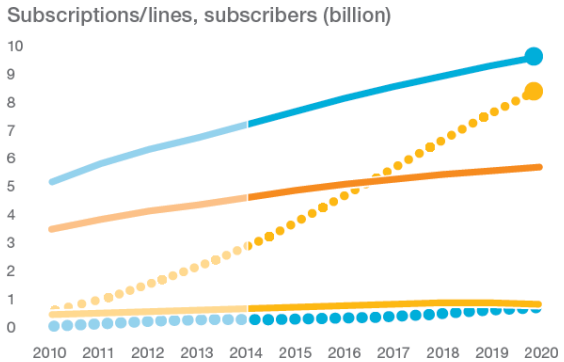
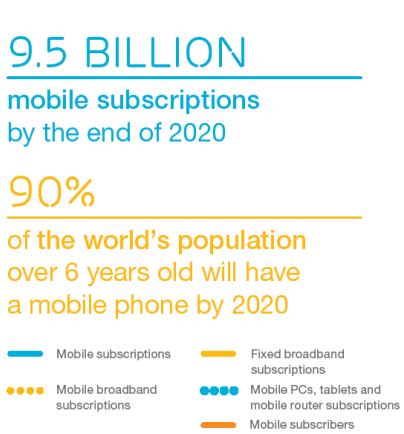
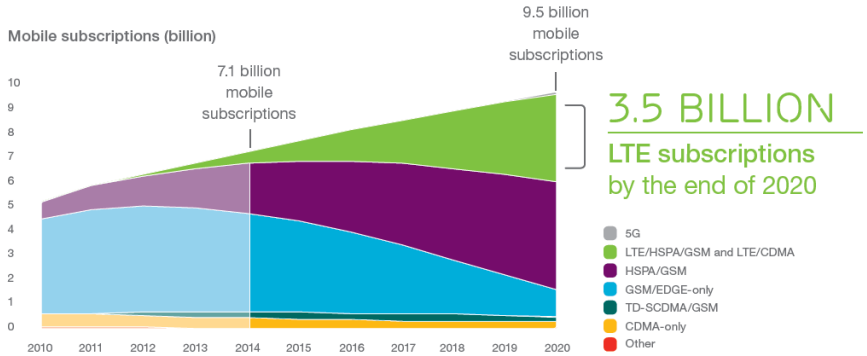
Trends: Mobile subscriptions









2.5 BILLION
mobile broadband subscriptions
globally in Q3 2014

Source: Ericsson mobility report Nov/2014: http://www.ericsson.com/res/docs/2014/ericsson-mobility-report-november-2014.pdf

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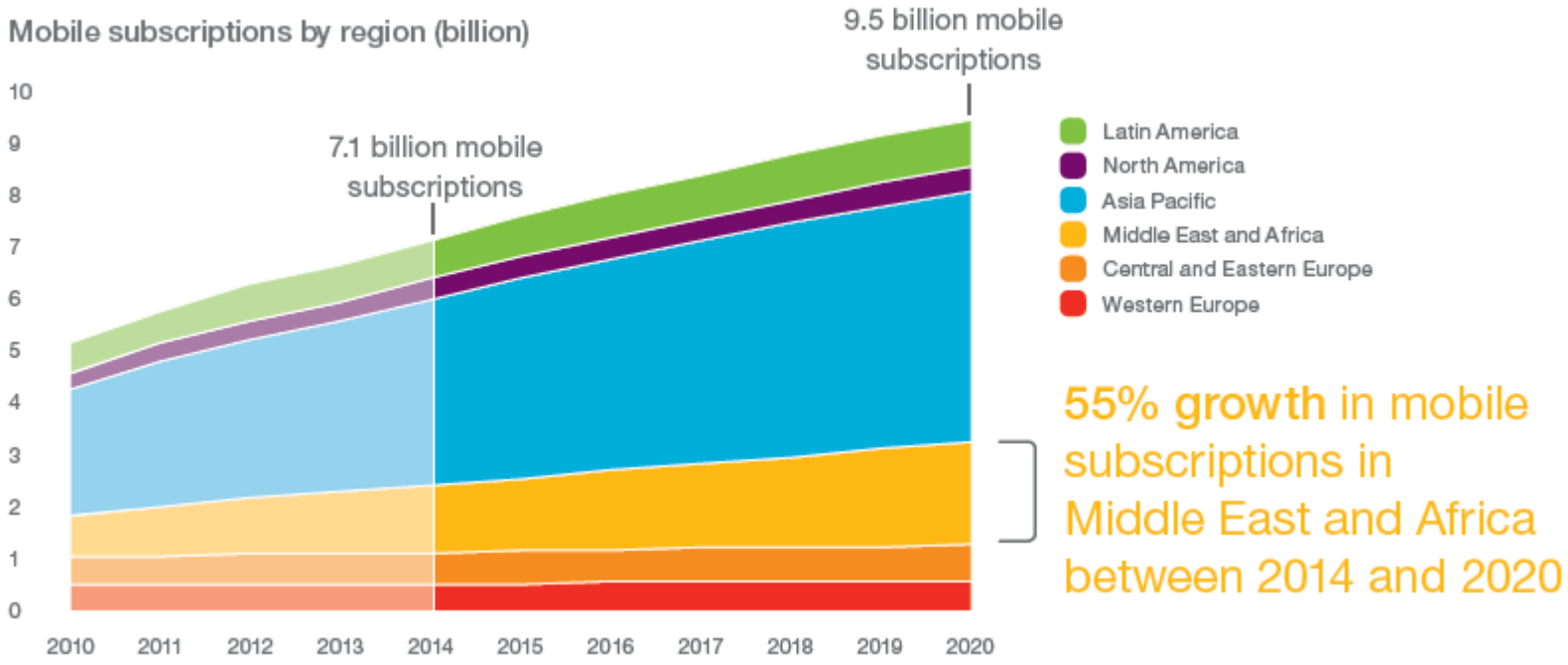
Mobile subscription by region



Source: Ericsson mobility report Nov/2014

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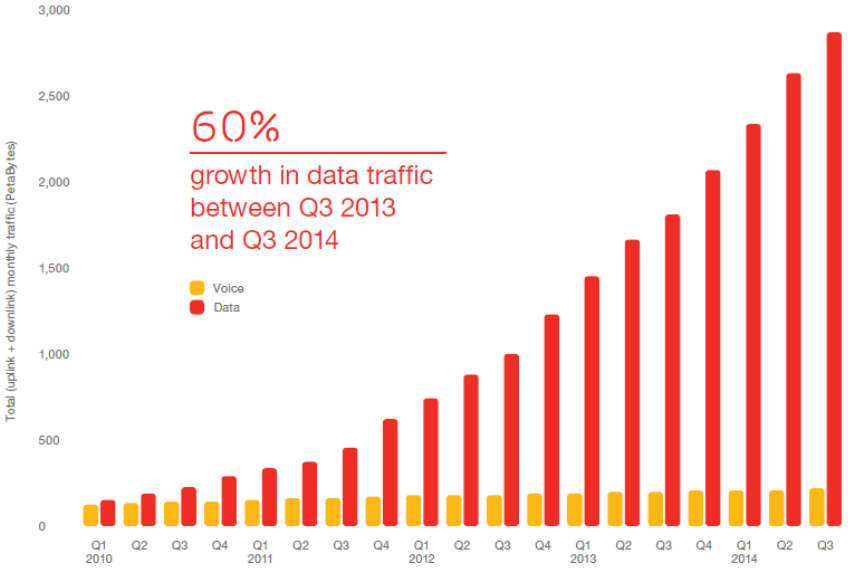
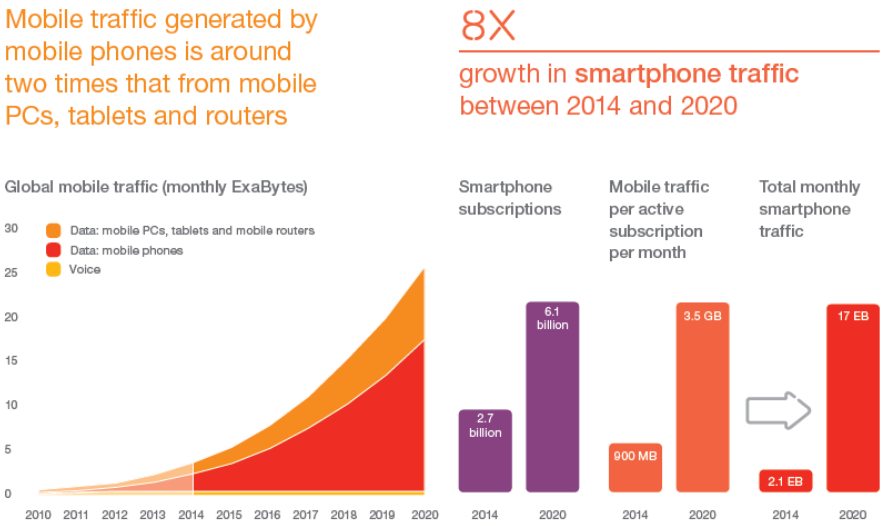
Trend: Traffic development





Take away-

- Mobile data is already the several times of capacity than voice in most Operators network
- And data growth will continue exponentially in the years to come

Source: Ericsson mobility report Nov/2014

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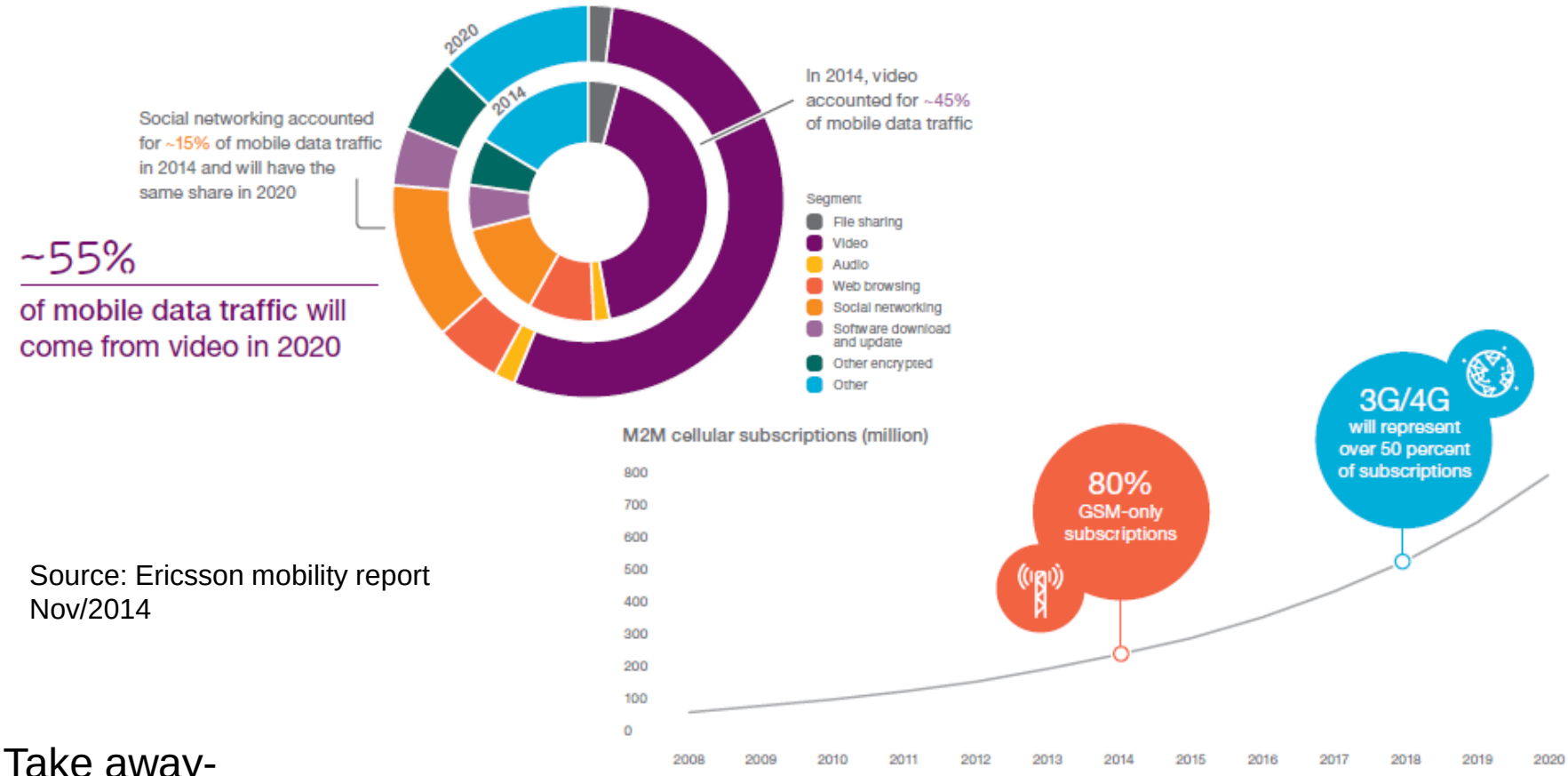
Trend: Application



Source: Ericsson mobility report Nov/2014

Take away-

- Video is dominant traffic already and will be more dominant in the future
- Machine-to-machine (M2M) will grow from 230 (2014) to 800 million subscriptions by 2020 and more will be 3G/4G devices

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Challenges of building future mobile networks

Some of the challenges include

- Provide mobile subscriptions to the low income segment
- Build network capacity to meet the data traffic explosion while revenue growth is minimal
- Limited spectrum
- Invest in new technology (e.g. HSPA+, LTE) while need to keep legacy network (e.g. GSM, CDMA) for many more years
- Main revenue sources of Operators like voice, SMS is increasingly being commoditized by internet players
- Prediction of huge Machine-to-Machine (M2M) subscription which will have low ARPU*.

*ARPU: Average Revenue per User

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- Basic functionality

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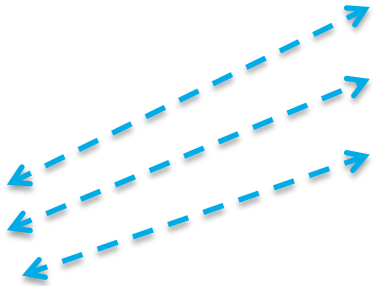
Basic elements

Base station tower

Users with phones



Baseband unit and Radio unit

Mobile switching centre

The telephone network and the Internet

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Architecture of GSM Network

Base Station Systems BSS

Switching Subsystem SSS

Other networks

SIM

BTS

AC

HLR

VLR

EIR

PSTN

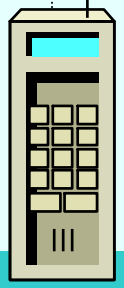
ISDN

BTS

BSC

MSC

Data networks



MS

OMC-B

Operation & Maintenance Centers

OMC-S

Other MSCs

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Basic elements in mobile communication systems

- **SIM** – A smart card stores identification (IMSI) of a subscriber, holds Auth. Key that identifies SIM on the mobile network
- **ME/MU/MS** – the mobile device
- **BTS** – Facilitate wirlesss communication between UE/ME and the network
- **BSC** – Allocates radio channel to ME, several BTS under the control of one BSC
- **MSC** – carries out call switiching (ME-ME, ME-phones of other network)
- **VLR** – linked to MSC, temporary DB of subscriber who roamed into a specific MSC
- **HLR** – a central DB of ME
- **AuC** – to authenticate each SIM
- **EIR** – keeps lists of ME which are to be banned or monitored

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Some concepts in mobile communications

- **Cell** – A limited geographic area covered by a BTS (e.g. max. Cell size of GSM cell 35km, typically several km)
- **Control channel** – Radio channel used for all control info. e.g. call request, call set up etc.
- **Information channel** – Radio channel used for user info. e.g. data or voice
- **Downlink (forward channel)** – communication from BTS till ME
- **Uplink (reverse channel)** – communication from ME till BTS
- **Handover (handoff)** – transferring an ongoing communication from one BTS to another BTS typically due to movement
- **Full duplex/half duplex/simplex** –
  - Both direction simultaneously/ both direction but only one direction at a time/Only one way communication

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Basic elements

Typical macrocell

Typical microcell

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Circuit switching and packet switching

- **Circuit Switching (CS):** In circuit-switched networks , a *dedicated path* is set up between the two parties. This path remains for the exclusive use of both parties for the duration of the call, and is therefore not available to any other users.
  - Inefficient mode
  - E.g. GSM and UMTS used CS for voice
- **Packet switching (PS):** Packet switching involves dividing the data into *packets* (or cells or frames) prior to transmission. The length of the packets varies enormously, depending on the technology employed.
  Added to each packet is the destination address, together with other control information. The packets are then transmitted across the network. This addressing means there is no requirement to set up a pre-established link. To some extent, each individual packet can be viewed as being able to find its own way to its destination.
  In a packet-switched network, the resources are shared between many users.
  - More efficient than CS but needs extra data fields in each packet
  - E.g. from 2.5 G uses PS
  - 4G uses PS for voice also (VoLTE)

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Message services

- **SMS**

  A text communication service of mobile communication system using standard communication protocols that allow short text messages (typically 160 characters) between mobile devices or between fixed lines and mobile devices.

  SMS service is the most successful mobile service commercially

- **MMS**

  MMS is a standard way to send multimedia content (e.g. text, audio, video) to and from Phone

  Both SMS and MMS are ’store and forward’ service

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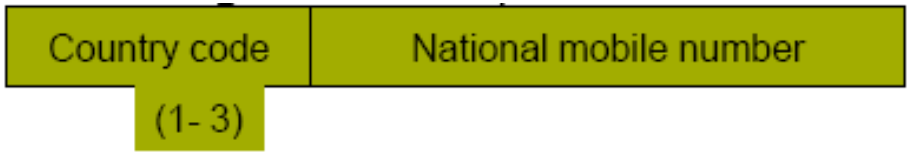
Identification of user and mobile phones

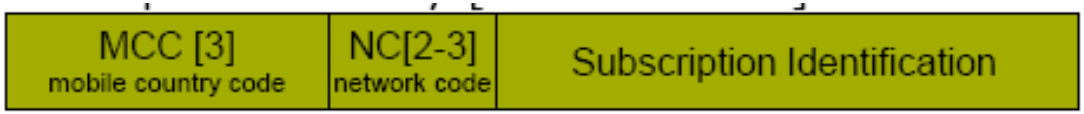
- A typical mobile number (MS-ISDN number) follows the numbering plan for telephony (max. 15 digits)



MSISDN = CC + NDC + SN

Where, CC = Country Code, NDC= National Destination Code, SN= Subscriber Number

- IMSI used to identify (uniquely) mobile subscription internationally (max. 15 digits)



IMSI = MCC + MNC + MSIN

- **IMEI used to identify ME**

Type *#06# to get IMEI

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Security functionality

- The purpose of security features is to protect users and the network against abuse:
  - Verification that the user has a valid subscription
  - Verfication of the network that the user communicates with a ’real’ network entity
  - Protection of user’s identity against tracking
  - Protection against evesdropping by radio link

- Mutual authentication crucial (e.g. In 3G and 4G, not in 2G)
- User’s identity information is stored both in SIM card and in the network
- Advanced encryption method is used on radio channel to protect information
- Security mechanisms are also used in core network (not only in access network where information is transmitted over the radio)
- BUT there is no appropriate location privacy in today’s mobile network

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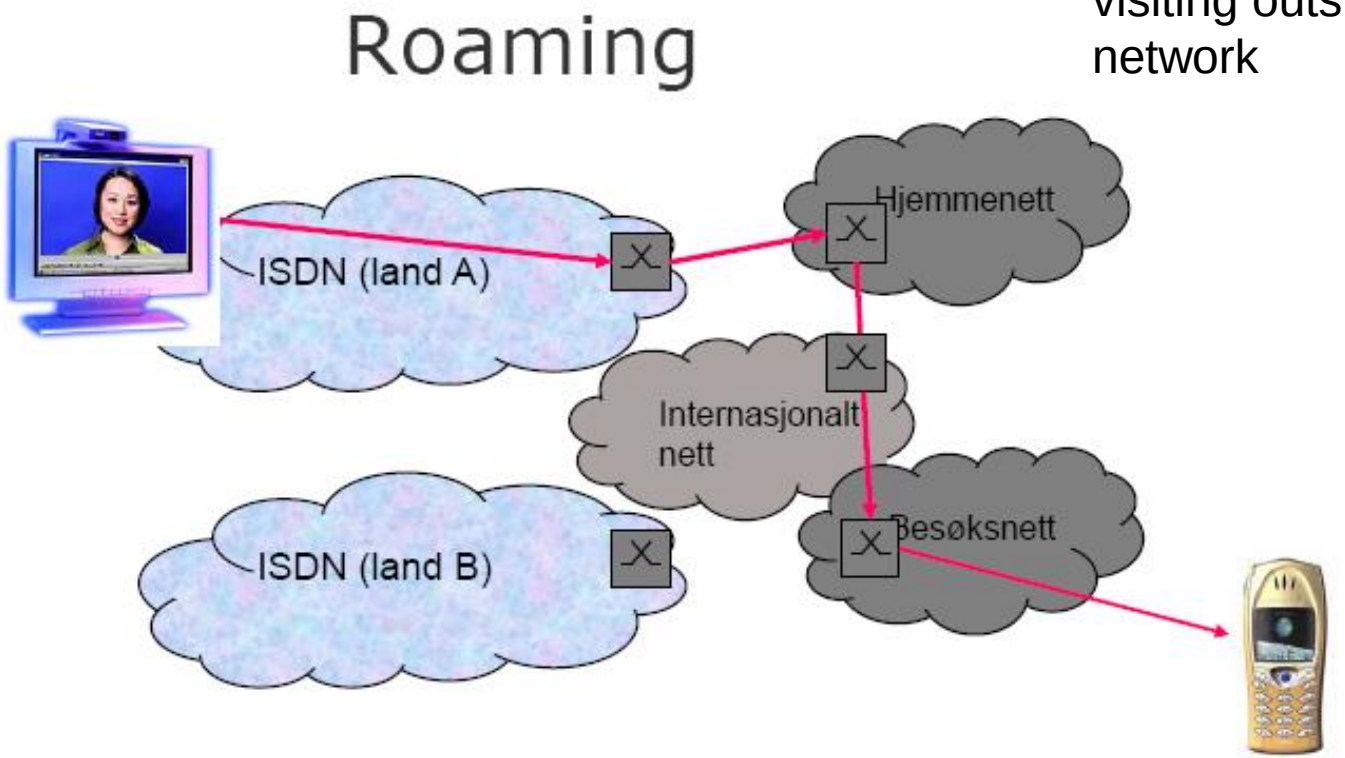
Roaming

- The continuity of communication services in a location that is different from the home location where the service was registered.

Call to a phone that is visiting outside home network



Summary

- Mobile communication system allows communication to and from handheld devices during movement
- Radio telephone services were started already in 1947 in the USA, but the real success came when GSM was introduced in the 1990s
- The basic elements of a mobile communications system are the user device, the base station and the switching and routing centres
- Basic services in mobile communications are telephony, messaging and internet access
- Basic functionality is the possibility to use these services on the move

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