Mobile Communications
Chapter 4: Wireless Telecommunication Systems
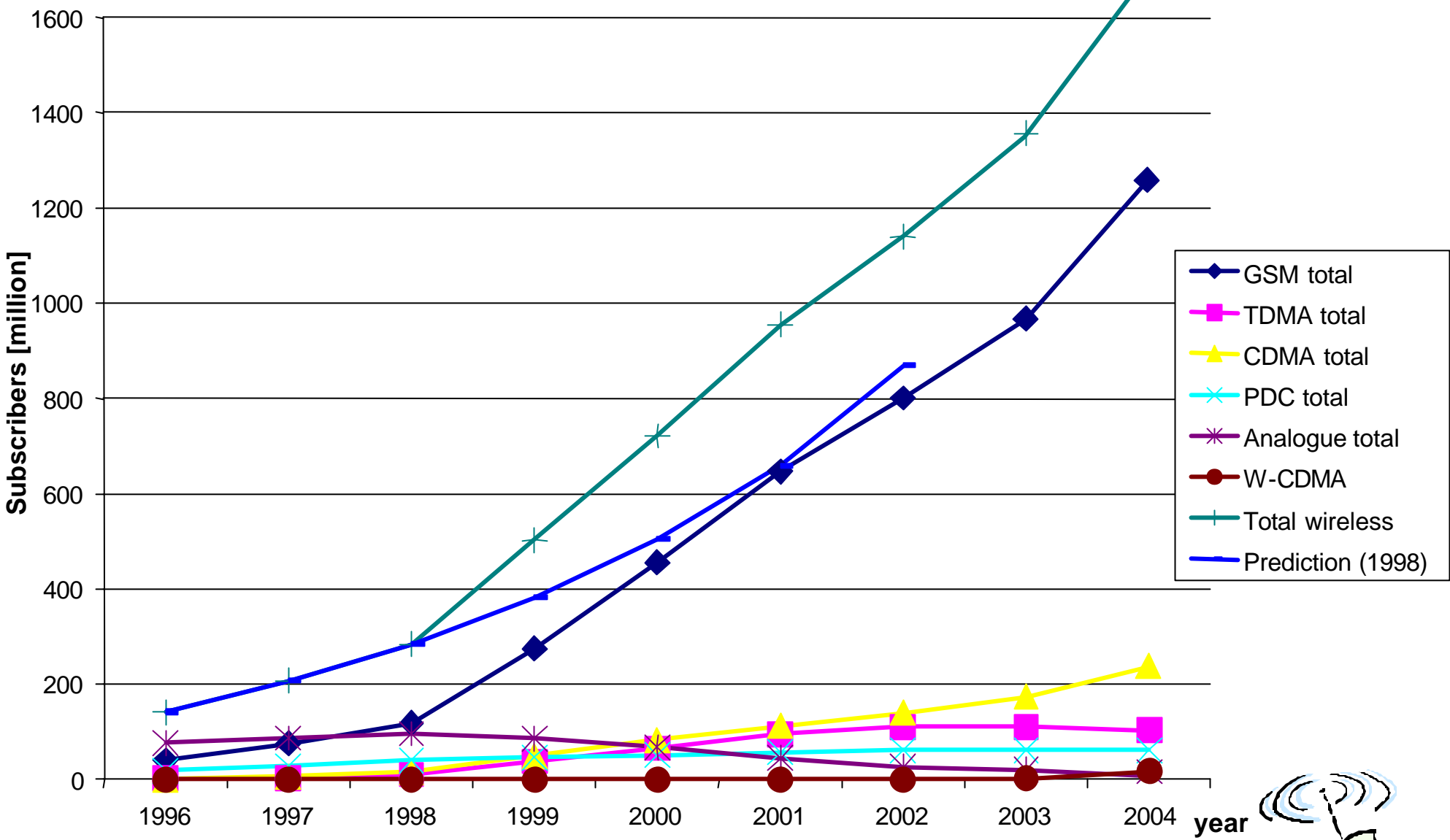
slides by Jochen Schiller
with modifications by Emmanuel Agu

- ❑ Market
- ❑ GSM
    - ❑ Overview
    - ❑ Services
    - ❑ Sub-systems
    - ❑ Components

Mobile phone subscribers worldwide

approx. 1.7 bn

Legend:
- GSM total
- TDMA total
- CDMA total
- PDC total
- Analogue total
- W-CDMA
- Total wireless
- Prediction (1998)

GSM

- formerly: Groupe Spéciale Mobile (founded 1982)
- now: Global System for Mobile Communication
- Pan-European standard (ETSI, European Telecommunications Standardisation Institute)
- simultaneous introduction of essential services in three phases (1991, 1994, 1996) by the European telecommunication administrations (Germany: D1 and D2)
  - ➔ seamless roaming within Europe possible
- today many providers all over the world use GSM (more than 200 countries in Asia, Africa, Europe, Australia, America)
- more than 1.2 billion subscribers in more than 630 networks
- more than 75% of all digital mobile phones use GSM (74% total)
- over 200 million SMS per month in Germany, > 550 billion/year worldwide (> 10% of the revenues for many operators)
  [be aware: these are only rough numbers…]

Performance characteristics of GSM (wrt. analog sys.)

Communication

- ❑ mobile, wireless communication; voice and data services

Total mobility

- ❑ international access, chip-card enables use of access points of different providers

Worldwide connectivity

- ❑ one number, the network handles localization

High capacity

- ❑ better frequency efficiency, smaller cells, more customers per cell

High transmission quality

- ❑ high audio quality and reliability for wireless, uninterrupted phone calls at higher speeds (e.g., from cars, trains)

Security functions

- ❑ access control, authentication via chip-card and PIN

Disadvantages of GSM

There is no perfect system!!

❑ no end-to-end encryption of user data

❑ no full ISDN bandwidth of 64 kbit/s to the user, no transparent B-channel

❑ reduced concentration while driving

❑ electromagnetic radiation

❑ abuse of private data possible

❑ roaming profiles accessible

❑ high complexity of the system
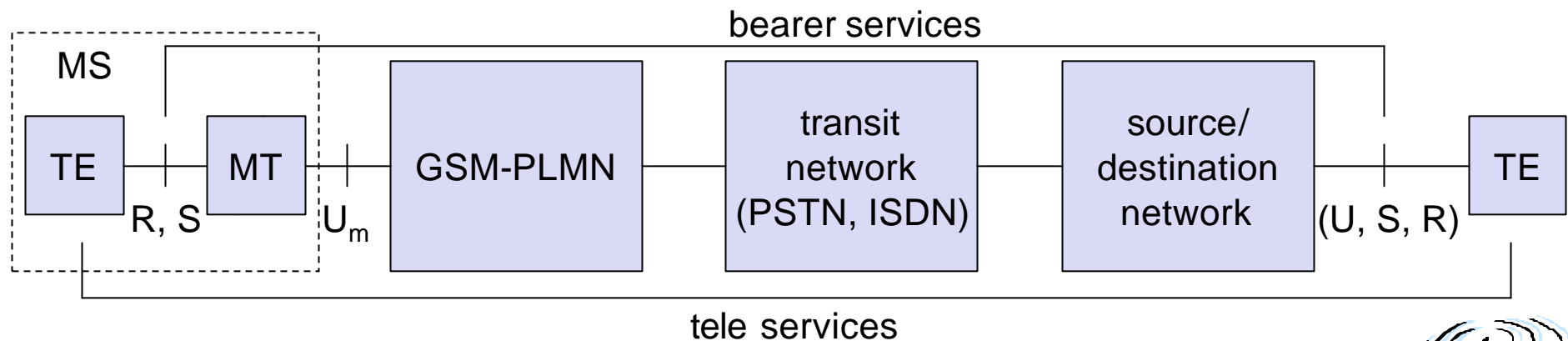
❑ several incompatibilities within the GSM standards

GSM: Mobile Services

GSM offers

- several types of connections
  - voice connections, data connections, short message service
- multi-service options (combination of basic services)

Three service domains

- Bearer Services
- Telematic Services
- Supplementary Services

bearer services

MS						
TE	MT	GSM-PLMN	transit network (PSTN, ISDN)	source/ destination network		TE

R, S U_m (U, S, R)

tele services

Bearer Services

❑ Telecommunication services to transfer data between access points

❑ Specification of services up to the terminal interface (OSI layers 1-3)

❑ Different data rates for voice and data (original standard)

  ❑ data service (circuit switched)

   ● synchronous: 2.4, 4.8 or 9.6 kbit/s

   ● asynchronous: 300 - 1200 bit/s

  ❑ data service (packet switched)

   ● synchronous: 2.4, 4.8 or 9.6 kbit/s

   ● asynchronous: 300 - 9600 bit/s

Today: data rates of approx. 50 kbit/s possible – will be covered later!

Tele Services I

❑ Telecommunication services that enable voice communication via mobile phones

❑ All these basic services have to obey cellular functions, security measurements etc.

❑ Offered services

  ❑ mobile telephony
  primary goal of GSM was to enable mobile telephony offering the traditional bandwidth of 3.1 kHz

  ❑ Emergency number
  common number throughout Europe (112); mandatory for all service providers; free of charge; connection with the highest priority (preemption of other connections possible)

  ❑ Multinumbering
  several ISDN phone numbers per user possible

Tele Services II

Additional services

❑ Non-Voice-Teleservices

- group 3 fax

- voice mailbox (implemented in the fixed network supporting the mobile terminals)

- electronic mail (MHS, Message Handling System, implemented in the fixed network)

- ...

- Short Message Service (SMS)
alphanumeric data transmission to/from the mobile terminal (160 characters) using the signaling channel, thus allowing simultaneous use of basic services and SMS
(almost ignored in the beginning now the most successful add-on!)

Supplementary services

- ❑ Services in addition to the basic services, cannot be offered stand-alone
- ❑ Similar to ISDN services besides lower bandwidth due to the radio link
- ❑ May differ between different service providers, countries and protocol versions
- ❑ Important services
  - ❑ identification: forwarding of caller number
  - ❑ suppression of number forwarding
  - ❑ automatic call-back
  - ❑ conferencing with up to 7 participants
  - ❑ locking of the mobile terminal (incoming or outgoing calls)
  - ❑ ...

Architecture of the GSM system

GSM is a PLMN (Public Land Mobile Network)

- ❑ several providers setup mobile networks following the GSM standard within each country

- ❑ components
  - MS (mobile station)
  - BS (base station)
  - MSC (mobile switching center)
  - LR (location register)

- ❑ subsystems
  - RSS (radio subsystem): covers all radio aspects
  - NSS (network and switching subsystem): call forwarding, handover, switching
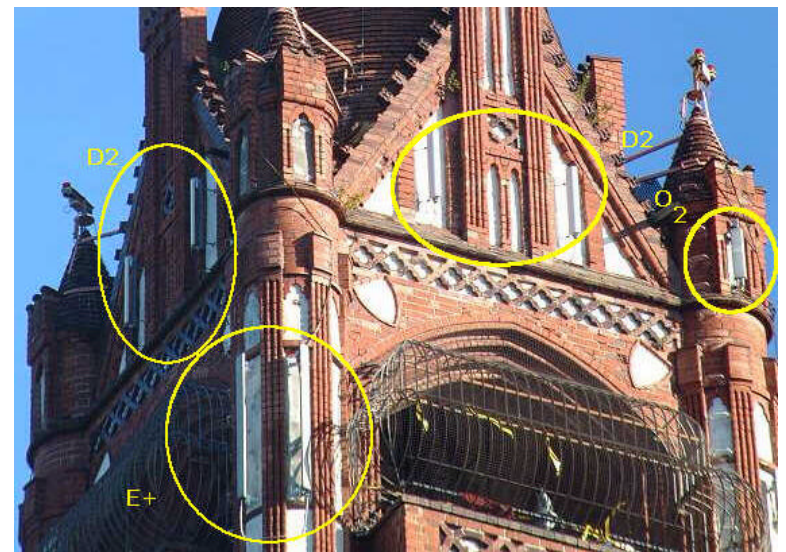 - OSS (operation subsystem): management of the network

Ingredients 1: Mobile Phones, PDAs & Co.

The visible but smallest part of the network!

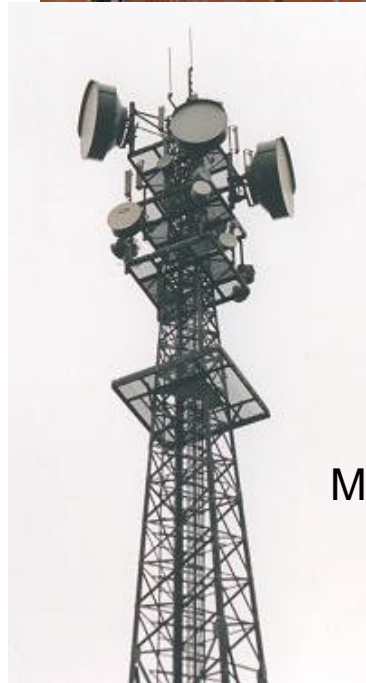# Ingredients 2: Antennas

Still visible – cause many discussions…

Ingredients 3: Infrastructure 1

Base Stations

Cabling

Microwave links

Not „visible", but comprise the major part of the network (also from an investment point of view…)

Management

Data bases

Switching units

Monitoring

GSM: overview
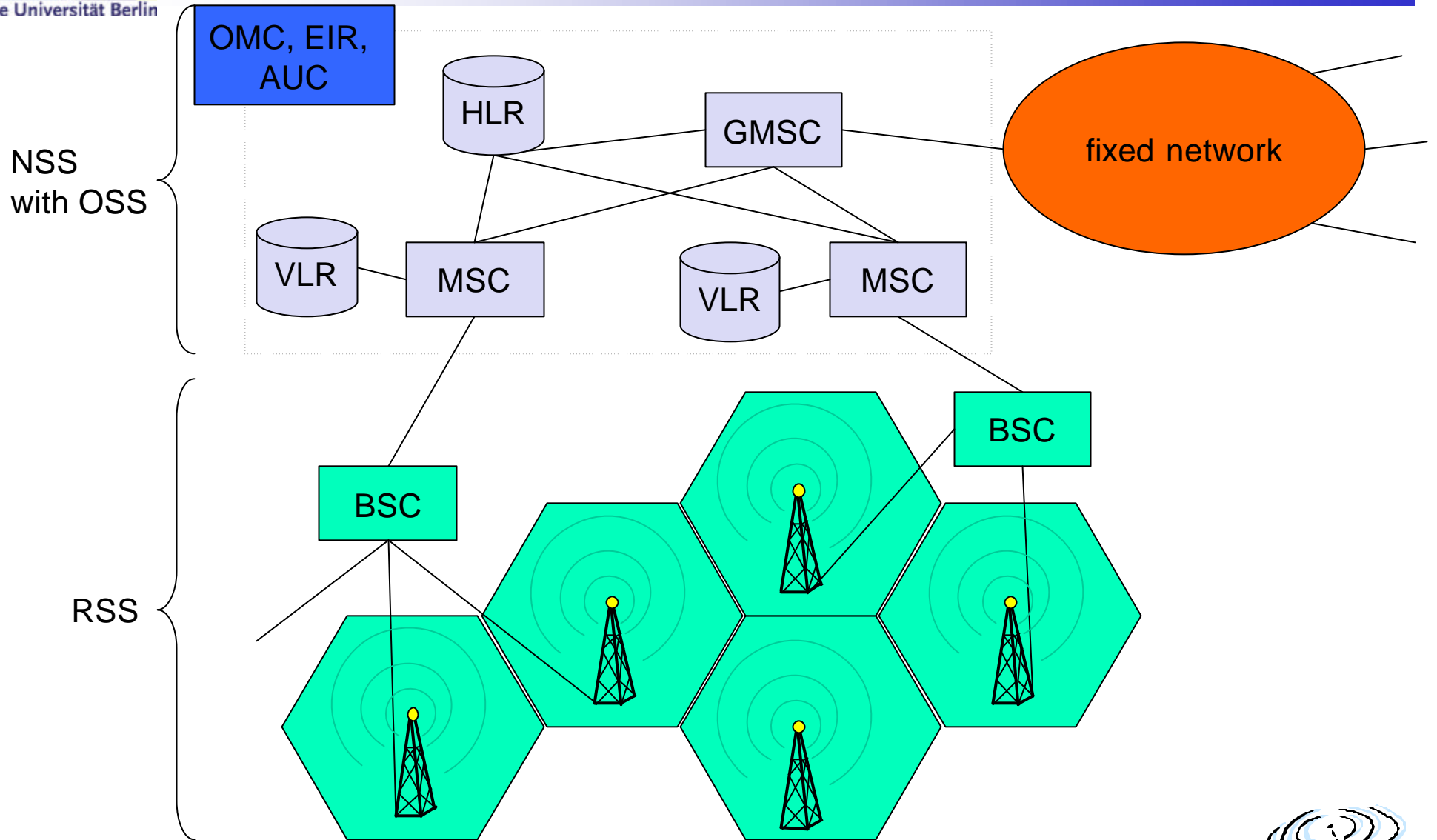
GSM: elements and interfaces
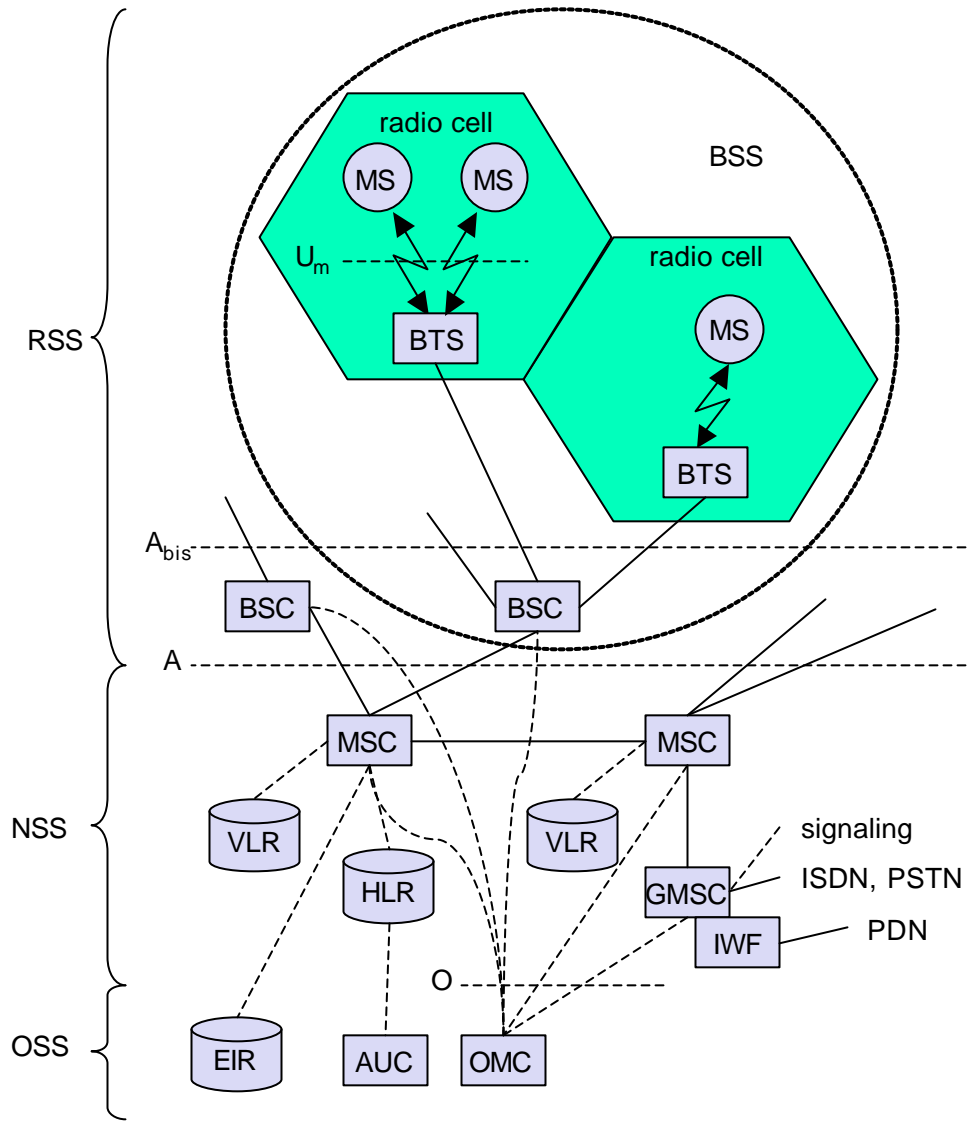
System architecture: radio subsystem

MS   MS

U_m

BTS A_{bis}

BTS → BSC → MSC

BTS

BTS → BSC → A → MSC

BSS
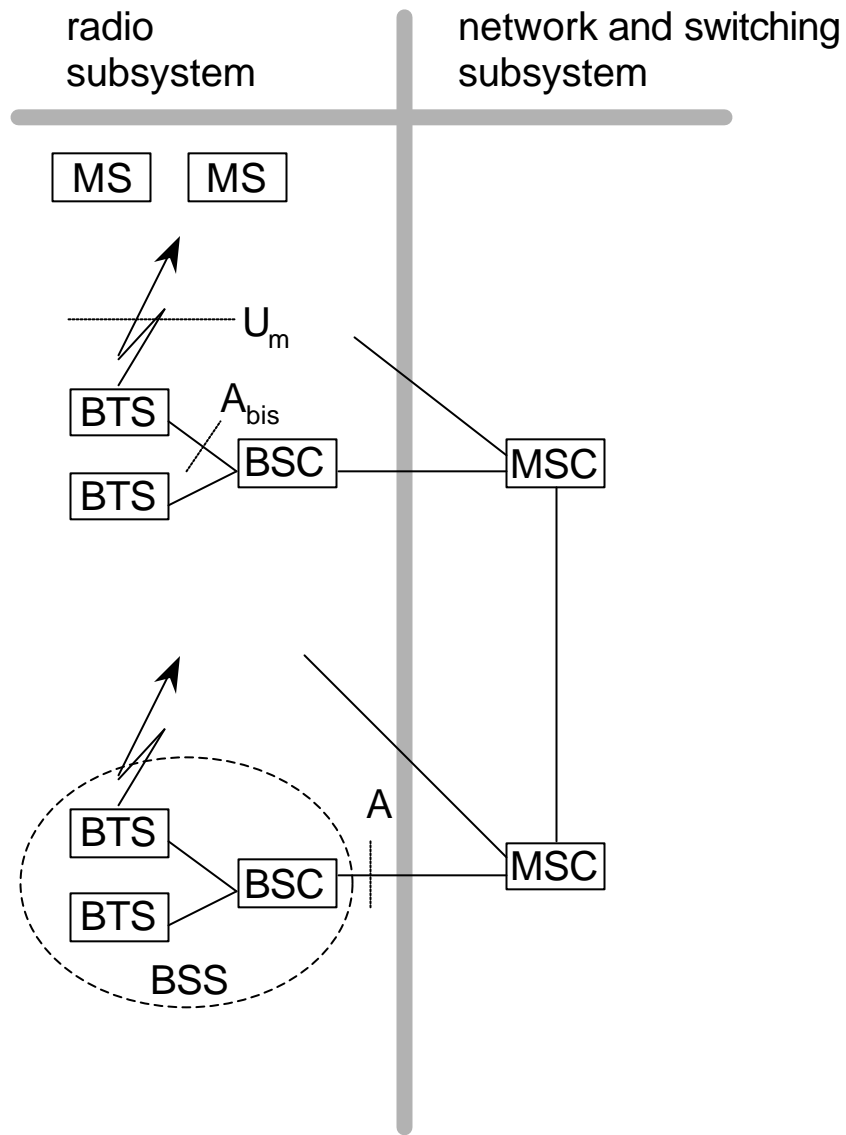
Components

- ❑ *MS* (Mobile Station)
- ❑ *BSS* (Base Station Subsystem): consisting of
  - ● *BTS* (Base Transceiver Station): sender and receiver
  - ● *BSC* (Base Station Controller): controlling several transceivers

Interfaces

- ❑ U_m : radio interface
- ❑ A_{bis} : standardized, open interface with 16 kbit/s user channels
- ❑ *A*: standardized, open interface with 64 kbit/s user channels

radio subsystem

network and switching subsystem

Radio subsystem

The Radio Subsystem (RSS) comprises the cellular mobile network up to the switching centers

❑ Components

  ❑ Base Station Subsystem (BSS):

  - Base Transceiver Station (BTS): radio components including sender, receiver, antenna - if directed antennas are used one BTS can cover several cells
  - Base Station Controller (BSC): switching between BTSs, controlling BTSs, managing of network resources, mapping of radio channels (U_m) onto terrestrial channels (A interface)

  - BSS = BSC + sum(BTS) + interconnection

  ❑ Mobile Stations (MS)

GSM: cellular network

segmentation of the area into cells

possible radio coverage of the cell

idealized shape of the cell
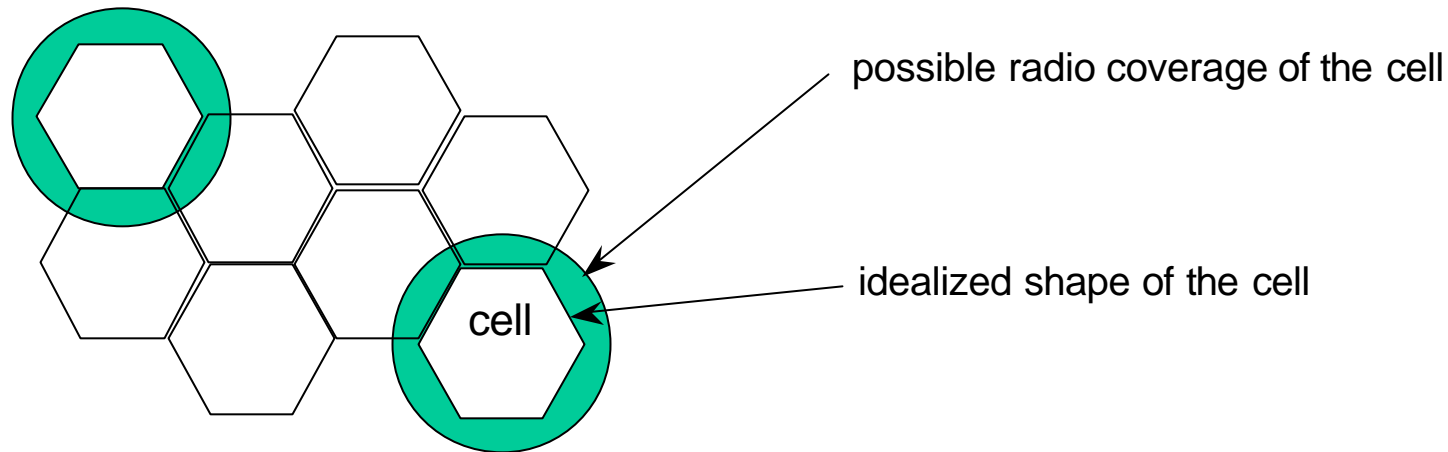
cell

❑ use of several carrier frequencies

❑ not the same frequency in adjoining cells

❑ cell sizes vary from some 100 m up to 35 km depending on user density, geography, transceiver power etc.

❑ hexagonal shape of cells is idealized (cells overlap, shapes depend on geography)

❑ if a mobile user changes cells
  ⬇ handover of the connection to the neighbor cell

GSM frequency bands

Type	Channels	Uplink [MHz]	Downlink [MHz]
GSM 850 (Americas)	128-251	824-849	869-894
GSM 900 classical extended	0-124, 955-1023 124 channels +49 channels	876-915 890-915 880-915	921-960 935-960 925-960
GSM 1800	512-885	1710-1785	1805-1880
GSM 1900 (Americas)	512-810	1850-1910	1930-1990
GSM-R exclusive	955-1024, 0-124 69 channels	876-915 876-880	921-960 921-925

- Additionally: GSM 400 (also named GSM 450 or GSM 480 at 450-458/460-468 or 479-486/489-496 MHz
- Please note: frequency ranges may vary depending on the country!
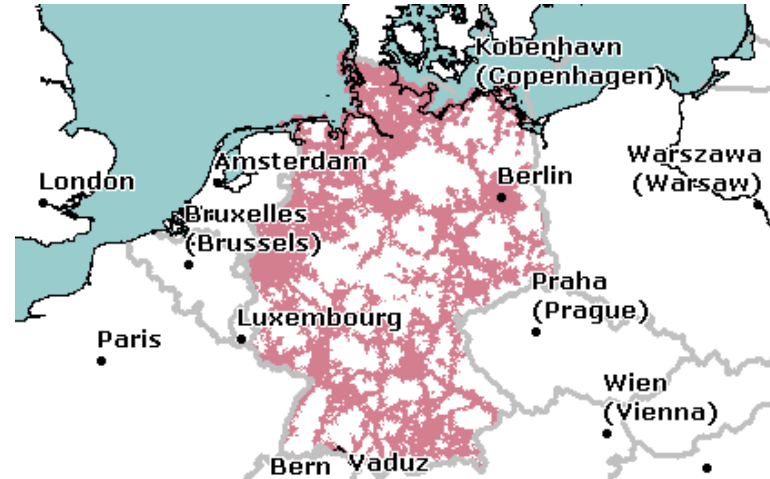- Channels at the lower/upper edge of a frequency band are typically not used

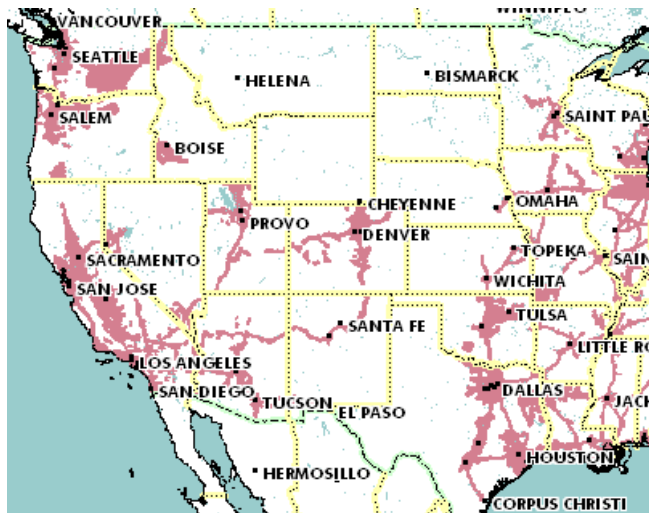# Example coverage of GSM networks (www.gsmworld.com)
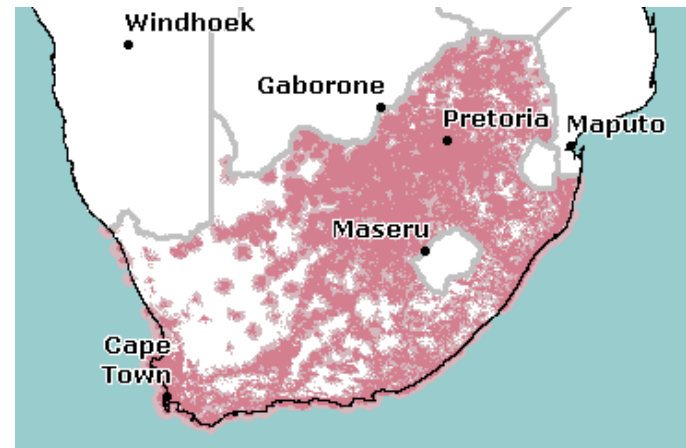
T-Mobile (GSM-900/1800) Germany
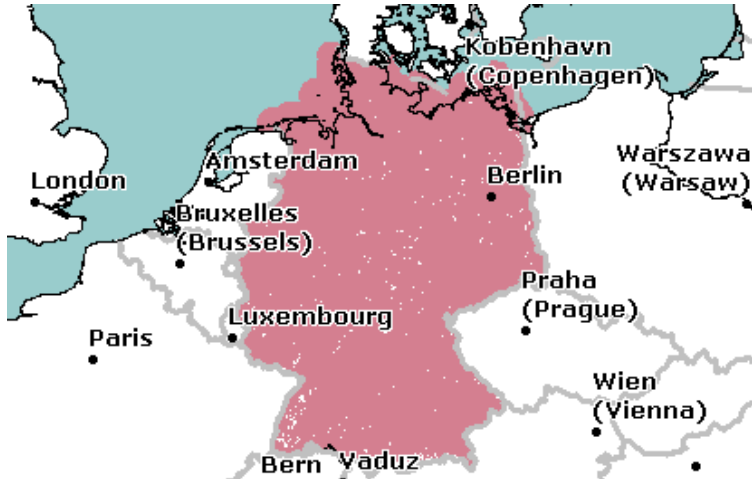
O$_2$ (GSM-1800) Germany

AT&T (GSM-850/1900) USA

Vodacom (GSM-900) South Africa
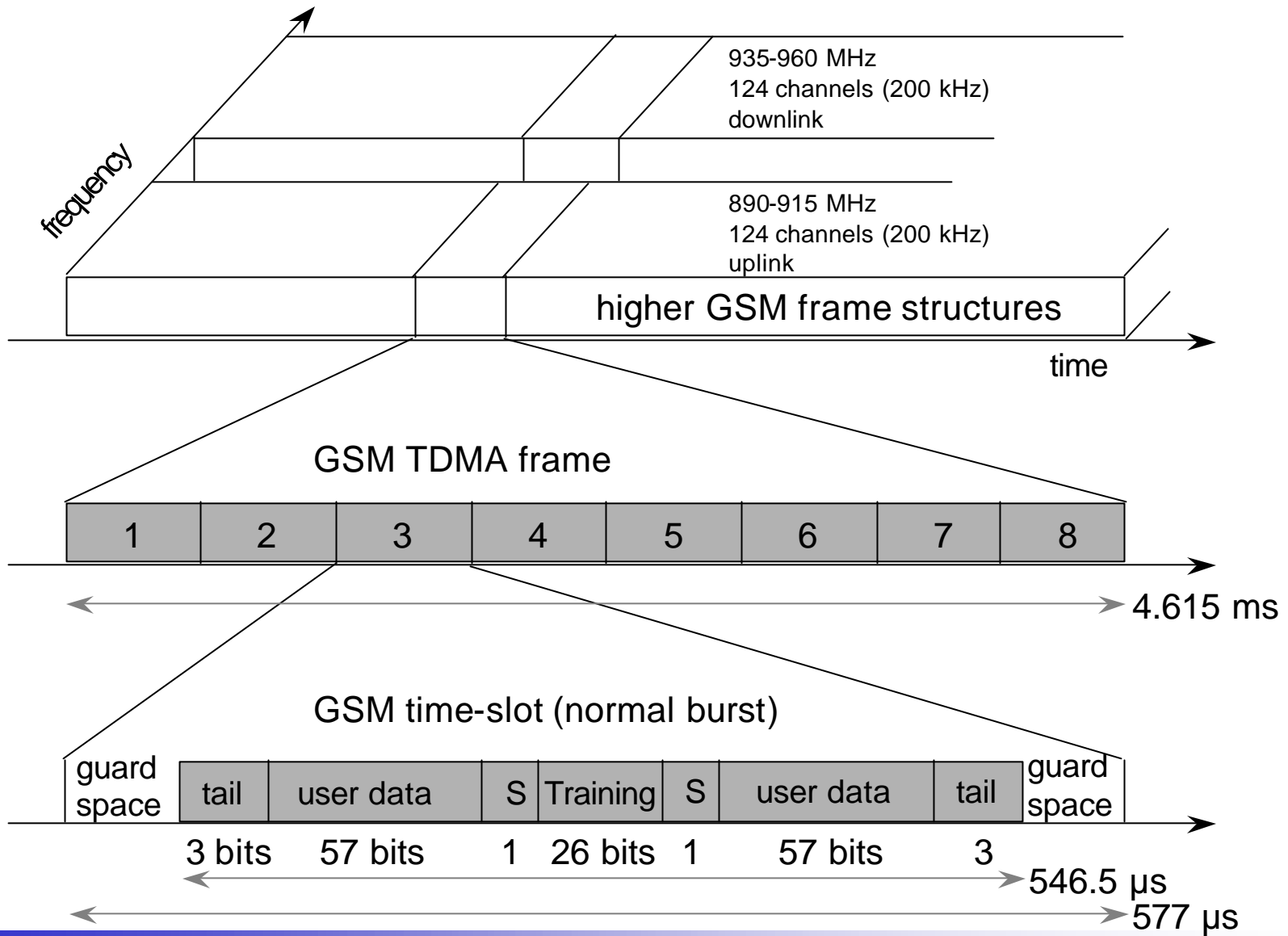
Base Transceiver Station and Base Station Controller

Tasks of a BSS are distributed over BSC and BTS

❑ BTS comprises radio specific functions
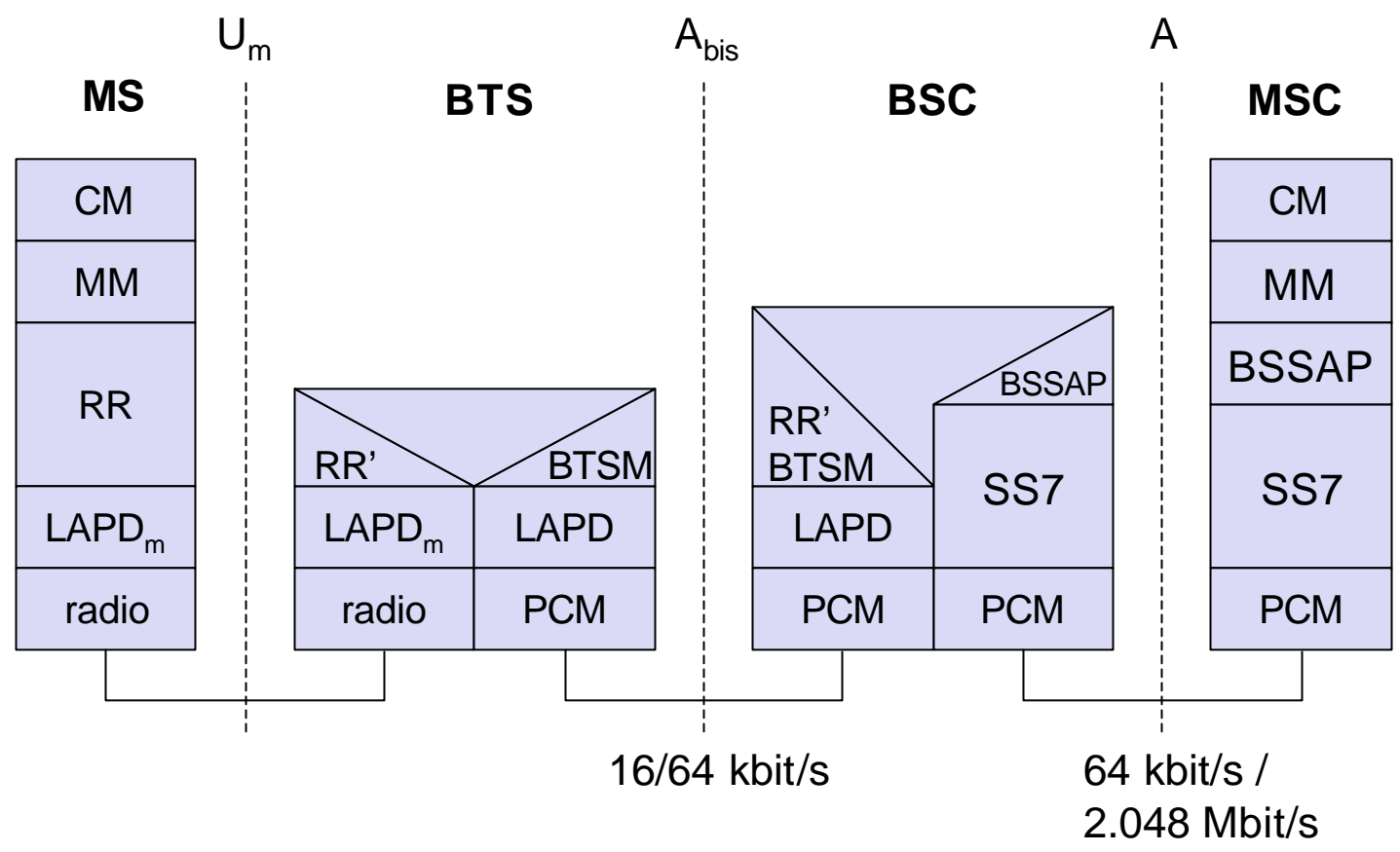
❑ BSC is the switching center for radio channels

Functions	BTS	BSC
Management of radio channels		X
Frequency hopping (FH)	X	X
Management of terrestrial channels		X
Mapping of terrestrial onto radio channels		X
Channel coding and decoding	X	
Rate adaptation	X	
Encryption and decryption	X	X
Paging	X	X
Uplink signal measurements	X	
Traffic measurement		X
Authentication		X
Location registry, location update		X
Handover management		X

GSM - TDMA/FDMA

935-960 MHz
124 channels (200 kHz)
downlink

890-915 MHz
124 channels (200 kHz)
uplink

frequency

higher GSM frame structures

time

GSM TDMA frame

1	2	3	4	5	6	7	8

4.615 ms

GSM time-slot (normal burst)

guard space	tail	user data	S	Training	S	user data	tail	guard space
	3 bits	57 bits	1	26 bits	1	57 bits	3	

546.5 µs

577 µs

GSM protocol layers for signaling

Prof. Dr.-Ing. Jochen Schiller, http://www.jochenschiller.de/   MC SS05   4.25

4 types of handover
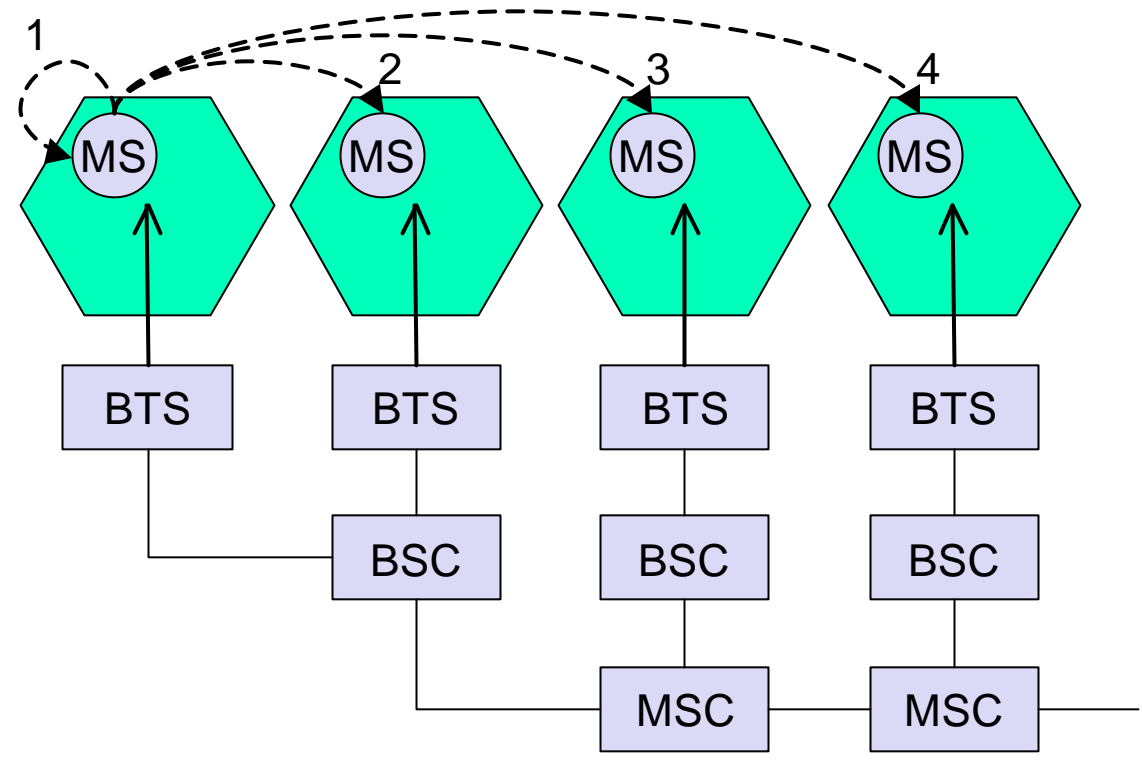
Handover decision

Handover procedure

MS BTS$_{old}$ BSC$_{old}$ MSC BSC$_{new}$ BTS$_{new}$

measurement report

measurement result

HO decision

HO required → HO request →

resource allocation

ch. activation →

HO command ← HO command ← HO command ← HO request ack ← ch. activation ack ←

HO access →

Link establishment

HO complete ← HO complete ←

clear command ← clear command ←
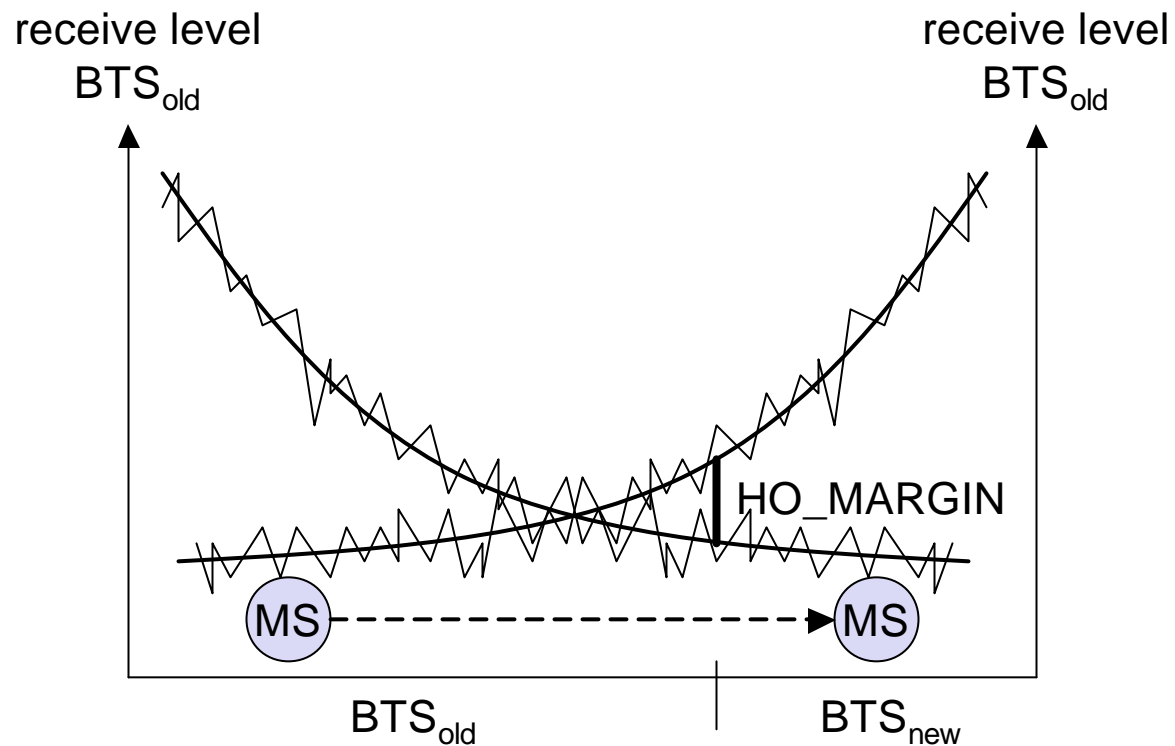
clear complete → clear complete →
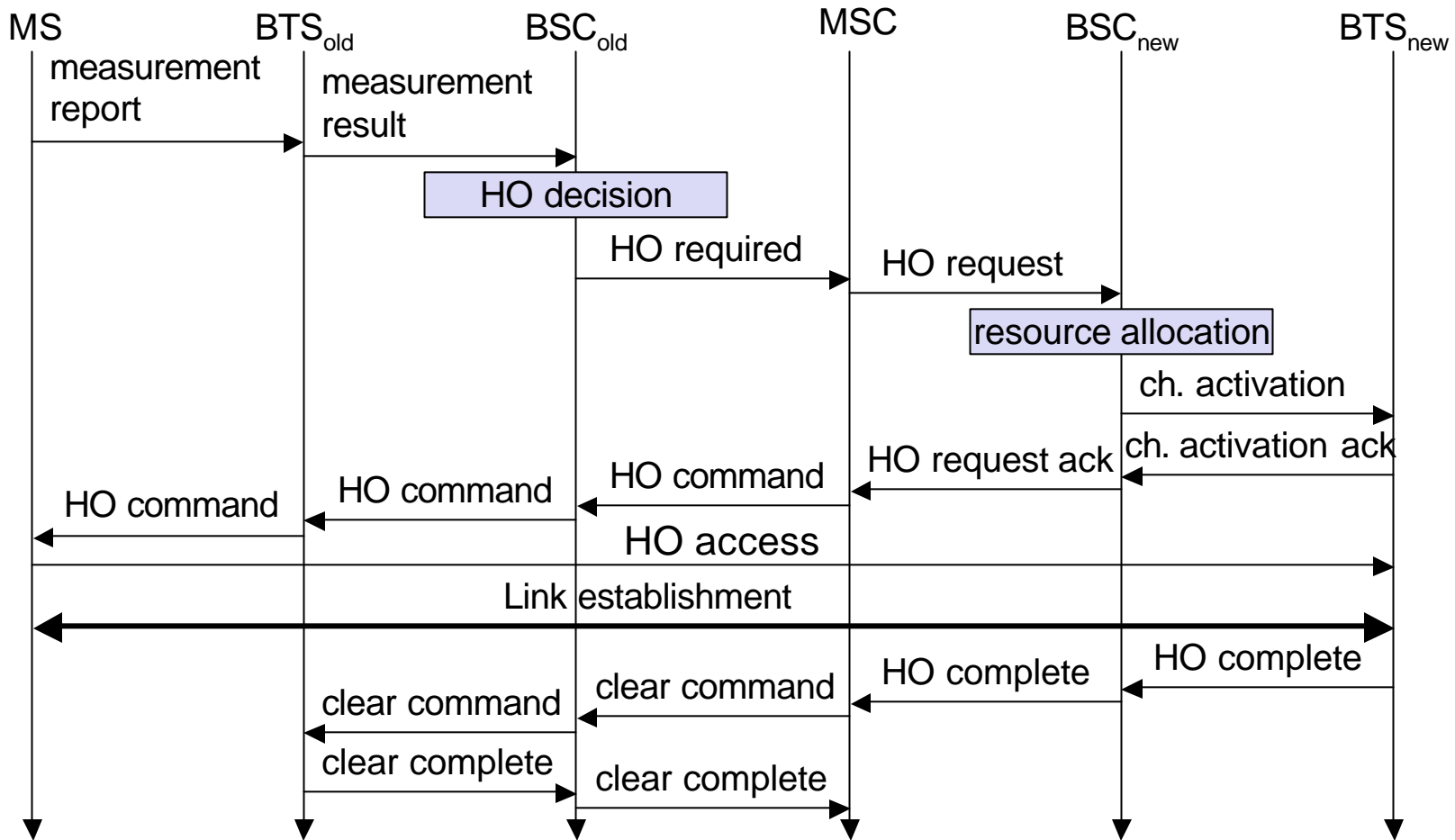
Security in GSM

Security services

- ☐ access control/authentication
  - • user ⇔ SIM (Subscriber Identity Module): secret PIN (personal identification number)
  - • SIM ⇔ network: challenge response method
- ☐ confidentiality
  - • voice and signaling encrypted on the wireless link (after successful authentication)
- ☐ anonymity
  - • temporary identity TMSI (Temporary Mobile Subscriber Identity)
  - • newly assigned at each new location update (LUP)
  - • encrypted transmission

3 algorithms specified in GSM

- ☐ A3 for authentication ("secret", open interface)
- ☐ A5 for encryption (standardized)
- ☐ A8 for key generation ("secret", open interface)

> "secret":
> • A3 and A8 available via the Internet
> • network providers can use stronger mechanisms

Data services in GSM II

GSM Data transmission standardized with only 9.6 kbit/s

- advanced coding allows 14,4 kbit/s
- not enough for Internet and multimedia applications

GPRS (General Packet Radio Service)

- packet switching
- using free slots only if data packets ready to send
  (e.g., 50 kbit/s using 4 slots temporarily)
- standardization 1998, introduction 2001
- advantage: one step towards UMTS, more flexible
- disadvantage: more investment needed (new hardware)

Example 3G Networks: Japan
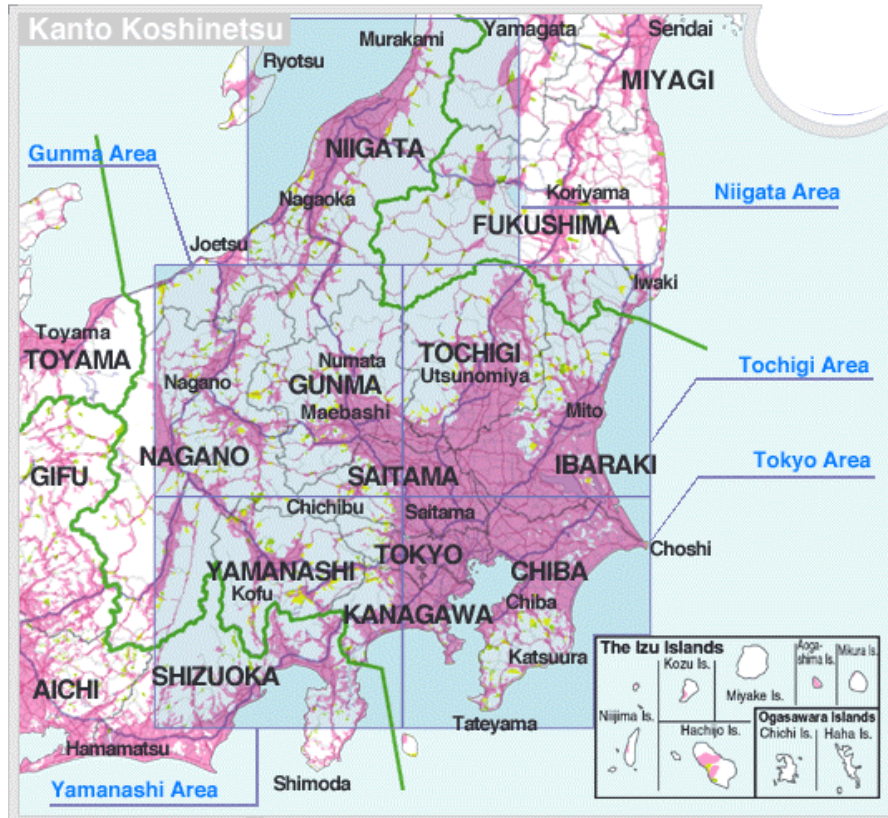
FOMA (Freedom Of Mobile multimedia Access) in Japan

Examples for FOMA phones
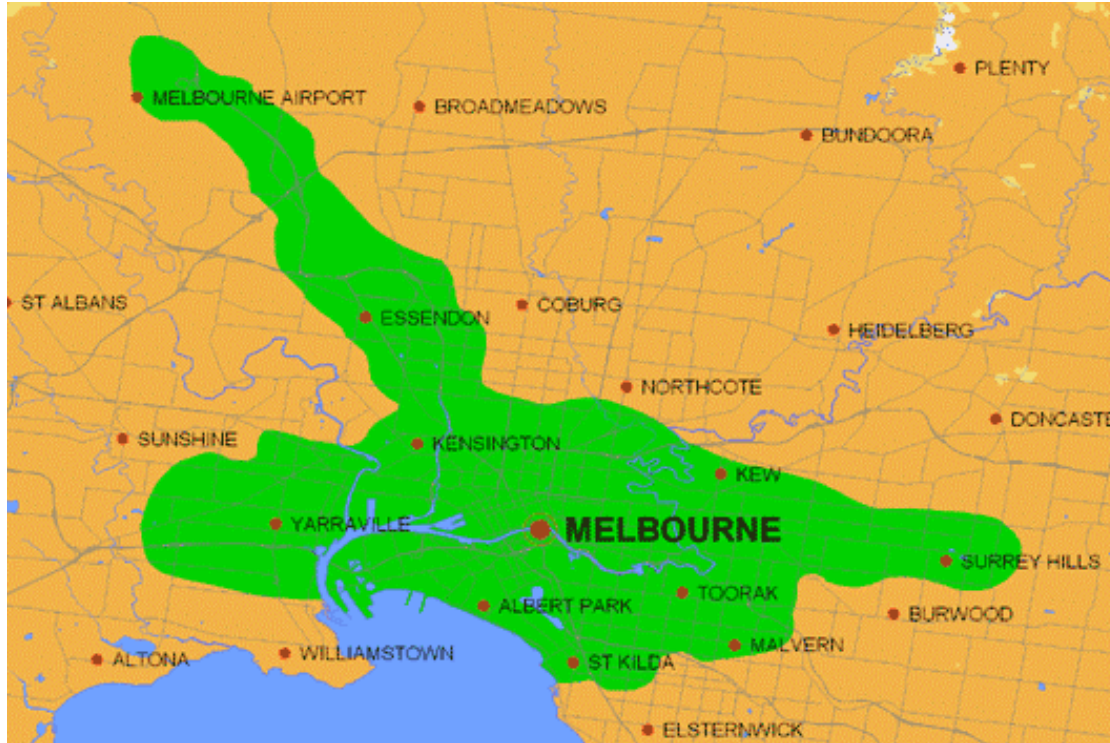
cdma2000 1xEV-DO in Melbourne/Australia

Examples for 1xEV-DO devices

Isle of Man – Start of UMTS in Europe as Test

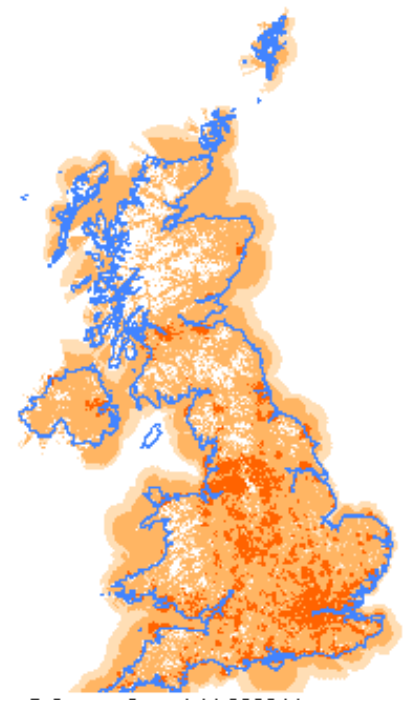Europe's first urban UMTS network

SIEMENS mobile   NEC   MONACO TELECOM

Jardin exotique

La Colle

Herculis

Monaco

Ministère d'état

Core Network

La Costa

Le Sporting

Beach Plaza

Key applications
- Multimedia services (music, video, …)
- Location based services
- Mobile office
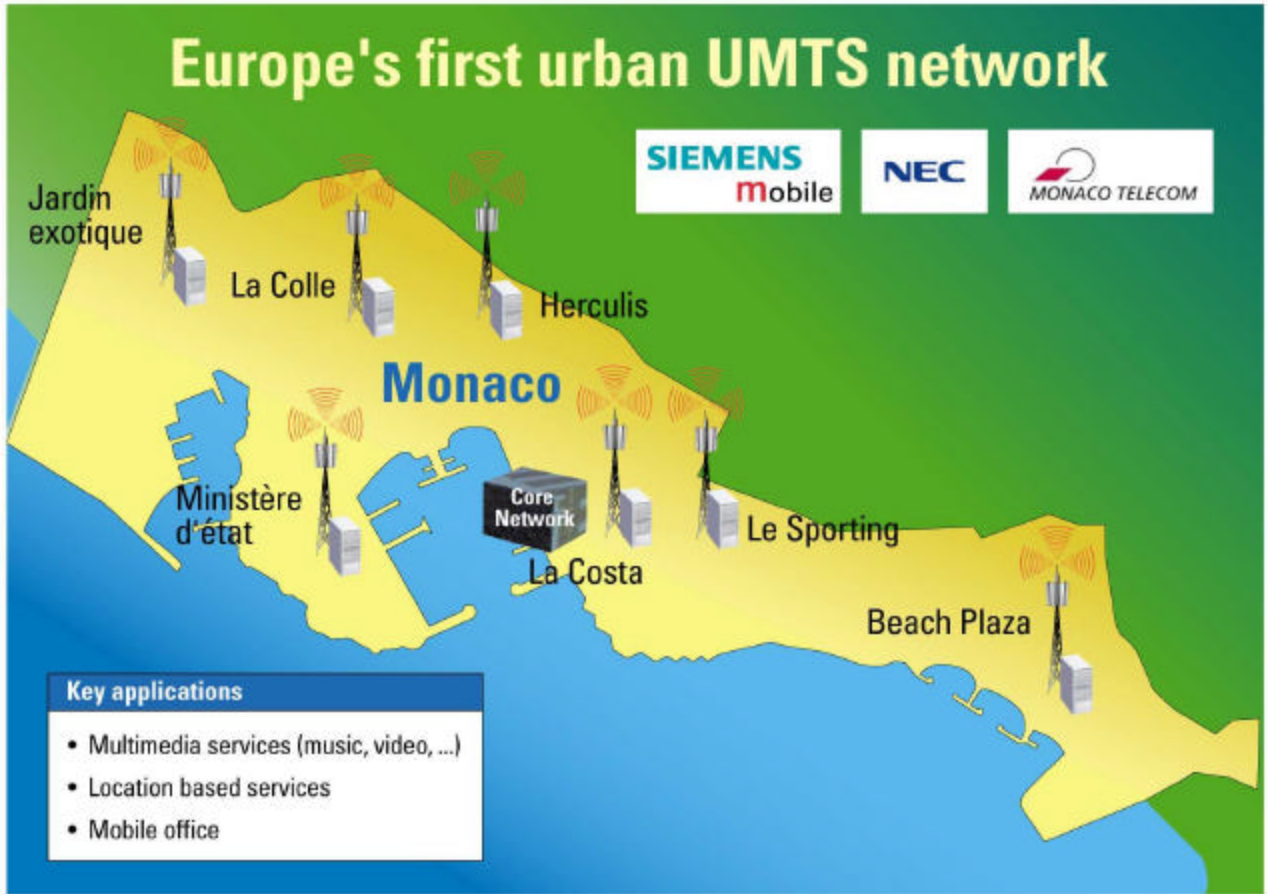
UMTS in Europe
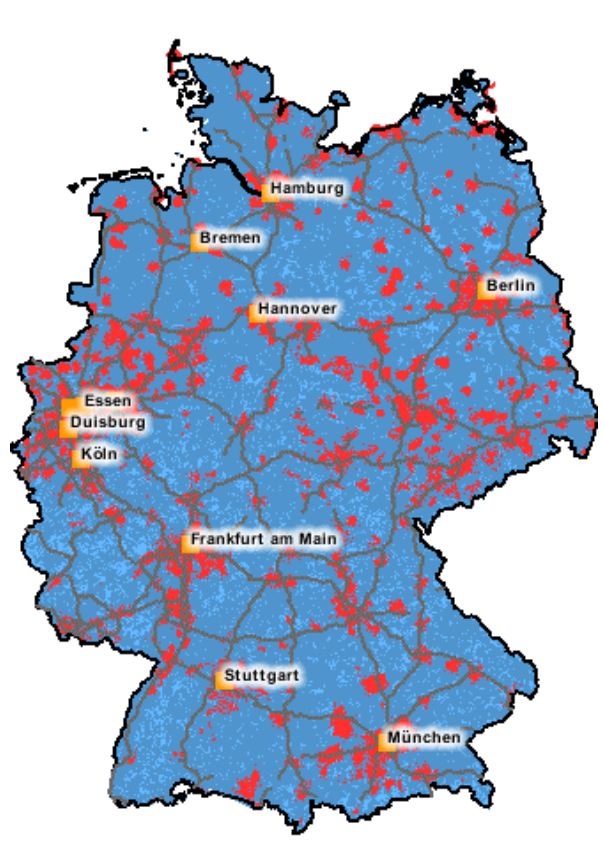
Vodafone/Germany

Orange/UK