Mobile Communications II
Chapter 4:

- DECT
- TETRA
- UMTS

Literature for GSM / GPRS

Jochen Schiller

Mobilkommunikation

2. Überarbeitete Auflage, Addison-Wesley, Pearson Studium

- Kapitel 4.1 (S. 129-167)

Detaillierter in

Bernhard Walke

Mobilfunknetze und Ihre Protokolle

3. Auflage, Teubner

- Band1: Kapitel 3. (S. 135-345)

DECT

European wide cordless telephone system

Digital CT as follower of CT1 with high security access

Can also be used for last mile access networks

Supports also Hot-Spot telephony

- High scalability: >10000 user/km^2
- Radio interface for pedestrian speed only
- Handover defined
- Low cost entities: < 100 €/base-station

Combined GSM/DECT devices were not successful on the market

- To few hot-spots offered DECT services
- The operators blocked this opportunity to strengthen GSM
- GSM was supposed to also handle CT services but failed until now

DECT

DECT (Digital European Cordless Telephone) standardized by ETSI (ETS 300.175-x) for cordless telephones

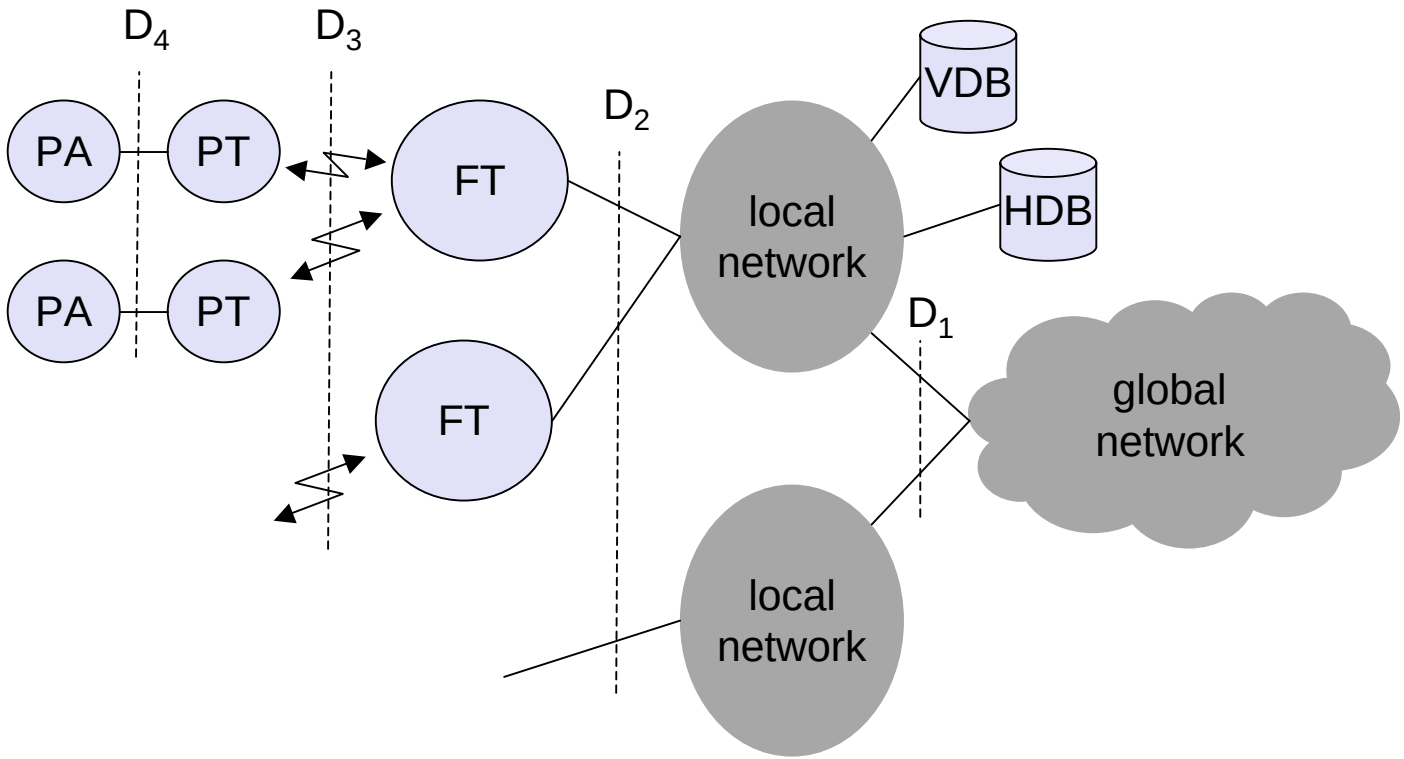
Standard describes air interface between base-station and mobile phone

DECT has been renamed for international marketing reasons into „Digital Enhanced Cordless Telecommunication“

Characteristics

- frequency: 1880 - 1990 MHz
- DECT@ISM for USA at 2.4 GHz with frequency hopping
- channels: 120 full duplex
- duplex mechanism: TDD (Time Division Duplex) with 10 ms frame length
- multiplexing scheme: FDMA with 10 carrier frequencies, TDMA with 2 x 12 slots
- Duplex scheme TDD
- modulation: digital, Gaussian Minimum Shift Key (GMSK)
- power: 10 mW average (max. 250 mW) (10 dBm - 23.5 dBm)
- range: approx. 50 m in buildings, 300m-1km open space

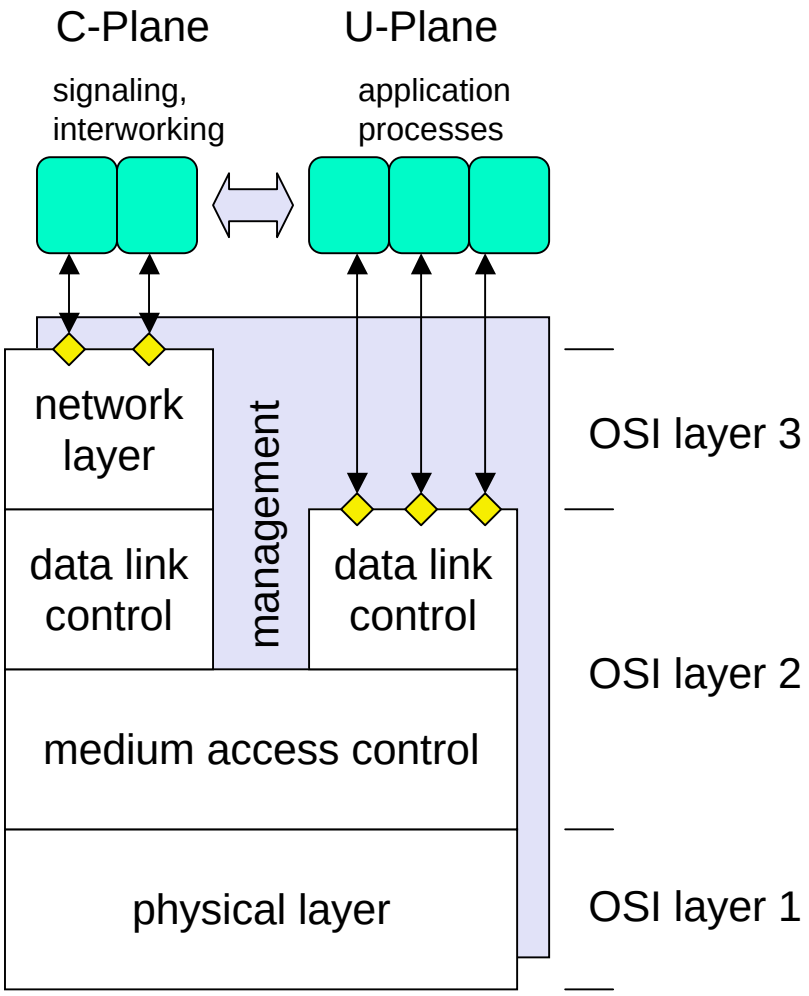
DECT system architecture reference model



PA: Portable Application
PT: Portable radio Termination
FT: Fixed radio Termination

VDB: Visitor Data Base
HDB: Home Data Base
local network: offers local telecommunication services; considered as part of DECT

DECT reference model



- close to the OSI reference model
- management plane covers all layers
- several services in C (control)- and U (user)-plane
- vertical management plane

- User-services access directly layer-3 services
- Only for signaling networks services are needed

DECT layers I

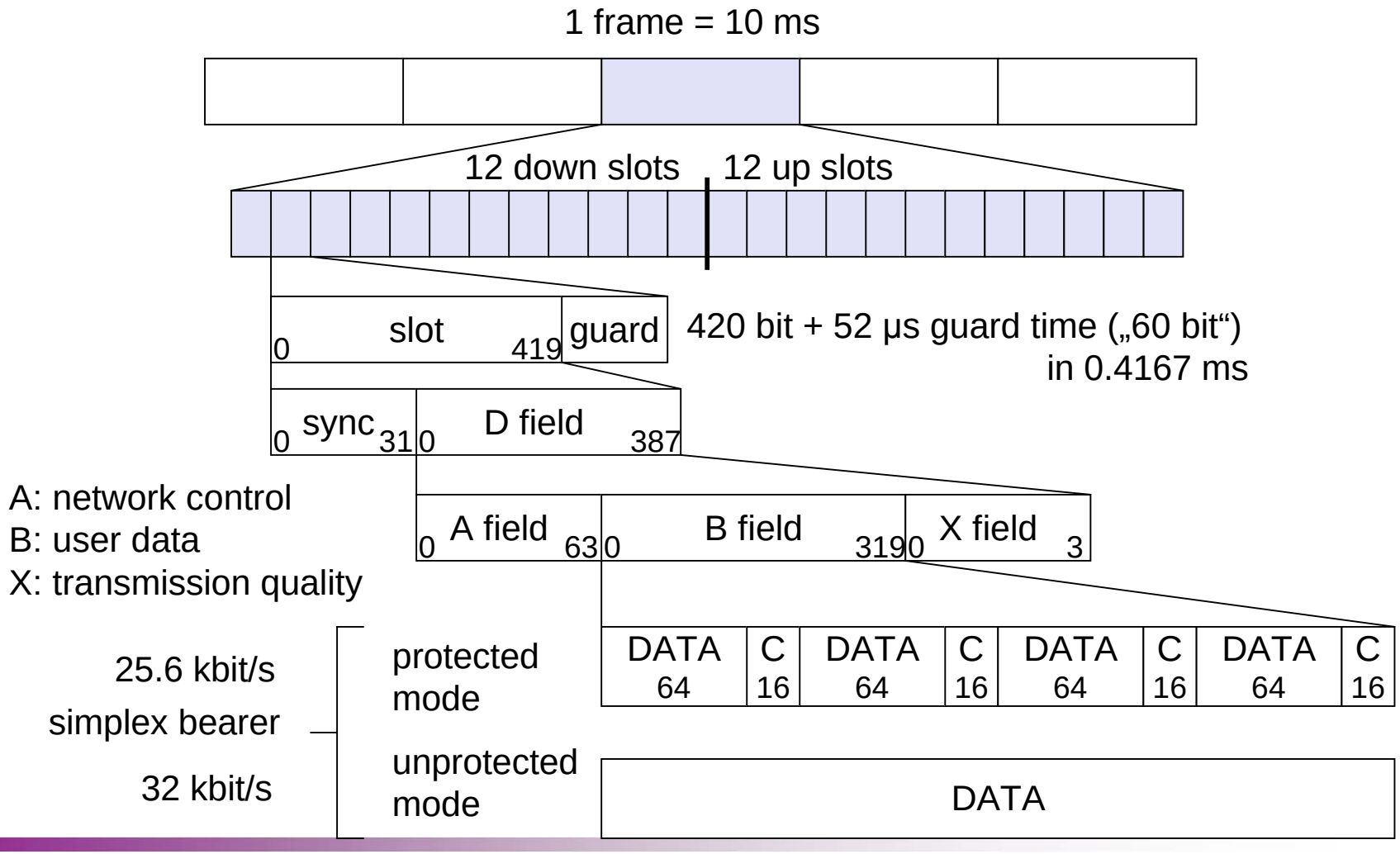
Physical layer

- modulation/demodulation
- generation of the physical channel structure with a guaranteed throughput
- controlling of radio transmission
  - channel assignment on request of the MAC layer
  - detection of incoming signals
  - sender/receiver synchronization
  - collecting status information for the management plane

MAC layer

- maintaining basic services, activating/deactivating physical channels
- multiplexing of logical channels
  - e.g., C: signaling, I: user data, P: paging, Q: broadcast
- segmentation/reassembly
- error control/error correction

DECT time multiplex frame



DECT layers II

Data link control layer

- creation and keeping up reliable connections between the mobile terminal and base station
- two DLC protocols for the control plane (C-Plane)
  - connectionless broadcast service:
    paging functionality (Lb)
  - LAPC+Lc protocol:
    in-call signaling (similar to LAPD within ISDN), adapted to the underlying MAC service
- several services specified for the user plane (U-Plane)
  - null-service: offers unmodified MAC services
  - frame relay: simple packet transmission
  - frame switching: time-bounded packet transmission
  - error correcting transmission: uses FEC, for delay critical, time-bounded services
  - bandwidth adaptive transmission
  - „Escape“ service: for further enhancements of the standard

DECT layers III

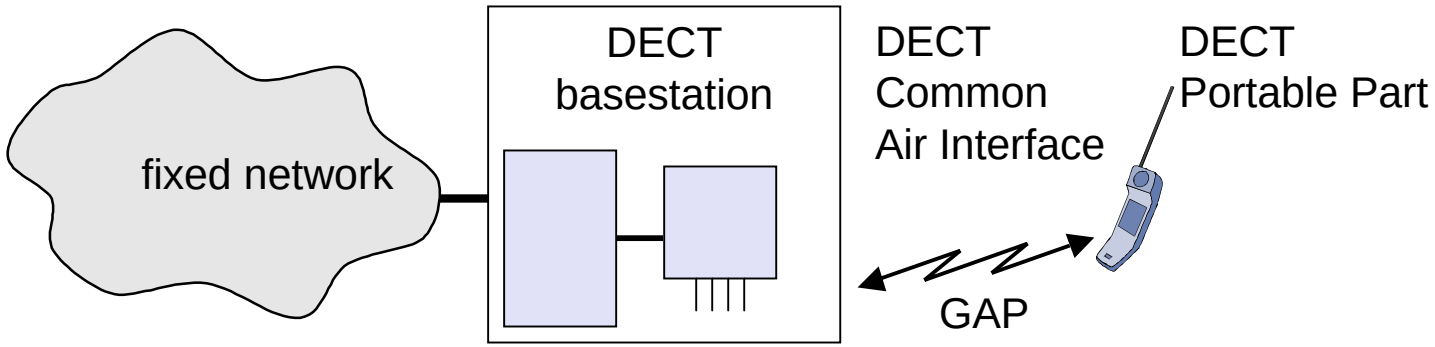
Network layer

- similar to ISDN (Q.931) and GSM (04.08)
- offers services to request, check, reserve, control, and release resources at the base-station and mobile terminal
- resources
  - necessary for a wireless connection
  - necessary for the connection of the DECT system to the fixed network
- main tasks
  - call control: setup, release, negotiation, control
  - call independent services: call forwarding, accounting, call redirecting
  - mobility management: identity management, authentication, management of the location register

Enhancements of the standard

Several „DECT Application Profiles“ in addition to the DECT specification

- GAP (Generic Access Profile) standardized by ETSI in 1997
  - assures interoperability between DECT equipment of different manufacturers (minimal requirements for voice communication)
  - enhanced management capabilities through the fixed network: Cordless Terminal Mobility (CTM)



- DECT/GSM Interworking Profile (GIP): connection to GSM
- ISDN Interworking Profiles (IAP, IIP): connection to ISDN
- Radio Local Loop Access Profile (RAP): public telephone service
- CTM Access Profile (CAP): support for user mobility

TETRA - Terrestrial Trunked Radio

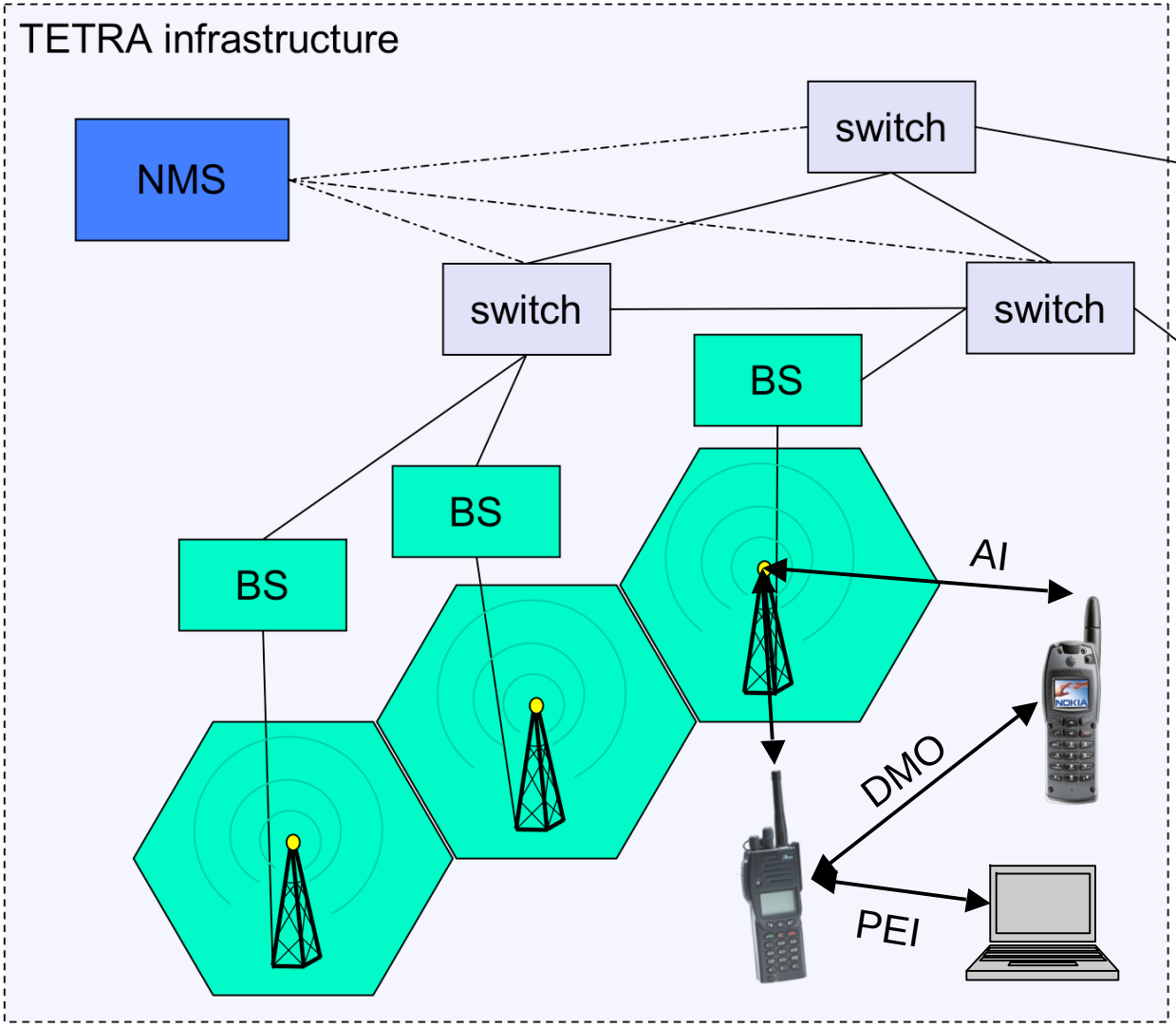
Trunked radio systems

- many different radio carriers
- assign single carrier for a short period to one user/group of users
- taxi service, fleet management, rescue teams
- interfaces to public networks, voice and data services
- very reliable, fast call setup, local operation

TETRA - ETSI standard

- formerly: Trans European Trunked Radio
- offers Voice+Data and Packet Data Optimized service
- point-to-point and point-to-multipoint
- ad-hoc and infrastructure networks
- several frequencies: 380 - 400 MHz, 410 - 430 MHz
- FDD, DQPSK
- group call, broadcast, sub-second group-call setup

TETRA – Network Architecture

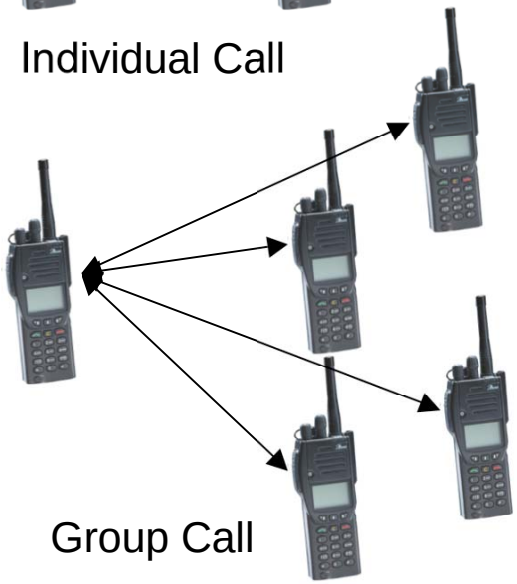


AI: Air Interface
BS: Base Station
DMO: Direct Mode Operation
ISI: Inter-System Interface
NMS: Network Management System
PEI: Peripheral Equipment Interface

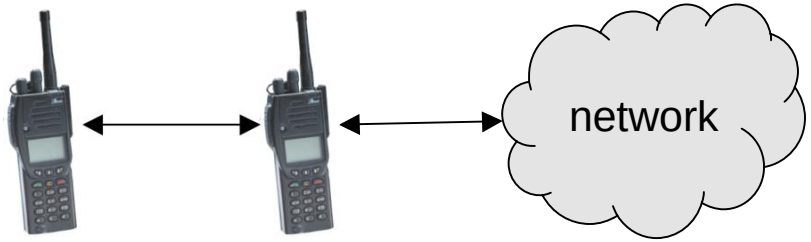
TETRA – Direct Mode I

Direct Mode enables ad-hoc operation and is one of the most important differences to pure infrastructure-based networks such as GSM, cdma2000 or UMTS.

Individual Call



Group Call



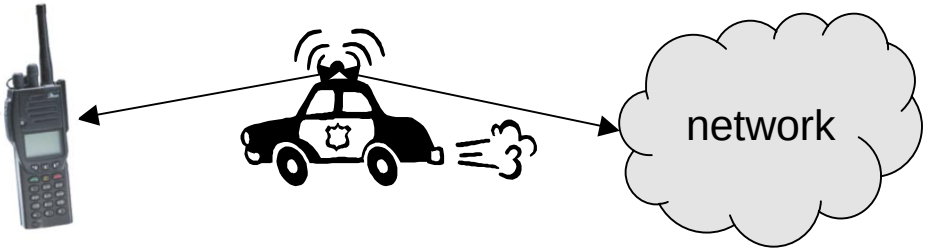
“Dual Watch” – alternating participation in Infrastructure and ad-hoc

Managed Direct Mode

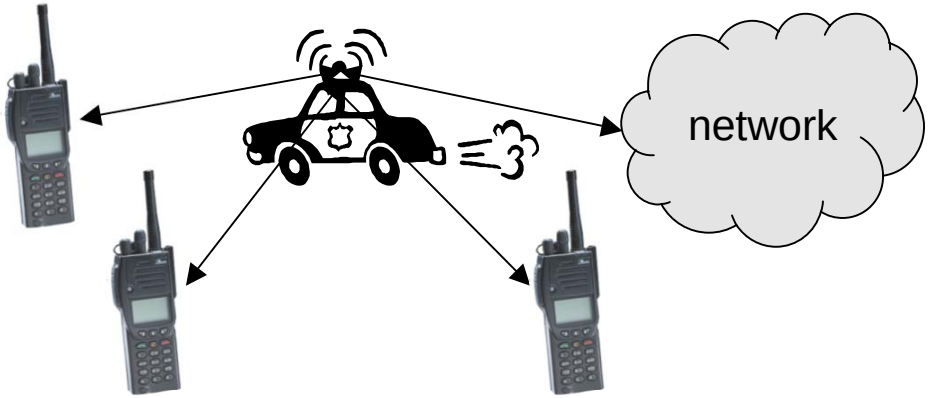
TETRA – Direct Mode II

An additional repeater may increase the transmission range (e.g. police car)

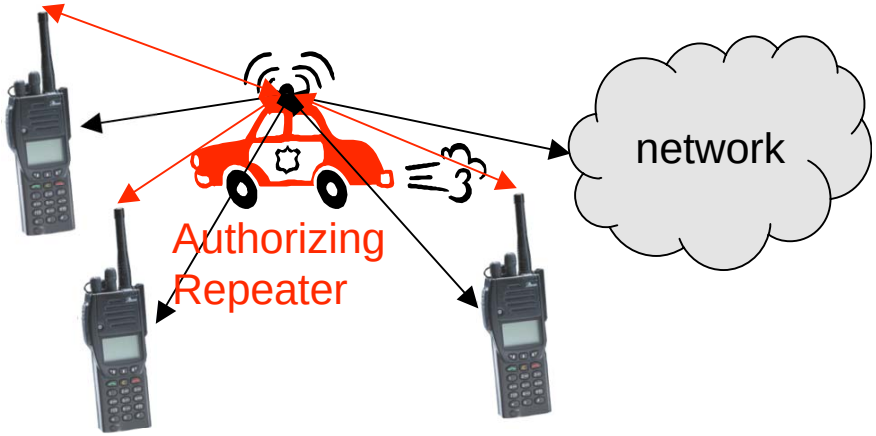
Direct Mode with Repeater



Direct Mode with Gateway



Direct Mode with Repeater/Gateway



Managed Repeater/Gateway

TETRA - Terrestrial Trunked Radio

Trunked radio systems

- many different radio carriers
- assign single carrier for a short period to one user/group of users
- taxi service, fleet management, rescue teams
- interfaces to public networks, voice and data services
- very reliable, fast call setup, local operation

TETRA - ETSI standard

- formerly: Trans European Trunked Radio
- point-to-point and point-to-multipoint
- encryption (end-to-end, air interface), authentication of devices, users and networks
- group call, broadcast, sub-second group-call setup
- ad-hoc (“direct mode”), relay and infrastructure networks
- call queuing with pre-emptive priorities

TETRA – Technology

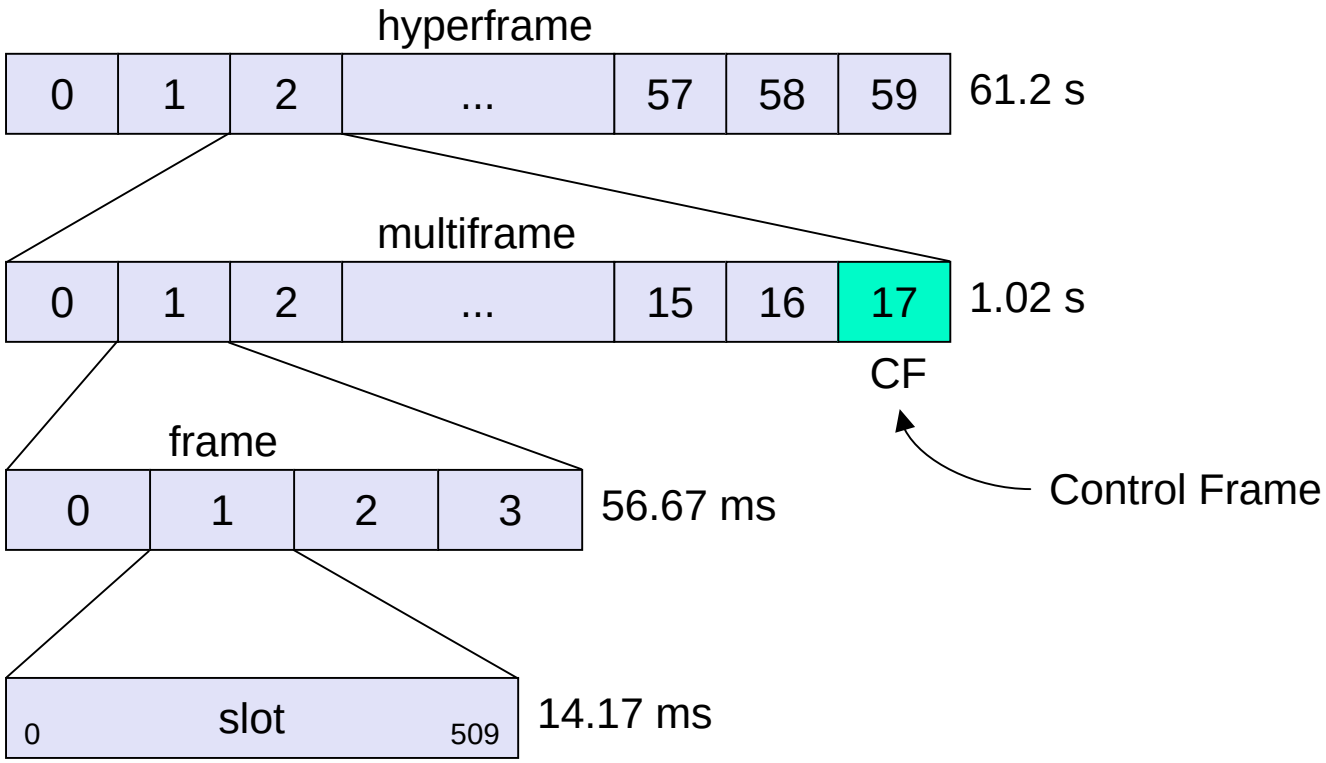
Services

- Voice+Data (V+D) and Packet Data Optimized (PDO)
- Short data service (SDS)

Frequencies

- Duplex: FDD, Modulation: DQPSK
- Europe (in MHz, not all available yet)
  - 380-390 UL / 390-400 DL; 410-420 UL / 420-430 DL, 450-460 UL / 460-470 DL; 870-876 UL / 915-921 DL
- Other countries
  - 380-390 UL / 390-400 DL; 410-420 UL / 420-430 DL, 806-821 UL / 851-866 DL

TDMA structure of the voice+data system



TETRA – Data Rates

Infrastructure mode, V+D in kbit/s

No. of time slots	1	2	3	4
No protection	7.2	14.4	21.6	28.8
Low protection	4.8	9.6	14.4	19.2
High protection	2.4	4.8	7.2	9.6

TETRA Release 2 – Supporting higher data rates

- TEDS (TETRA Enhanced Data Service)
- up to 100 kbit/s
- backward compatibility

UMTS

Goal to create an Universal Personal Communication (UPN) system

- Home (stationary), Car (speed up to 500 km/h), Satellite (slow mobility in rural areas), Pedestrian (10 km/h, high speed, high quality)

Initiative for a Future Public Land Mobile Telecommunication System (FPLMTS)

First initiative already in 1988/89

Spectrum Reservation in 1992 for IMT-2000 at WRC (World Radio Conference)

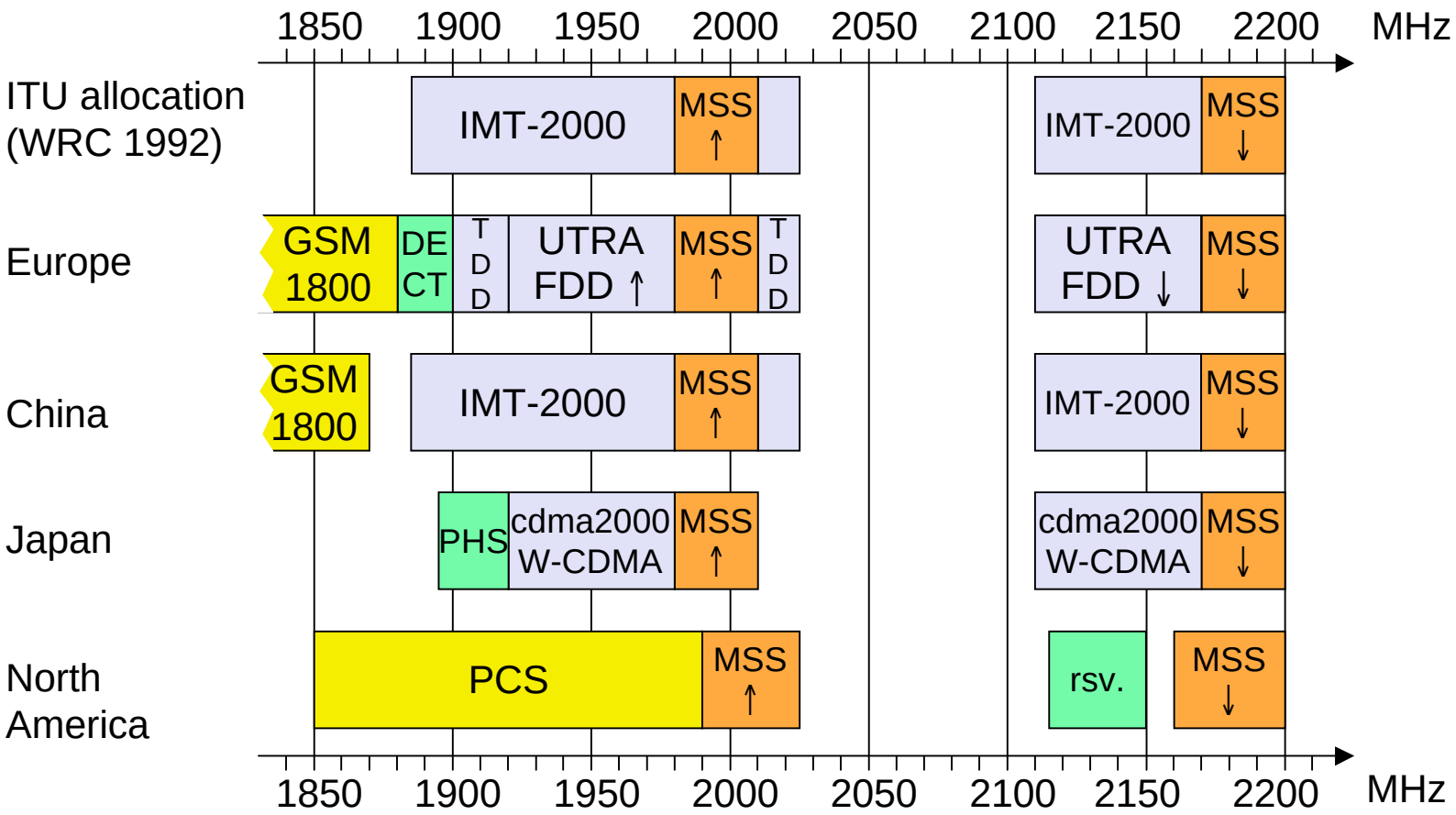
Additional spectrum was granted at WRC-2000 for IMT-2000

- 800 - 1000 MHz; 1700 - 1900 MHz; 2500 - 2700 MHz

Original goal to define a world wide unique standard failed

- Interests of the network operators was to move evolutionary towards IMT-2000 services
- GSM-industry wanted to keep commercial lead in further developments
- National interests prohibited the agreement
- Frequency regulators and existing services prohibited the unique frequency band

Frequencies for IMT-2000



UMTS and IMT-2000

Proposals for IMT-2000 (International Mobile Telecommunications)

- UWC-136 (as an evolution of D-AMPS), cdma2000 (as an evolution of IS-95, cdmaOne), WP-CDMA (as an evolution of GSM/GPRS based systems)
- UMTS (Universal Mobile Telecommunications System) from ETSI

UMTS

- UTRA (Universal Terrestrial Radio Access; Air Interface)
- enhancements of GSM
  - EDGE (Enhanced Data rates for GSM Evolution): GSM up to 384 kbit/s
    - 8-PSK, in GSM Frequency range using same TDMA slot structure
  - CAMEL (Customized Application for Mobile Enhanced Logic)
    - Intelligent service environment for visitors in foreign networks
    - VHE (virtual Home Environment)
- fits into GMM (Global Multimedia Mobility) initiative from ETSI
- requirements
  - min. 144 kbit/s rural (goal: 384 kbit/s; speed up to 500 km/h)
  - min. 384 kbit/s suburban (goal: 512 kbit/s; speed up to 120 km/h)
  - up to 2 Mbit/s urban (pedestrian speed)

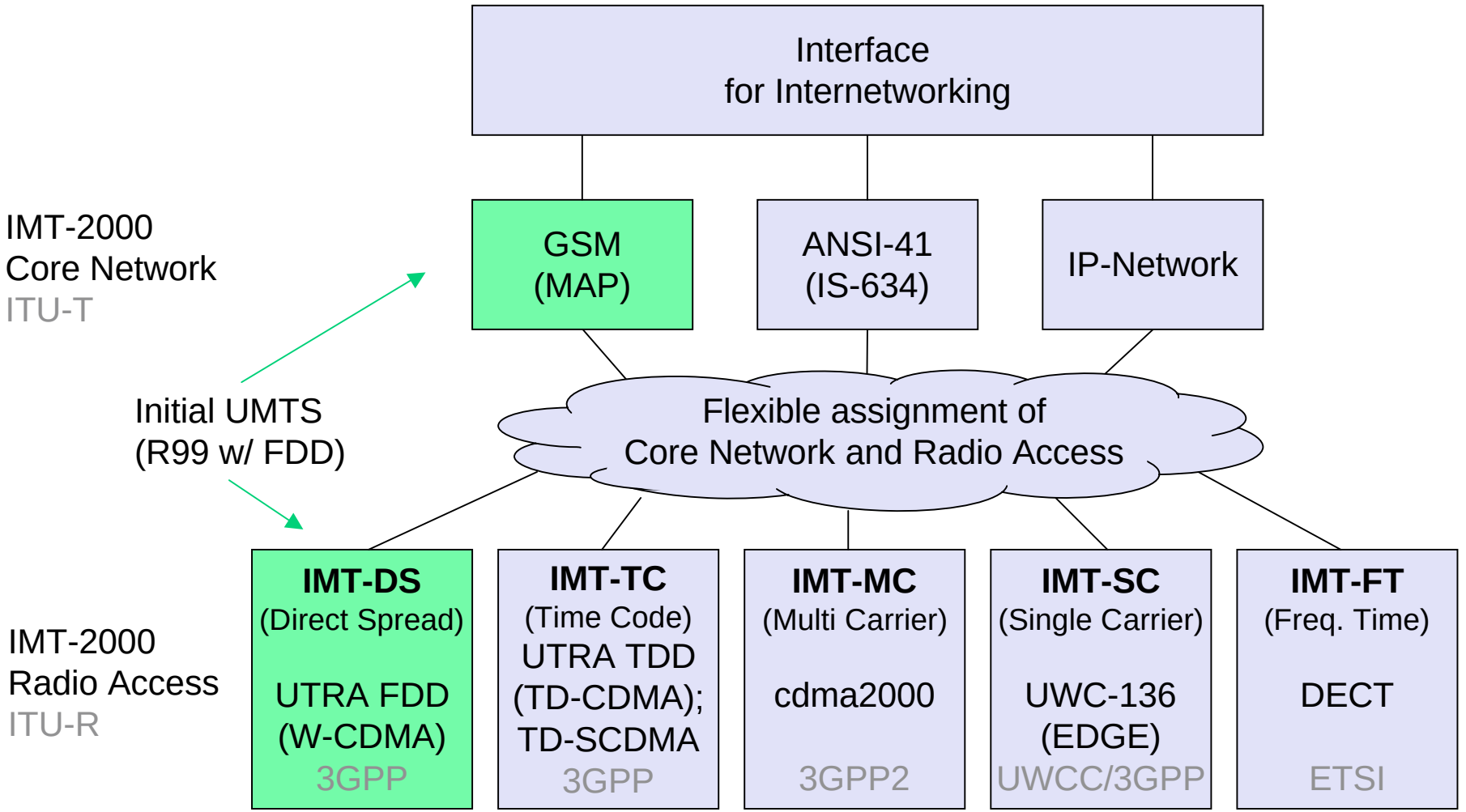
Standardisation Issues

All activities towards 3G systems were transferred to 3GPP (3G partnership program)

Instead of defining a single unique standard 3GPP decided to build a family of standards for IMT-2000

- IMT-DS (direct spread): W-CDMA systems like UTRA-FDD
- IMT-TC (time code): originally only UTRA-TDD but now also TD-SCDMA (time division synchronous) as the Chinese variant for low speed high performance communication
- IMT-MC (Multi Carrier): members are CDMA-2000 but moved into 3GPP2 for the further evolution of IMT-2000 performance (mainly pushed by Qualcom)
- IMT-SC (Single Carrier): members are UWC136 (D-AMPS) mainly evolutionary path via EDGE (pushed by US-operators)
- IMT-FT (Frequency Time): improved version of DECT

IMT-2000 family



GSM and UMTS Releases

GSM/EDGE Release	3G Release	Abbreviated name	Spec version number	Freeze date (indicative only)
Phase 2+ Release 6	Release 6	Rel-6	6.x.y	December 2004 - March 2005
Phase 2+ Release 5	Release 5	Rel-5	5.x.y	March - June 2002
Phase 2+ Release 4	Release 4	Rel-4	4.x.y	March 2001
-	Release 2000	R00	4.x.y	Renaming…
Phase 2+ Release 2000	-		9.x.y	
-	Release 1999	R99	3.x.y	March 2000
Phase 2+ Release 1999	-		8.x.y	
Phase 2+ Release 1998	-	R98	7.x.y	early 1999
Phase 2+ Release 1997	-	R97	6.x.y	early 1998
Phase 2+ Release 1996	-	R96	5.x.y	early 1997
Phase 2	-	Ph2	4.x.y	1995
Phase 1	-	Ph1	3.x.y	1992

More Standardisation

3GPP develops standards in form of releases

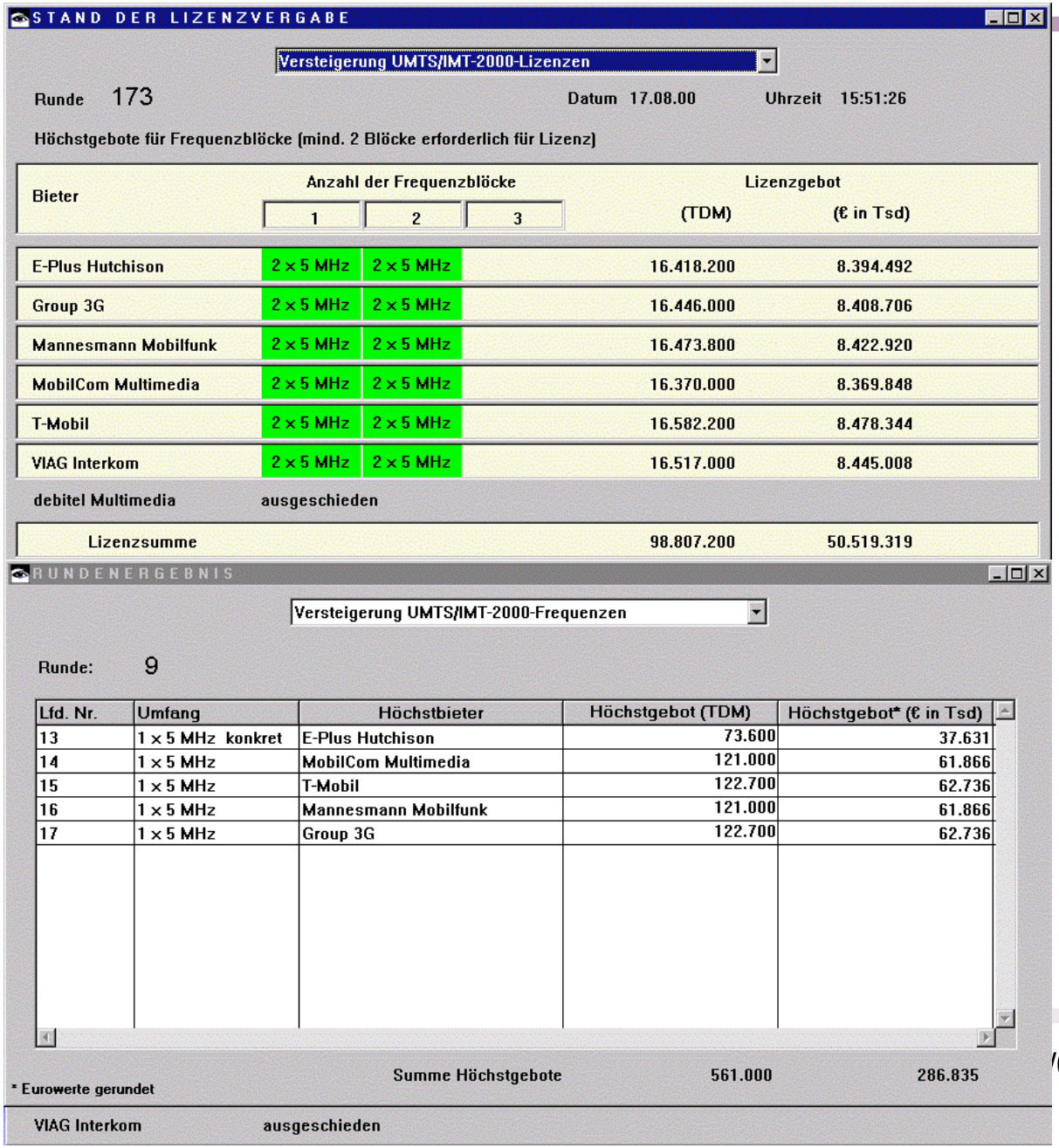
Currently Release-99 is being introduced

The evolution towards a “full IP based IMT-2000” is reflected in the different release states

- Release 4: introduces QoS within the core network, mobile execution environments (MExE), new service architectures
- Release 5: introduces a fundamentally different core network as a full IP based network (convergence from today’s CS-Architectures); IETF will be more and more important for service levels of IMT-Releases; parts of SS7 signalling architecture will be replaced by SIP (session initialisation protocol) for multi-media streaming; additionally introduction of HSDPA (High speed downlink packet access 8 - 10 Mb/s)
- Release 6: additionally MIMO structures for performance increase and better radio spectrum use

Currently 3GPP discusses Release 12 - 15 with additional combinations of WLANS and other data-oriented “hot-spot” technologies (towards 4G systems)

Licensing Example: UMTS in Germany, 18. August 2000



STAND DER LIZENZVERGABE

Versteigerung UMTS/IMT-2000-Lizenzen

Runde 173 Datum 17.08.00 Uhrzeit 15:51:26

Höchstgebote für Frequenzblöcke (mind. 2 Blöcke erforderlich für Lizenz)

Bieter	Anzahl der Frequenzblöcke 1	2	3	Lizenzgebot (TDM)	(€ in Tsd)
E-Plus Hutchison	2 x 5 MHz	2 x 5 MHz		16.418.200	8.394.492
Group 3G	2 x 5 MHz	2 x 5 MHz		16.446.000	8.408.706
Mannesmann Mobilfunk	2 x 5 MHz	2 x 5 MHz		16.473.800	8.422.920
MobilCom Multimedia	2 x 5 MHz	2 x 5 MHz		16.370.000	8.369.848
T-Mobil	2 x 5 MHz	2 x 5 MHz		16.582.200	8.478.344
VIAG Interkom	2 x 5 MHz	2 x 5 MHz		16.517.000	8.445.008
debitel Multimedia	ausgeschieden				
Lizenzsumme				98.807.200	50.519.319

RUNDENERGEBNIS

Versteigerung UMTS/IMT-2000-Frequenzen

Runde: 9

Lfd. Nr.	Umfang	Höchstbieter	Höchstgebot (TDM)	Höchstgebot* (€ in Tsd)
13	1 x 5 MHz konkret	E-Plus Hutchison	73.600	37.631
14	1 x 5 MHz	MobilCom Multimedia	121.000	61.866
15	1 x 5 MHz	T-Mobil	122.700	62.736
16	1 x 5 MHz	Mannesmann Mobilfunk	121.000	61.866
17	1 x 5 MHz	Group 3G	122.700	62.736
		Summe Höchstgebote	561.000	286.835

* Eurowerte gerundet

VIAG Interkom ausgeschieden

- UTRA-FDD:
  - Uplink 1920-1980 MHz
  - Downlink 2110-2170 MHz
  - duplex spacing 190 MHz
  - 12 channels, each 5 MHz
- UTRA-TDD:
  - 1900-1920 MHz,
  - 2010-2025 MHz;
  - 5 MHz channels
- Coverage: 25% of the population until 12/2003, 50% until 12/2005

Sum: 50.81 billion €

UMTS architecture (Release 99 used here!)

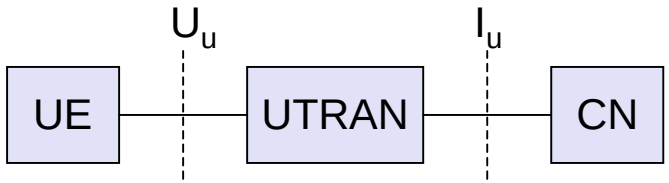
UTRAN (UTRA Network)

- Cell level mobility
- Radio Network Subsystem (RNS)
- Encapsulation of all radio specific tasks

UE (User Equipment)

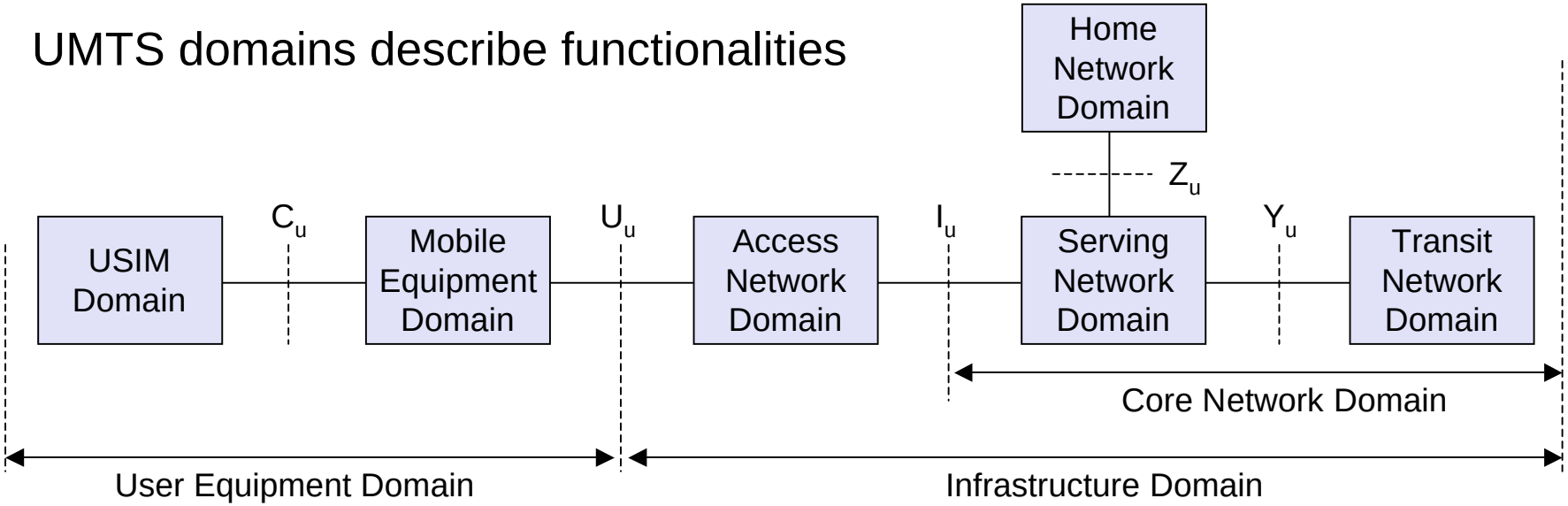
CN (Core Network)

- Inter system handover
- Location management if there is no dedicated connection between UE and UTRAN



UMTS domains and interfaces I

UMTS domains describe functionalities



User Equipment Domain

- Assigned to a single user in order to access UMTS services
  - USIM contains all personal data as well as a UMTS SIM Application Toolkit (interpreter for flexible creation of new services)

Infrastructure Domain

- Shared among all users
- Offers UMTS services to all accepted users

UMTS domains and interfaces II

Universal Subscriber Identity Module (USIM)

- Functions for encryption and authentication of users
- Located on a SIM inserted into a mobile device

Mobile Equipment Domain

- Functions for radio transmission
- User interface for establishing/maintaining end-to-end connections

Access Network Domain

- Access network dependent functions

Core Network Domain

- Access network independent functions
- Serving Network Domain
  - Network currently responsible for communication
- Home Network Domain
  - Location and access network independent functions

Spreading and scrambling of user data

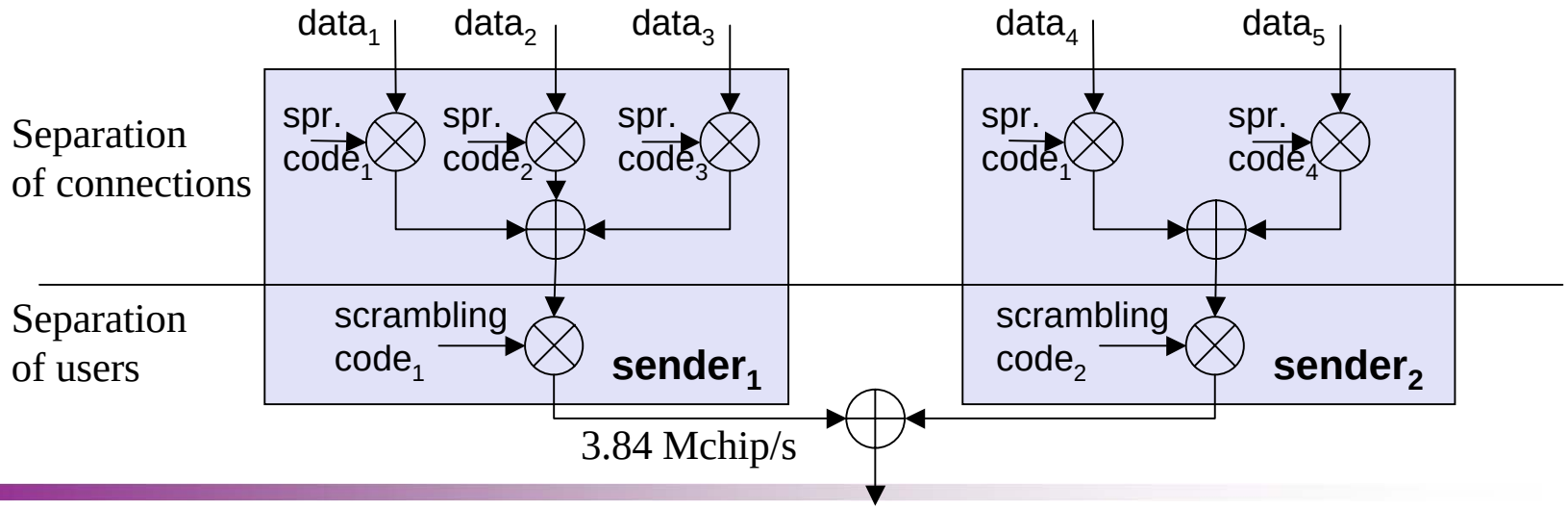
Constant chipping rate of 3.84 Mchip/s

Different user data rates supported via different spreading factors

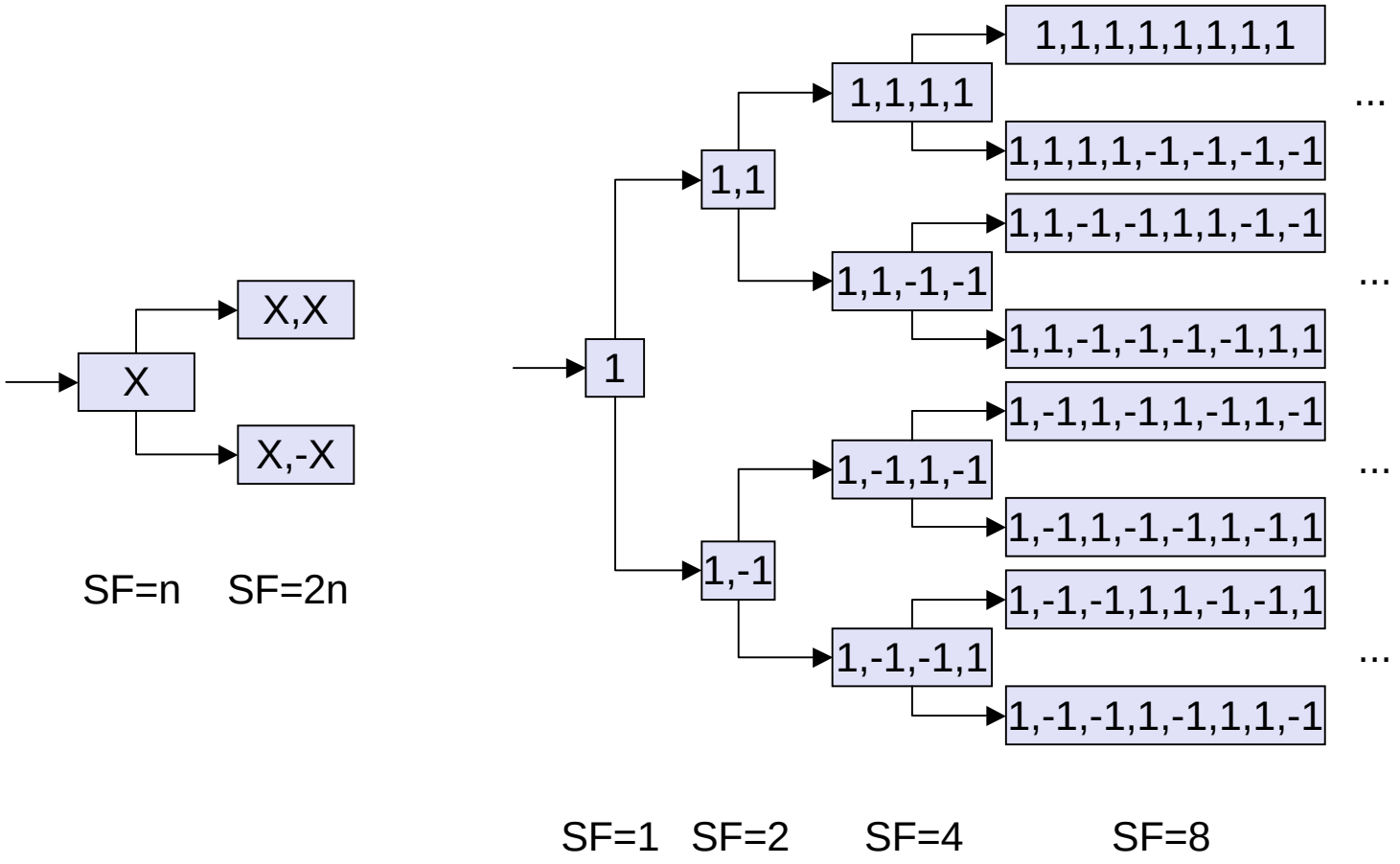
- higher data rate: less chips per bit and vice versa

User separation via unique, quasi orthogonal scrambling codes

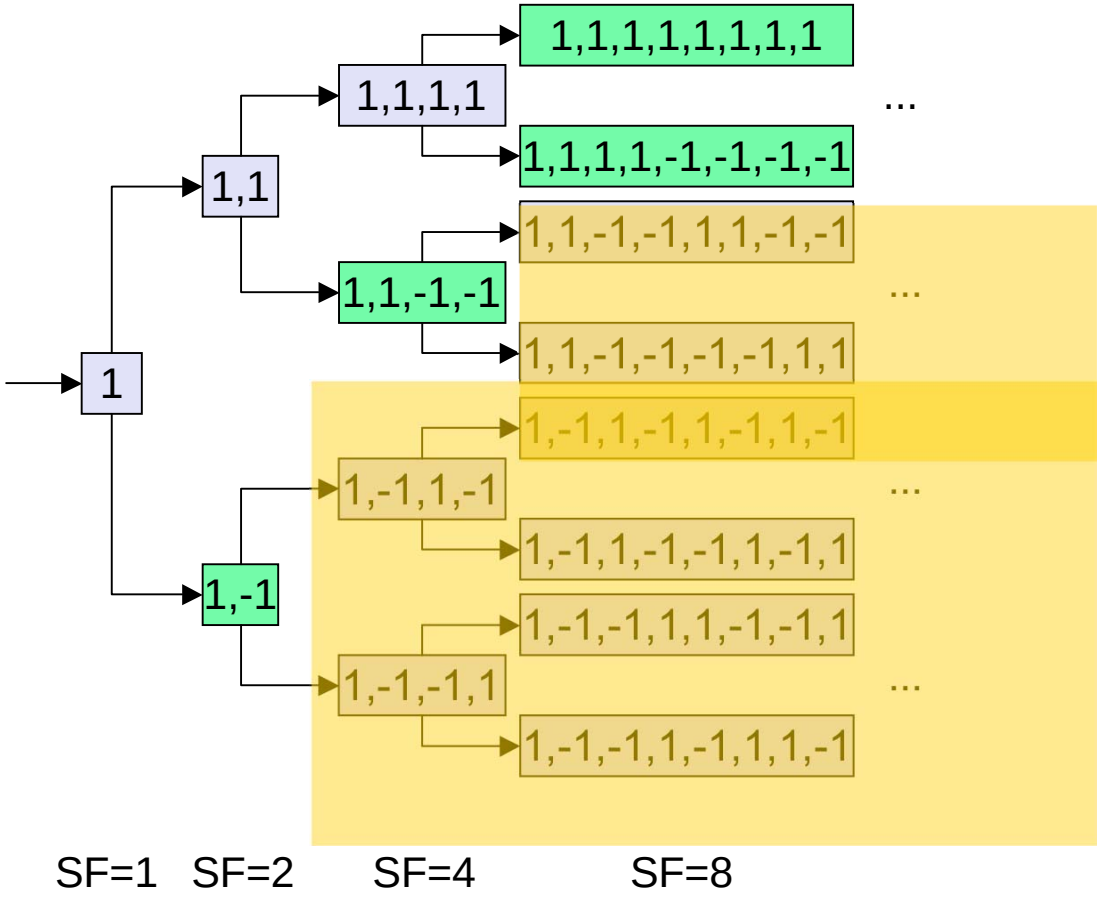
- users are not separated via orthogonal spreading codes
- much simpler management of codes: each station can use the same orthogonal spreading codes
- precise synchronization not necessary as the scrambling codes stay quasi-orthogonal



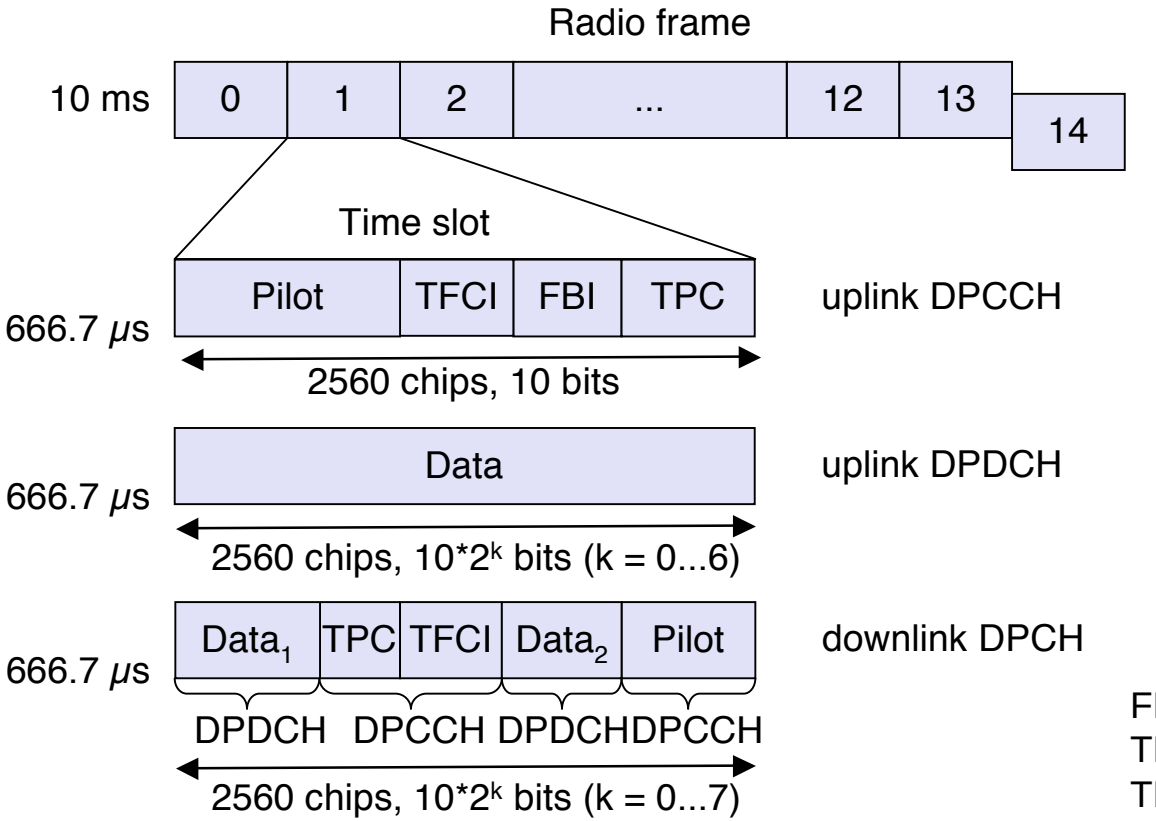
OVSF (Orthogonal Variable Spreading Factor) coding



Example of OVSF use for 4 connections with different bit-rates



UMTS FDD frame structure



W-CDMA

- 1920-1980 MHz uplink
- 2110-2170 MHz downlink
- chipping rate: 3.840 Mchip/s
- soft handover
- QPSK
- complex power control (1500 power control cycles/s)
- spreading: UL: 4-256; DL:4-512

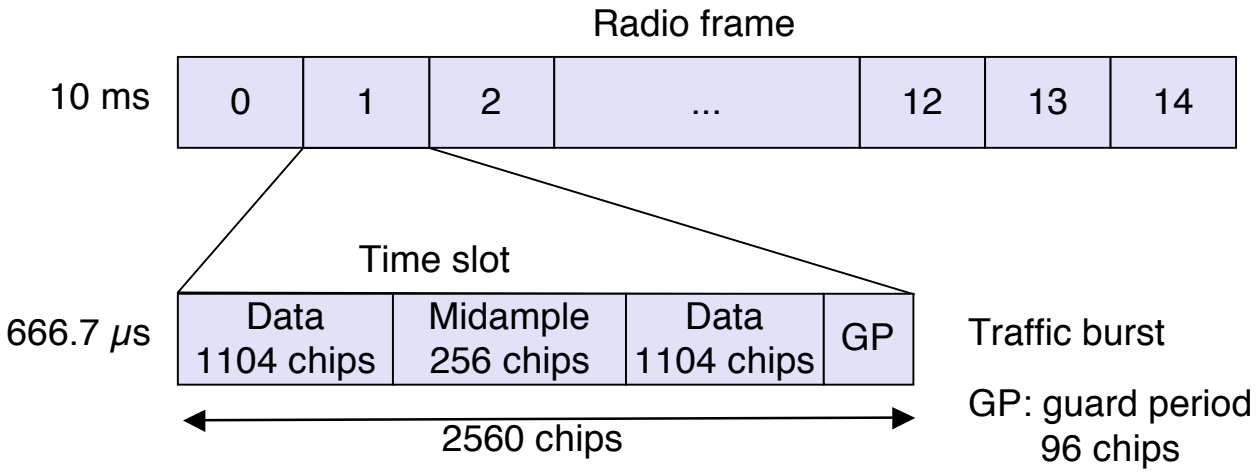
Slot structure NOT for user separation but synchronisation for periodic functions!

FBI: Feedback Information
TPC: Transmit Power Control
TFCI: Transport Format Combination Indicator
DPCCH: Dedicated Physical Control Channel
DPDCH: Dedicated Physical Data Channel
DPCH: Dedicated Physical Channel

Typical UTRA-FDD uplink data rates

User data rate [kbit/s]	**12.2 (voice)**	**64**	**144**	**384**
DPDCH [kbit/s]	60	240	480	960
DPCCH [kbit/s]	15	15	15	15
Spreading	64	16	8	4

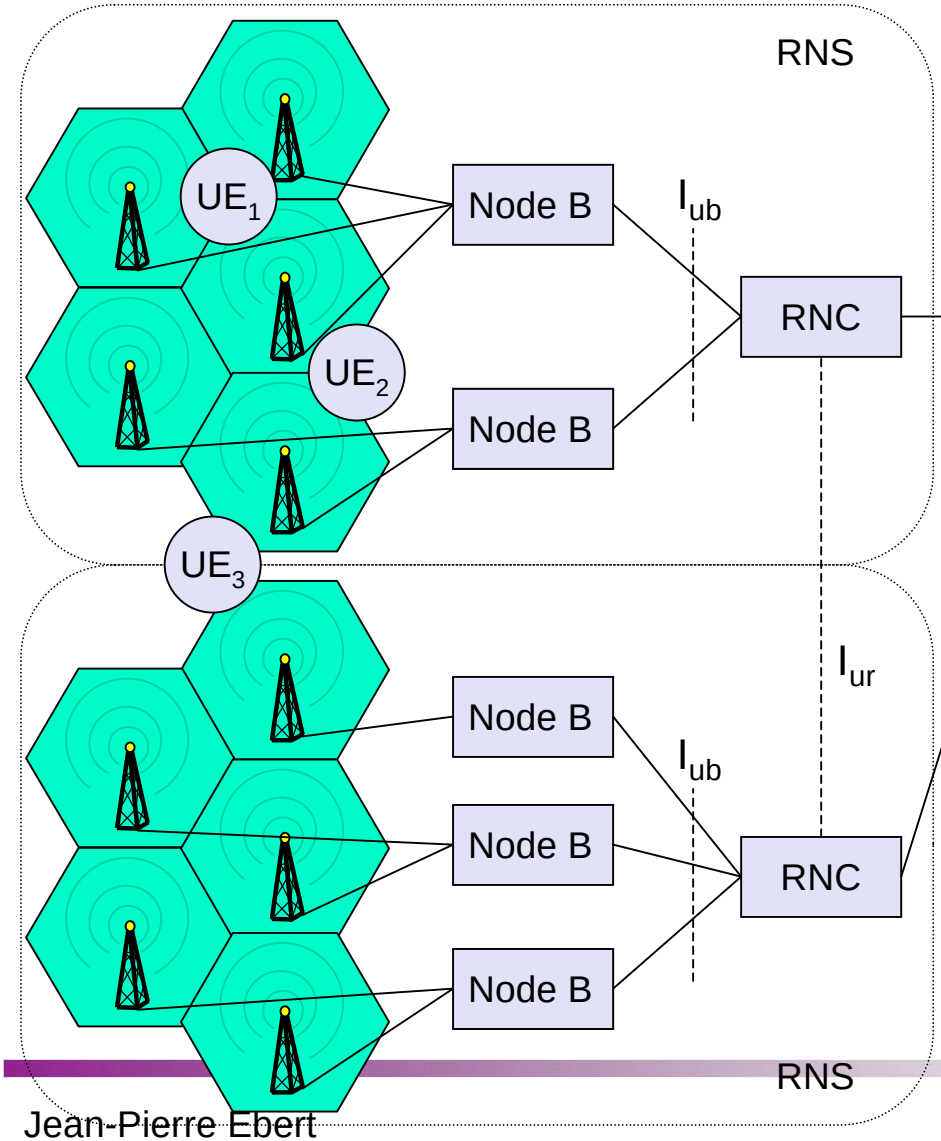
UMTS TDD frame structure (burst type 2)



TD-CDMA

- 2560 chips per slot
- spreading: 1 - 16
- symmetric or asymmetric slot assignment to UL/DL (min. 1 per direction)
- tight synchronisation needed
- simpler power control (100 - 800 power control cycles/s)

UTRAN architecture



RNC: Radio Network Controller

RNS: Radio Network Subsystem

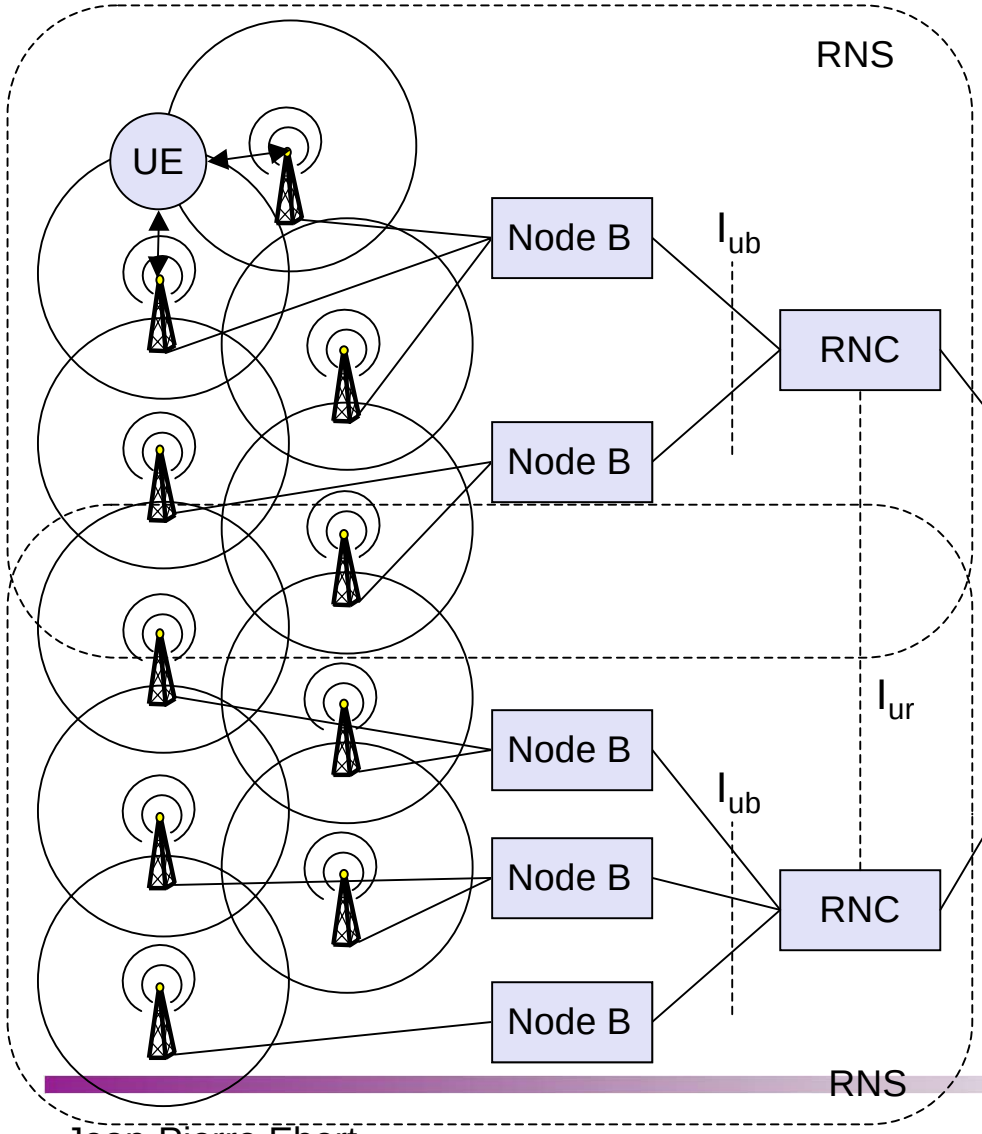
UTRAN comprises several RNSs

Node B can support FDD or TDD or both

RNC is responsible for handover decisions requiring signalling to the UE

Cell offers FDD or TDD

UTRAN architecture



RNC: Radio Network Controller

RNS: Radio Network Subsystem

UTRAN comprises several RNSs

Node B can support FDD or TDD or both

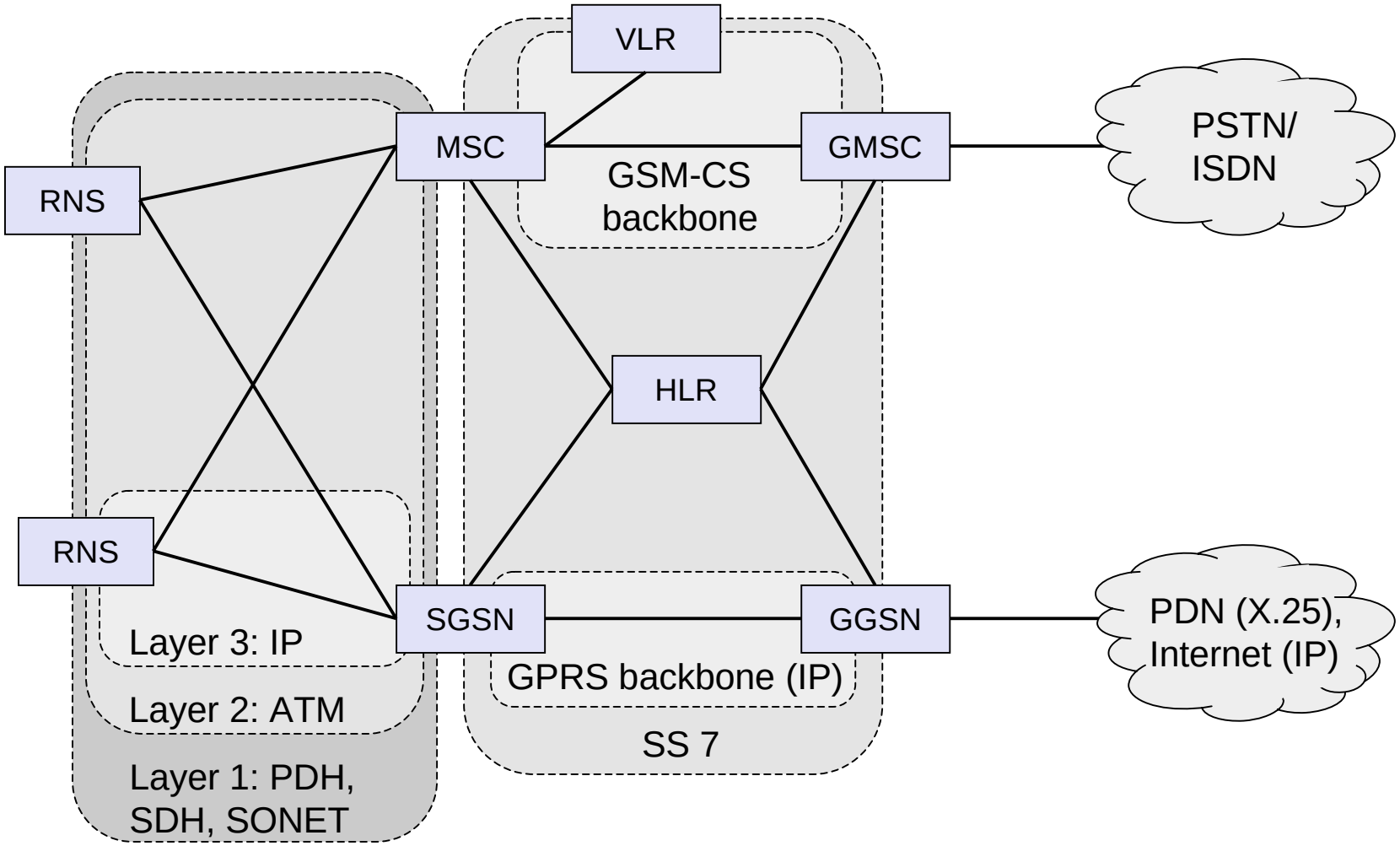
RNC is responsible for handover decisions requiring signaling to the UE

Cell offers FDD or TDD

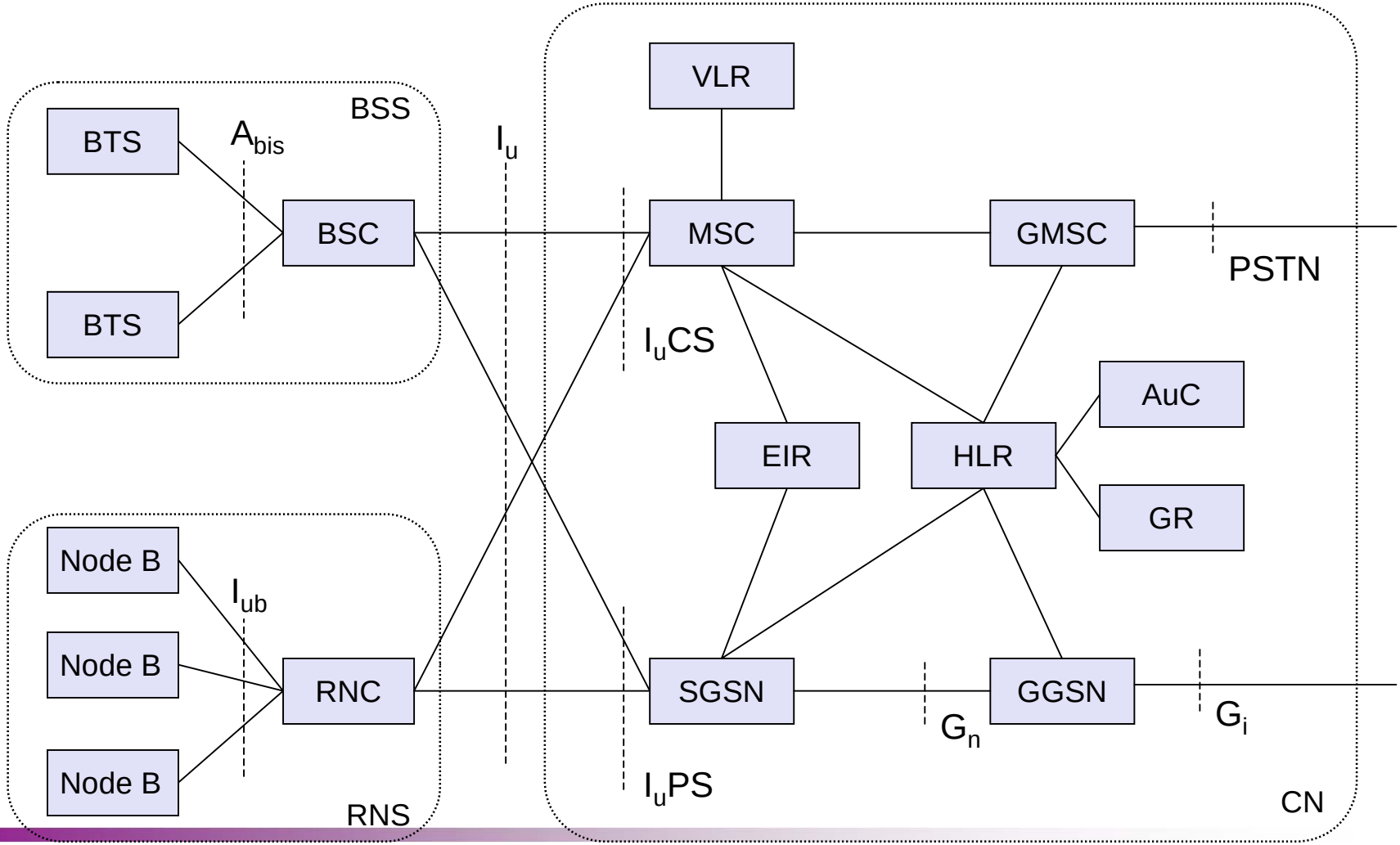
UTRAN functions

Admission control
Congestion control
System information broadcasting
Radio channel encryption
Handover
SRNS moving
Radio network configuration
Channel quality measurements
Macro diversity
Radio carrier control
Radio resource control
Data transmission over the radio interface
Outer loop power control (FDD and TDD)
Channel coding
Access control

Core network: protocols



Core network: architecture



Core network

The Core Network (CN) and thus the Interface I_u, too, are separated into two logical domains:

Circuit Switched Domain (CSD)

- Circuit switched service incl. signaling
- Resource reservation at connection setup
- GSM components (MSC, GMSC, VLR)
- I_uCS

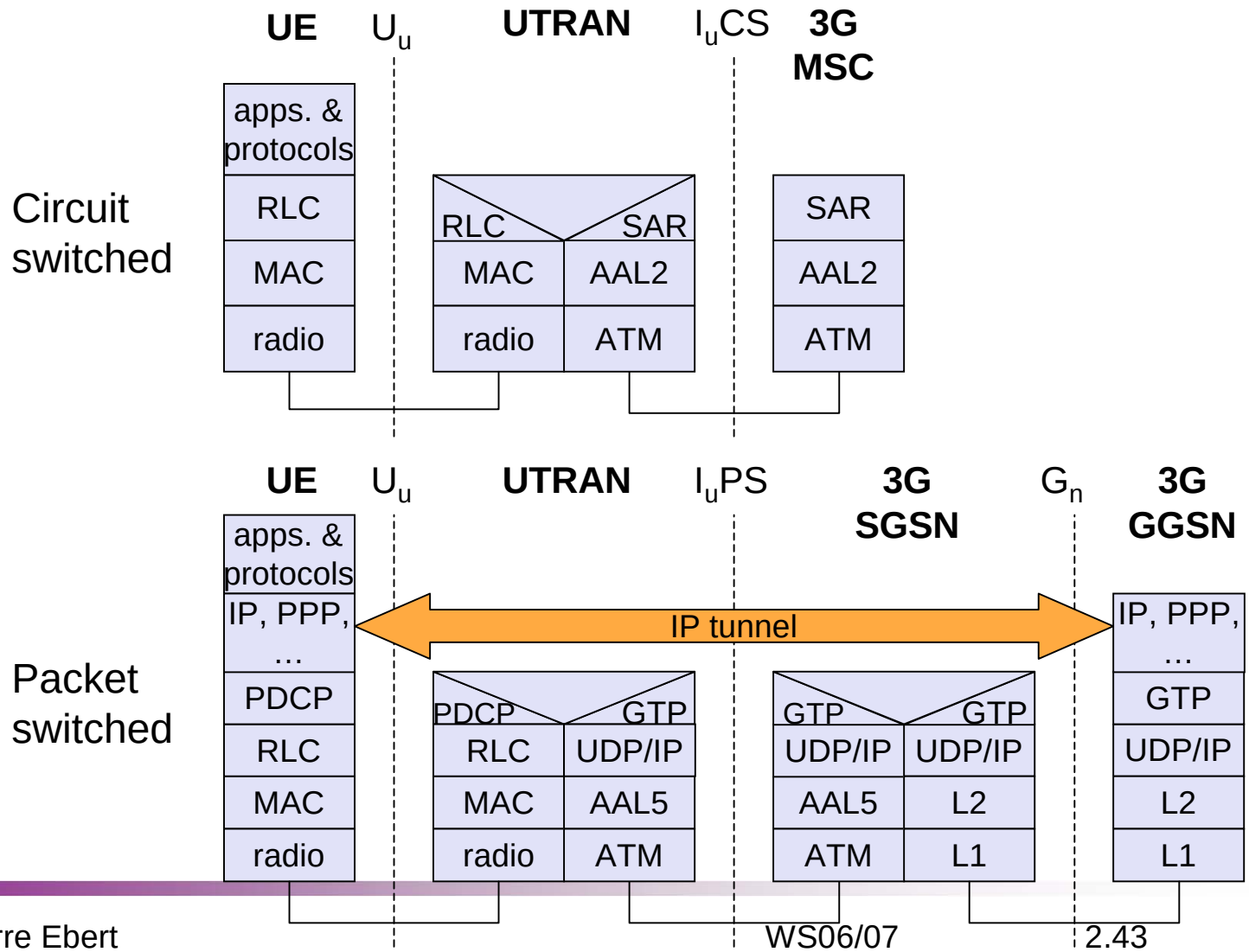
Packet Switched Domain (PSD)

- GPRS components (SGSN, GGSN)
- I_uPS

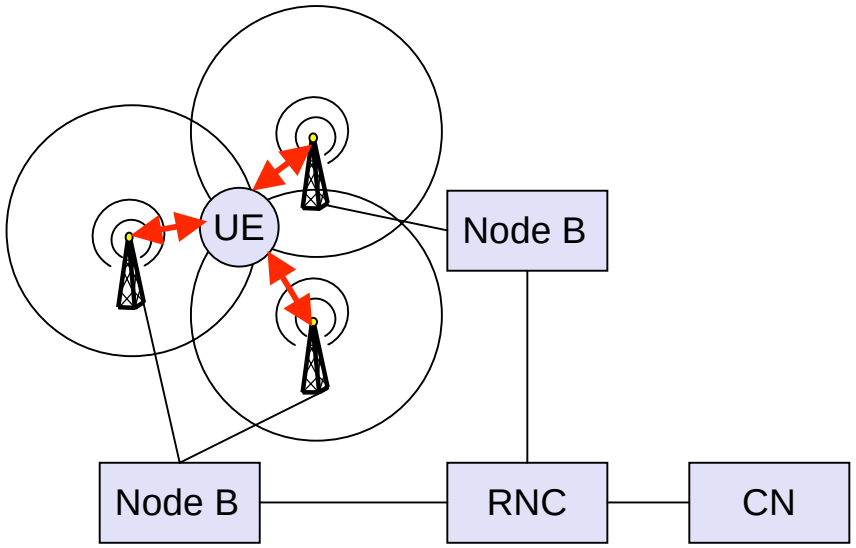
Release 99 uses the GSM/GPRS network and adds a new radio access!

- Helps to save a lot of money …
- Much faster deployment
- Not as flexible as newer releases (5, 6)

UMTS protocol stacks (user plane)



Support of mobility: macro diversity



SRNC: Serving RNC
DRNC: Drift RNC

- Multicasting of data via several physical channels
  - Enables soft handover
  - FDD mode only
- Uplink
  - simultaneous reception of UE data at several Node Bs
  - Reconstruction of data at Node B, SRNC or DRNC
- Downlink
  - Simultaneous transmission of data via different cells
  - Different spreading codes in different cells

Support of mobility: handover

From and to other systems (e.g., UMTS to GSM)

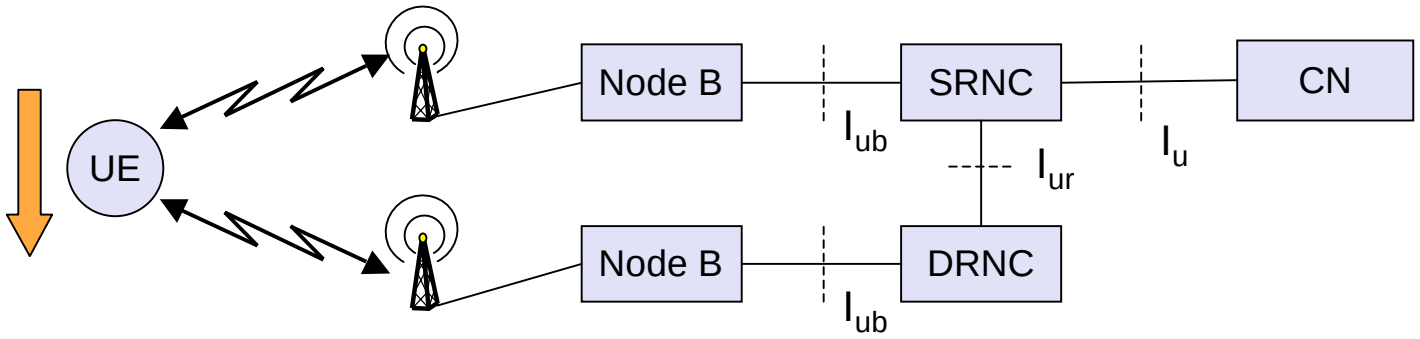
- This is a must as UMTS coverage will be poor in the beginning

RNS controlling the connection is called SRNS (Serving RNS)

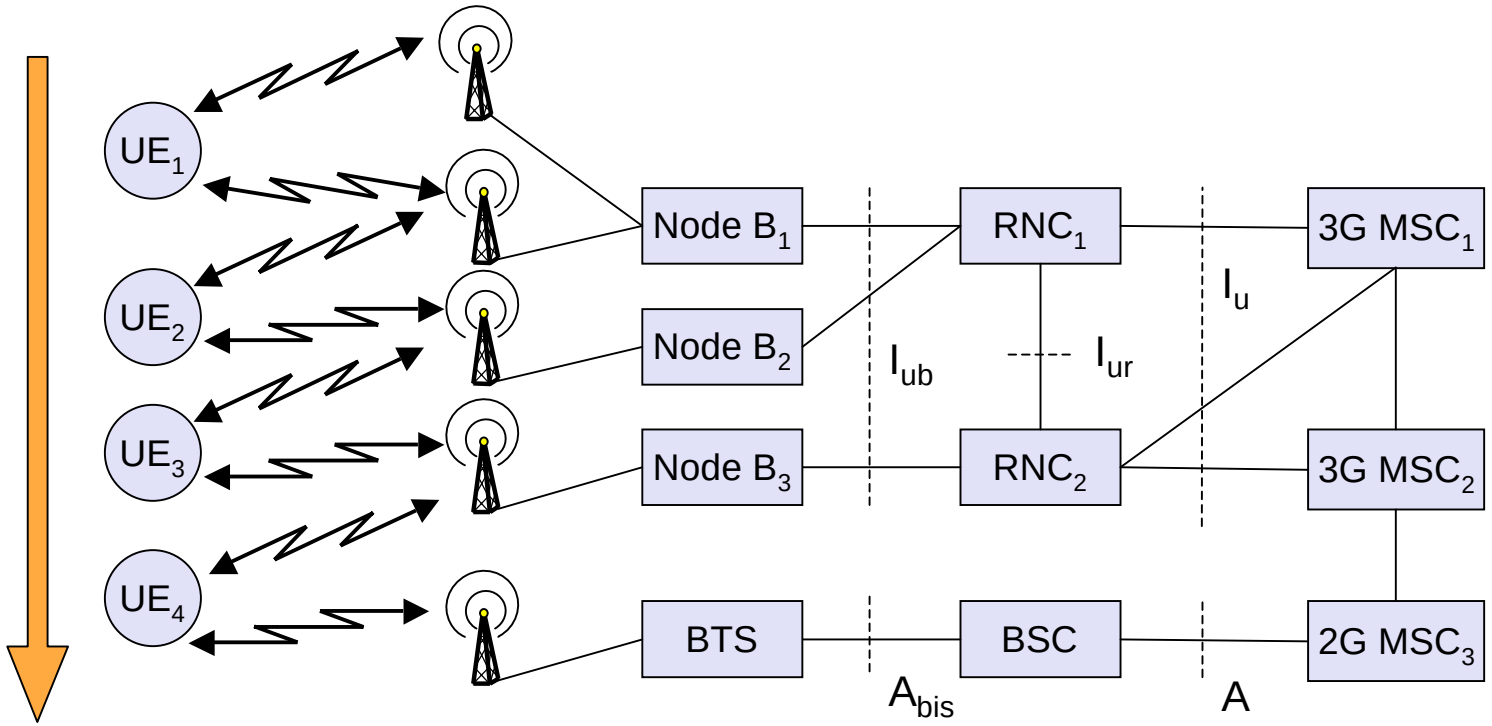
RNS offering additional resources (e.g., for soft handover) is called Drift RNS (DRNS)

End-to-end connections between UE and CN only via I_u at the SRNS

- Change of SRNS requires change of I_u
- Initiated by the SRNS
- Controlled by the RNC and CN



Example handover types in UMTS/GSM



Breathing Cells

GSM

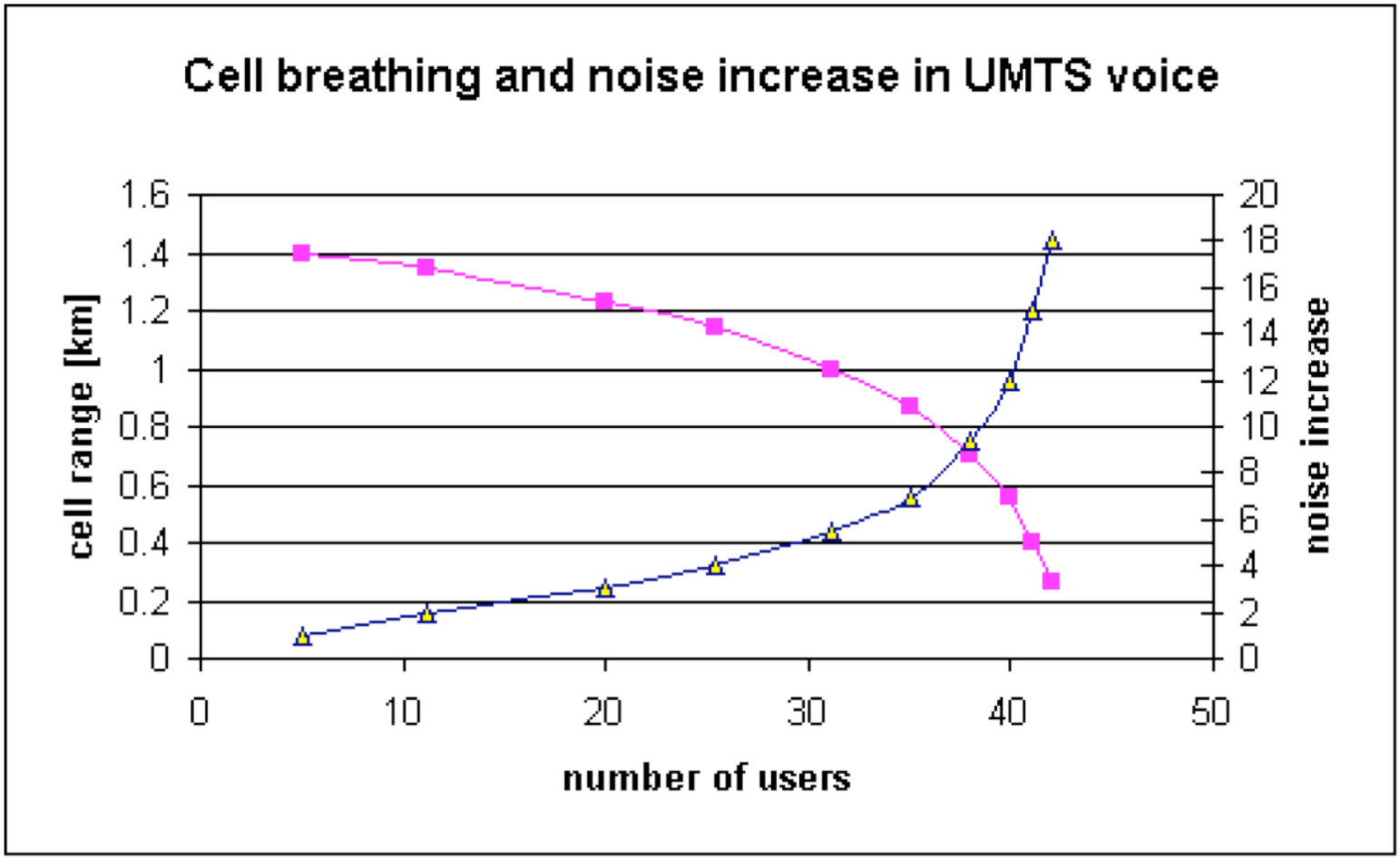
- Mobile device gets exclusive signal from the base station
- Number of devices in a cell does not influence cell size

UMTS

- Cell size is closely correlated to the cell capacity
- Signal-to-nose ratio determines cell capacity
- Noise is generated by interference from
  - other cells
  - other users of the same cell
- Interference increases noise level
- Devices at the edge of a cell cannot further increase their output power (max. power limit) and thus drop out of the cell
  ⇨ no more communication possible
- Limitation of the max. number of users within a cell required

- Cell breathing complicates network planning

Breathing Cells: Example



UMTS services (originally)

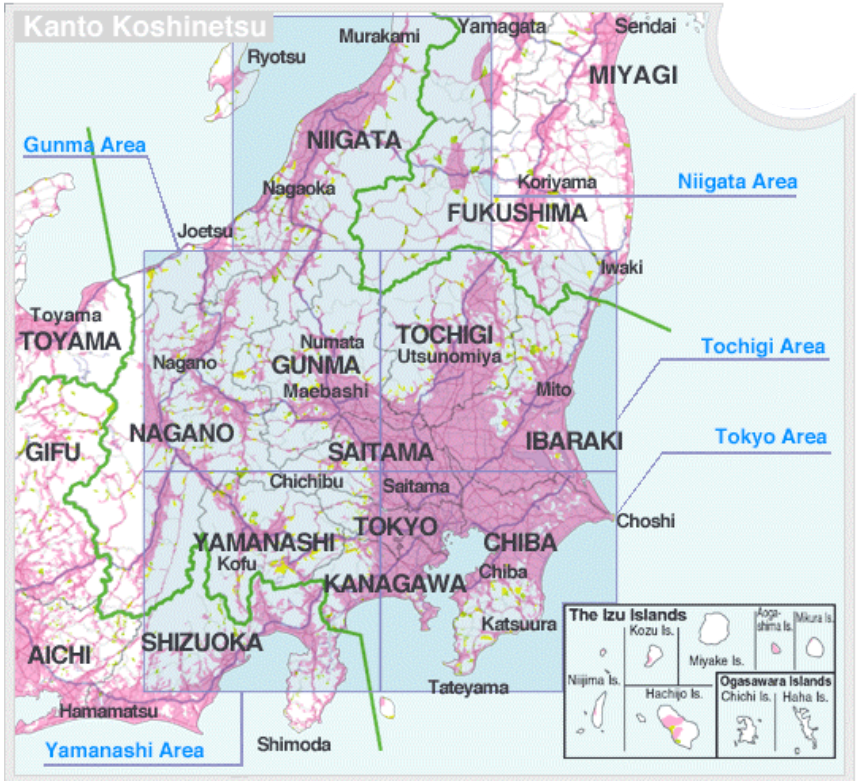
Data transmission service profiles

Service Profile	Bandwidth	Transport mode	
High Interactive MM	128 kbit/s	Circuit switched	Bidirectional, video telephone
High MM	2 Mbit/s	Packet switched	Low coverage, max. 6 km/h
Medium MM	384 kbit/s	Circuit switched	asymmetrical, MM, downloads
Switched Data	14.4 kbit/s	Circuit switched	
Simple Messaging	14.4 kbit/s	Packet switched	SMS successor, E-Mail
Voice	16 kbit/s	Circuit switched	

Virtual Home Environment (VHE)

- Enables access to personalized data independent of location, access network, and device
- Network operators may offer new services without changing the network
- Service providers may offer services based on components which allow the automatic adaptation to new networks and devices
- Integration of existing IN services

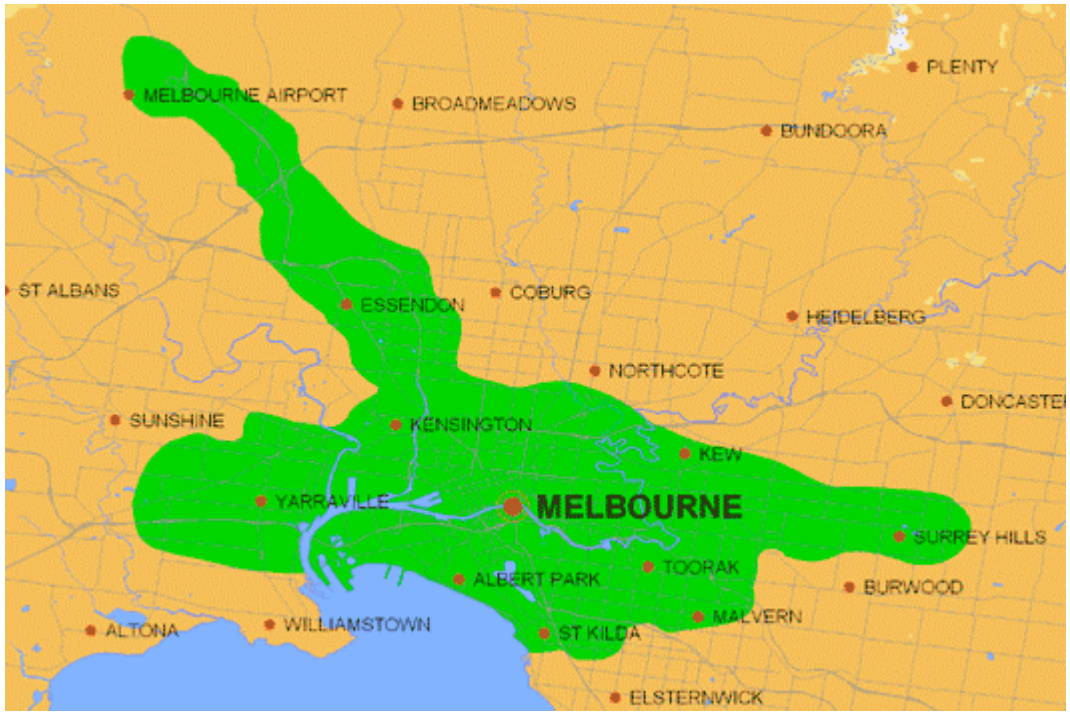
Example 3G Networks: Japan



FOMA (Freedom Of Mobile multimedia Access) in Japan

Examples for FOMA phones

Example 3G networks: Australia

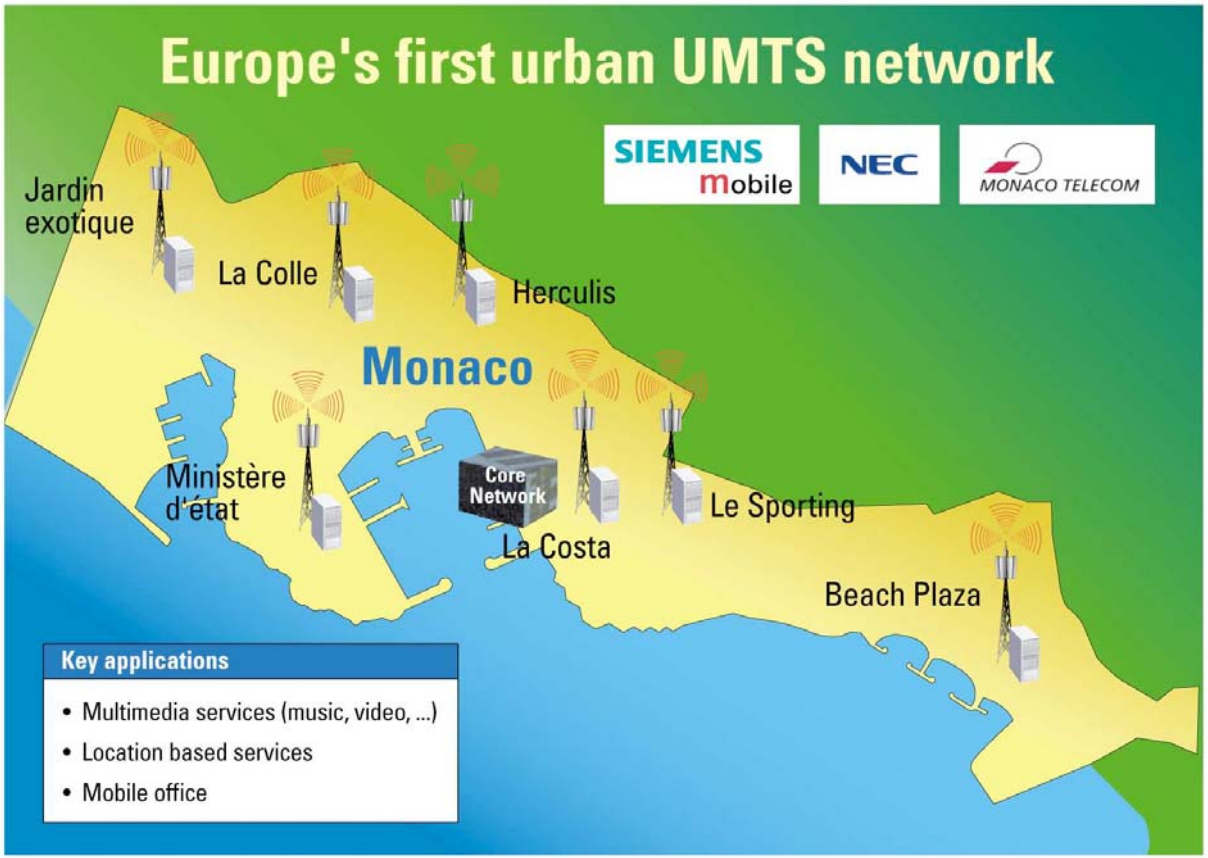


cdma2000 1xEV-DO in Melbourne/Australia

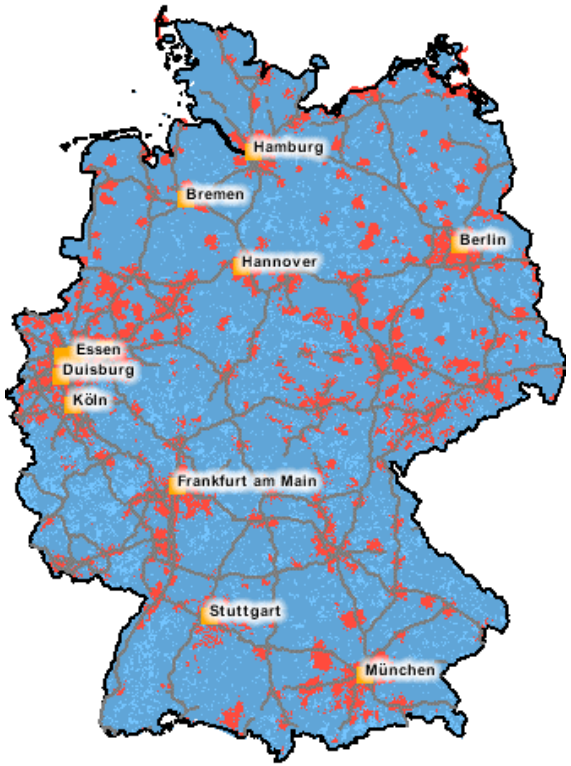
Examples for 1xEV-DO devices

Isle of Man – Start of UMTS in Europe as Test

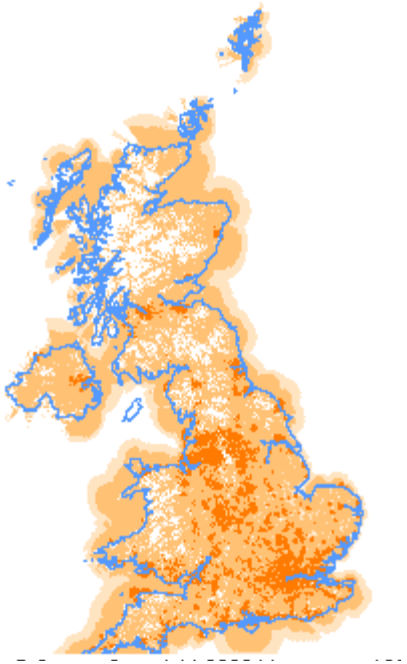
UMTS in Monaco



UMTS in Europe



Vodafone/Germany



Orange/UK

Some current enhancements

GSM

- EMS/MMS
  - EMS: 760 characters possible by chaining SMS, animated icons, ring tones, was soon replaced by MMS (or simply skipped)
  - MMS: transmission of images, video clips, audio
    - see WAP 2.0 / chapter 10
- EDGE (Enhanced Data Rates for Global [was: GSM] Evolution)
  - 8-PSK instead of GMSK, up to 384 kbit/s
  - new modulation and coding schemes for GPRS ➔ EGPRS
    - MCS-1 to MCS-4 uses GMSK at rates 8.8/11.2/14.8/17.6 kbit/s
    - MCS-5 to MCS-9 uses 8-PSK at rates 22.4/29.6/44.8/54.4/59.2 kbit/s

UMTS

- HSDPA (High-Speed Downlink Packet Access)
  - initially up to 10 Mbit/s for the downlink, later on 20 Mbit/s using MIMO- (Multiple Input Multiple Output-) antennas
  - uses 16-QAM instead of QPSK

UMTS Conclusions

UMTS is part of the IMT-2000 initiative driven by 3GPP

It is a continuously changing system that develops evolutionary towards an ALL-IP network for integrated data, voice and multi-media services

In Europe currently Release 99 is being introduced

Release 99 is a evolution path from GSM to UMTS

Coverage in rural areas will not be given for long time even though the licence agreement requires 50 % coverage within 2 years

Instead GPRS services will be enhanced to serve rural areas for lower cost

UMTS is a big step forward towards UPN even though is will not be achieved in a single step

The creation of 3GPP to moderate the convergence process was a good means to approach a user demanded long term goal

Literature for DECT / TETRA / UMTS

Jochen Schiller

Mobilkommunikation

2. Überarbeitete Auflage, Addison-Wesley, Pearson Studium

- DECT - Kapitel 4.2 (S. 168-173)
- TETRA - Kapitel 4.3 (S. 173-175)
- UMTS - Kapitel 4.4 (S. 175-200)

Detaillierter in

Bernhard Walke

Mobilfunknetze und Ihre Protokolle

3. Auflage, Teubner

- Band 2: DECT - Kapitel 5 (S. 105-213)
- Band 2: TETRA - Kapitel 2 (S. 15-81)
- Band 1: UMTS - Kapitel 5 (S. 369-459)