Mobile Communications II
Chapter 4:

- DECT
- TETRA
- UMTS
Literature for GSM / GPRS

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2. Überarbeitete Auflage, Addison-Wesley, Pearson Studium
  - Kapitel 4.1 (S. 129-167)

Detaillierter in
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  - 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/km²
  - Radio interface for pedestrian speed only
  - Handover defined
  - Low cost entities: < 100 €/base-station

Combined GSM/DECT devices were not successful on the market
  - Too 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](https://example.com) 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

1 frame = 10 ms

12 down slots  12 up slots

slot  guard  420 bit + 52 μs guard time ("60 bit")

in 0.4167 ms

A: network control
B: user data
X: transmission quality

25.6 kbit/s
simplex bearer

32 kbit/s

protected mode

unprotected mode

DATA

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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
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
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.
TETRA – Direct Mode II

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

Direct Mode with Repeater

Managed Repeater/Gateway

Direct Mode with Gateway

Managed Repeater/Gateway

Authorizing Repeater
TETRA - Terrestrial Trunked Radio

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- 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 queueing 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)
- 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

hyperframe

multiframe

frame

slot

Control Frame

CF

0 1 2 ... 57 58 59

61.2 s

0 1 2 ... 15 16 17

1.02 s

0 1 2 3

56.67 ms

0 slot 509

14.17 ms
## TETRA – Data Rates

Infrastructure mode, V+D in kbit/s

<table>
<thead>
<tr>
<th>No. of time slots</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>No protection</td>
<td>7.2</td>
<td>14.4</td>
<td>21.6</td>
<td>28.8</td>
</tr>
<tr>
<td>Low protection</td>
<td>4.8</td>
<td>9.6</td>
<td>14.4</td>
<td>19.2</td>
</tr>
<tr>
<td>High protection</td>
<td>2.4</td>
<td>4.8</td>
<td>7.2</td>
<td>9.6</td>
</tr>
</tbody>
</table>

## 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
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
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 Qualcomm)
- 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
# GSM and UMTS Releases

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

- **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

Separation of connections
Separation of users
3.84 Mchip/s
OVSF (Orthogonal Variable Spreading Factor) coding

SF=n  SF=2n

SF=1  SF=2  SF=4  SF=8
Example of OVSF use for 4 connections with different bit-rates

```
SF=1 SF=2 SF=4 SF=8
```

```
1,1,1,1,1,1,1,1
```

```
1,1,1,1
```

```
1,1,-1,-1
```

```
1,-1,1,-1
```

```
1,-1,-1,1
```

```
1,-1,-1,1,1,-1,-1
```

```
1,-1,-1,1,-1,1,1,-1
```

```
1,-1,1,-1,1,-1,1,-1
```

```
1,-1,1,-1,-1,1,-1,1
```

```
1,1,-1,-1,1,1,-1,-1
```

```
1,1,-1,-1,-1,-1,1,1
```

```
1,1,1,1,1,1,1,1
```

```
1,1,1,1,-1,-1,-1,-1
```

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!**
## Typical UTRA-FDD uplink data rates

<table>
<thead>
<tr>
<th>User data rate [kbit/s]</th>
<th>12.2 (voice)</th>
<th>64</th>
<th>144</th>
<th>384</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPDCH [kbit/s]</td>
<td>60</td>
<td>240</td>
<td>480</td>
<td>960</td>
</tr>
<tr>
<td>DPCCH [kbit/s]</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Spreading</td>
<td>64</td>
<td>16</td>
<td>8</td>
<td>4</td>
</tr>
</tbody>
</table>
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

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

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

RNC: Radio Network Controller
RNS: Radio Network Subsystem
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

- MSC
- GMSC
- VLR
- HLR
- SGSN
- GGSN
- RNS

Layer 1: PDH, SDH, SONET
Layer 2: ATM
Layer 3: IP

GPRS backbone (IP)
SS 7
GSM-CS backbone
PSTN/ISDN
PDN (X.25), Internet (IP)

UTRAN
CN
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$_u$CS

**Packet Switched Domain (PSD)**
- GPRS components (SGSN, GGSN)
- I$_u$PS

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)

Circuit switched:
- UE
- Uu
- UTRAN
- Iu
- 3G MSC
- MAC
- MAC
- RLC
- RLC
- SAR
- SAR
- AAL2
- AAL2
- ATM
- ATM
- Radio
- Radio

Packet switched:
- UE
- Uu
- UTRAN
- Iu
- 3G SGSN
- IP, PPP...
- UDP/IP
- GTP
- GTP
- MAC
- MAC
- RLC
- RLC
- AAL2
- AAL2
- ATM
- ATM

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Support of mobility: macro diversity

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

SRNC: Serving RNC
DRNC: Drift RNC
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-noise 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

Cell breathing and noise increase in UMTS voice

![Graph showing the relationship between cell range and number of users, with noise increase on the y-axis.]

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UMTS services (originally)

Data transmission service profiles

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

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

With Videophone you can enjoy conversations while facing each other.
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

Europe's first urban UMTS network

Key applications
- Multimedia services (music, video, ...)
- Location based services
- Mobile office
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 \(\rightarrow\) 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

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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

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