Proposals for IMT-2000 (International Mobile Telecommunications) as world-wide standardized 3G communication system:
• UWC-136, cdma2000, WP-CDMA
• UMTS (Universal Mobile Telecommunications System, ETSI)

UMTS
• … bases on UTRA: Universal Terrestrial Radio Access
• Integration of different mobile, cordless and pager systems into only one radio access network supporting world-wide roaming
• Integration of voice, data, and multimedia data services
• Enhancement of GSM: higher data rates, enhanced service concept, global roaming
• Data rates: 144 kBit/s up to 2 MBit/s
  – min. 144 kBit/s rural (target: 384 kBit/s)
  – min. 384 kBit/s suburban (target: 512 kBit/s)
  – up to 2 MBit/s urban
• Compatibility to GSM, ATM, ISDN and IP

Frequencies for IMT-2000

<table>
<thead>
<tr>
<th>Europe</th>
<th>China</th>
<th>Japan</th>
<th>North America</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITU allocation</td>
<td>GSM 1800</td>
<td>IMT-2000</td>
<td>cdma2000W-CDMA</td>
</tr>
<tr>
<td>UPTRA FDD ↑</td>
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</table>

MSS: Mobile satellite services
DECT: Digital Enhanced Cordless Telecommunications
PHS: Personal Handyphone System
PCS: Personal Communications Service (GSM1900)

IMT-2000 Family

<table>
<thead>
<tr>
<th>IMT-DS (Direct Spread)</th>
<th>IMT-TC (Time Code)</th>
<th>IMT-MC (Multi Carrier)</th>
<th>IMT-SC (Single Carrier)</th>
<th>IMT-FT (Freq. Time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTRA FDD (WD-CDMA)</td>
<td>UTRA TDD (TD-CDMA); TD-SCDMA</td>
<td>cdma2000</td>
<td>UWC-136 (EDGE)</td>
<td>DECT</td>
</tr>
</tbody>
</table>

UTRA FDD: Uplink 1920-1980 MHz, Downlink 2110-2170 MHz, 5 MHz channels

UTRA-TDD: 1900-1920 MHz, 2010-2025 MHz, 5 MHz channels

Licensing of UMTS in Germany, 18.8.2000

- UTRA-FDD: Uplink 1920-1980 MHz, Downlink 2110-2170 MHz, 12 channels, 5 MHz each
- UTRA-TDD: 1900-1920 MHz, 2010-2025 MHz, 5 MHz channels

Planned coverage: 25% of the population till 12/2003, 50% till 12/2005

Sum: 50.81 billion €
UMTS Architektur (Release 99)

- **UTRAN (UTRA Network)**
  - Cell level mobility
  - Comprises several Radio Network Subsystems (RNS)
  - Encapsulation of all radio specific tasks

- **UE (User Equipment)**

- **CN (Core Network)**
  - Handover between systems
  - Gateways to other systems
  - Location management, if there is no dedicated connection between UE and UTRAN
  - Usage of existing GSM/GPRS infrastructure, change to an IP-based core network?

![Diagram of UTRAN, UE, and CN connections]

UMTS Domains and Interfaces

- **User Equipment Domain**
  - Assigned to a single user in order to access UMTS services

- **Infrastructure Domain**
  - Shared among all users
  - Offers UMTS services to all accepted users

![Diagram of UMTS Domains and Interfaces]

UMTS Domains and Interfaces

- Universal Subscriber Identity Module (USIM)
  - Functions for encryption and authentication of users
  - Located on the SIM

- **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

![Diagram of USIM functions]

Spreading and Scrambling of User Data

- Constant chipping rate of 3.84 million chip/s
- Different user data rates supported via different spreading factors
  - Higher data rate: less chips per bit and vice versa
- User separation via unique, orthogonal scrambling codes
  - Users are separated via orthogonal spreading codes
  - Precise synchronization necessary as the scrambling codes stay quasi-orthogonal
  - Base station manages codes and provides synchronization

![Diagram of spreading and scrambling processes]
OSVF Coding

**OSVF: Orthogonal Variable Spreading Factors**
- Simple generation of orthogonal chip sequences
- Thus: simple user management

<table>
<thead>
<tr>
<th>SF = n</th>
<th>SF = 2n</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,1,1,1,1,1</td>
<td>1,1,1,1,1,1</td>
</tr>
<tr>
<td>1,1,1,1,1,1</td>
<td>1,1,1,1,1,1</td>
</tr>
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</tr>
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</tr>
</tbody>
</table>

**UMTS FDD Frame Structure**

- **10 ms**
  - 0 1 2 ... 12 13 14
  - Time slot
  - 666.7 µs
  - Pilot, TFCI, FBI, TPC
  - 666.7 µs
  - 2560 Chips, 10 Bits
  - 2560 Chips, 10*2^k Bits (k = 0...6)

**UMTS TDD Frame Structure**

- **10 ms**
  - 0 1 2 ... 12 13 14
  - Traffic burst
  - GP: guard period
  - 666.7 µs
  - 2560 Chips

**TD-CDMA**
- 2560 Chips per slot
- Spreading factor: 1-16
- Symmetric or asymmetric slot assignment to UL/DL (min. 1 per direction)
- Tight synchronization needed
- Simpler power control (100-800 power control cycles/s)

**UTRAN Architecture**

- RNC: Radio Network Controller
- RNS: Radio Network Subsystem
- Node B
- CN
- UE
- UTRAN comprises several RNSs
- Node B can support both, FDD or TDD
- 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
- Radio Network Configuration
- Channel Quality Measurements
- Macro Diversity
- Radio Carrier Control
- Radio Resource Control
- Data Transmission over the Radio Interface
- Power Control
- Channel Coding
- Access Control

Core Network: Protocols

- MSC
- RNS
- VLR
- SGSN
- GGSN
- GMSC
- HLR
- PSTN/ISDN
- SS7
- GSM-CS Backbone
- GPRS Backbone (IP)
- PDN (X.25), Internet (IP)

RNS can be UMTS RNS or GSM BSS

Support of Mobility: Macro Diversity

- A device can receive signals over 3 antennas in parallel
- Multicast of data via several physical channels
  - Enables soft handover
  - Only in FDD mode
- 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

The Core Network and thus also the interface I_{u} are separated into two logical domains:

- Circuit Switched Domain (CSD)
  - Circuit switched service inclusive signaling
  - Resource reservation at connection setup
  - GSM components (MSC, GMSC, VLR)
- Packet Switched Domain (PSD)
  - GPRS components (SGSN, GGSN)

Release 99 uses the GSM/GPRS network and just adds a new radio access
- Lower costs, faster deployment
- Not as flexible as newer releases 4, 5, 6 (change to IP based functions, …)
Support of Mobility: Handover

- From and to other systems (e.g. UMTS to GSM)
  - A must for the beginning when UMTS coverage is poor
- RNS controlling the connection is called SRNS (Serving RNS)
- RNS offering additional resources (e.g. for soft handover) is called DRNS (Drift RNS)
- End-to-end connections between UE and CN only via Iu at the SRNS
  - Change of SRNS requires change of Iu
- Initiated by SRNS
- Controlled by the RNC and CN

Example Handover Types in in UMTS/GSM

Cell Breathing

**GSM**
- Device gets full power from the base station
- Number of connected devices has no influence on the cell size

**UMTS**
- Cell size and capacity are tightly correlated
- Capacity is determined at the Signal-to-Noise-Ratio
- Noise is increased by interference...
  - with other cells
  - with other participants
- Devices at the cell border are not able to increase their signal strength (power limitation)
  - for too high noise no communication is possible
- Restriction of simultaneous number of users necessary
- Cell breathing makes cell planning complicated
### Data Transmission Service Profiles

<table>
<thead>
<tr>
<th>Service Profile</th>
<th>Bandbreite</th>
<th>Transportmodus</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Interactive MM</td>
<td>128 kBit/s</td>
<td>circuit switched</td>
</tr>
<tr>
<td></td>
<td></td>
<td>bidirectional, video telephone</td>
</tr>
<tr>
<td>High MM</td>
<td>2 MBit/s</td>
<td>packet switched</td>
</tr>
<tr>
<td></td>
<td></td>
<td>low coverage, max. 6 km/h</td>
</tr>
<tr>
<td>Medium MM</td>
<td>384 kBit/s</td>
<td>circuit switched</td>
</tr>
<tr>
<td></td>
<td></td>
<td>asymmetrical, MM, downloads</td>
</tr>
<tr>
<td>Switched Data</td>
<td>14.4 kBit/s</td>
<td>circuit switched</td>
</tr>
<tr>
<td>Simple Messaging</td>
<td>14.4 kBit/s</td>
<td>packet switched</td>
</tr>
<tr>
<td>Sprache</td>
<td>16 kBit/s</td>
<td>circuit switched</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SMS successor, E-Mail</td>
</tr>
</tbody>
</table>

### What is Next?

#### Cellular phones
- 1981: NMT 450
- 1986: NMT 900
- 1990: DCS 1800
- 1992: GSM
- 1994: GPRS
- 1999: UMTS

#### Satellites
- 1982: Inmarsat-A
- 1987: CT1
- 1989: CT2
- 1994: Iridium
- 1995: Iridian

#### Cordless phones
- 1992: Inmarsat B
- 1998: CT1
- 2001: IMT-2000

### Characteristics of Future Networks (?)

- Improved radio techniques and antennas
  - Intelligent antennas, direction, MIMO (multiple-input-multiple-output) antennas
  - Space multiplex for higher capacity, usage of multipath signal propagation
- Software defined radios (SDR)
  - Usage of different radio interfaces, download of new modulation and coding technologies
  - Needs high computing power (UMTS RF: 10000 GIPS)
- Dynamic frequency allocation
  - Dynamic assignment of frequencies improves capacity
- Convergence of core networks
  - IP-based, Quality of Service, Mobile IP
- Ad-hoc techniques
  - Spontaneous communication, power management, redundancies
- Simple and open service platform
  - Intelligence a network borders, not in the network (as in IN)
  - Thus: more service providers, not only the network providers
Exemplarily IP-based 4G/Next G/… Network

Possible Problems

- Quality of Service
  - The Internet provides best effort data transfer
  - Integrated Services has bad scalability, Differentiated Services have still to be proofed
  - Simplicity of the Internets? DoS attacks auf QoS?
- Internet Protocols are well-known…
  - …also for attackers, hackers, …
- Reliability, maintenance
  - Still an open question if Internet technology is cheaper, when a high reliability is needed (99.9999%) and all demanded services are integrated
- Missing accounting technology
  - Accounting based of technical parameters (data volume, time) makes no sense
  - A content- or application-based accounting is much better
- Killer Application! There is no single killer application:
  - The selection of provided services and the seamless access to the services using different access technologies is important