3G/4G Mobile Communications Systems

Dr. Stefan Brück
Qualcomm Corporate R&D Center Germany
Chapter III: System and Radio Access Network Architecture
System and Radio Access Network Architecture

- Definitions of UMTS and LTE
- UMTS and LTE in the Standards
- UTRAN and UMTS Core Architecture
- UMTS Protocol Stack
  - NAS, AS, control plane, user plane
- Network Architecture Evolution Concept
- E-UTRAN and EPC Architecture
- LTE Protocol Stack
  - NAS, AS, control plane, user plane
What is UMTS?

- A 3G mobile wireless solution that complies with the IMT-2000 standard
- Designed to be deployed on a GSM/GPRS 2G core network – Key driver in standardization!
- UMTS allows for different technologies to be used in the radio access network such as WCDMA (FDD) and TD-SCDMA (TDD)
- Designed to support multiple services with individual Quality of Service (QoS) requirements
- Delivers high capacity and high peak single user data throughputs
- For high speed packet data, UMTS supports
  - HSDPA (High Speed Downlink Packet Access)
  - HSUPA (High Speed Uplink Packet Access)
What is Wideband Code Division Multiple Access

- A radio access technology (RAT), used in the UMTS radio access network (RAN), based on direct-sequence CDMA with the chip rate of 3.84 Mcps
- The WCDMA RAN consists of the User Equipment (UE), Base Stations (Node B) and the Radio Network Controller (RNC)
- Frequency Division Duplex (FDD) in the 5 MHz paired frequency bands
- We focus on WCDMA FDD of the UMTS Terrestrial Radio Access Network (UTRAN)
- Often UMTS and WCDMA are used interchangeably. But they are actually two different concepts
Some UMTS Standards to explore

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- UMTS Specification
  - Segmented by layers
  - Available on the web
    - [http://www.3gpp.org/Specifications](http://www.3gpp.org/Specifications)
  - For a complete list of R99 specifications, see TS 21.101
  - For a list of acronyms, see TS 21.905
LTE and EPS

- **Long Term Evolution (LTE):** Evolution of 3GPP UMTS Terrestrial Radio Access technology (E-UTRA) technology

  - **EPS includes**
    - Radio Access Network: Evolved UTRA Network (E-UTRAN)
    - System Architecture: Evolved Packet Core (EPC)
Some additional LTE Standards to explore

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- LTE Specification
  - Segmented by layers
  - Available on the web
    - http://www.3gpp.org/Specifications
User Equipment (UE)

- Universal Subscriber Identity Module (USIM)
  - The application that manages UE subscription information and authentication functions
- Mobile Equipment
  - All other UE functions
- **User Equipment (UE)** – may be a mobile, a fixed station, a data terminal, etc.

- **Access Network** – includes all of the radio equipment necessary for accessing the network. It may be either UTRAN or GERAN

- **Core Network** – includes all of the switching and routing capability for connecting to either the PSTN (circuit-switched) or to Packet Data Network (packet-switched), for mobility, subscriber location management and for authentication services
The UTRAN consists of one or more Radio Network Subsystems (RNS)

Each RNS consists of one Radio Network Controller (RNC) and one or more Node Bs

Each Node B controls one or more cells and provides radio links to the UE
Functionality of the UTRAN

- **RNC**
  - Responsible for controlling the use and the integrity of the radio resources
  - The controlling RNC is responsible for controlling the radio resources of a Node B
    - For each Node B there is exactly one controlling RNC
  - The serving RNC maintains the Iu connection of the UE to the core network and performs frame selection and outer loop power control functions
    - For each UE having a connection to the UTRAN, there is exactly one serving RNC
  - The drift RNC transfers the frames exchanged over the Iur interface to the UE via one or more Node Bs
    - Each UE can have multiple drift RNCs

- **Node B**
  - Responsible for radio transmission/reception in one or more cells to/from the user equipment
  - Physical layer operation
UMTS supports both circuit-switched and packet-switched operation.

The MSC/VLR and GMSC are referred to as the CS domain, while the SGSN and the GGSN are referred to as the PS domain.

UMTS core networks may be connected to both GERAN and UTRAN.
Functionality of the UMTS Core Network

- **GGSN**
  - The GGSN is responsible for the interworking between the GPRS network and external packet switched networks
  - From an external network's point of view, the GGSN is a router to a sub-network
    - The GGSN ‘hides’ the GPRS infrastructure from the external network
  - Anchor point that enables the mobility of the user terminal
  - Maintains routing necessary to tunnel the data to the SGSN that serves a UE
  - IP address assignment, authentication and charging functions

- **SGSN**
  - Responsible for the delivery of data packets from and to the mobile stations
  - Packet routing and transfer, mobility management
  - The location register of the SGSN stores location information and user profiles of all users registered with this SGSN
    - e.g., current cell, IMSI, address(es) used in the packet data network
MSC = Mobile Switching Center – the switch that serves the UE in CS domain

GMSC = Gateway MSC – a user’s home MSC where CS calls are routed

HLR = Home Location Register

SGSN = Serving GPRS Support Node – analogous to MSC for PS domain

GGSN = Gateway GSN – analogous to GMSC for PS calls
Adding HSDPA/HSUPA requires no new entities but hardware/software changes.

Following entities are affected:
- UE and Node B – new channels and functions
- RNC – new signaling messages and channels
- Uu interface – new transport and physical channels
- lub interface – a new frame protocol needed for sending high-speed user data from RNC to Node B
The UMTS protocol stack is divided into **Access Stratum (AS)** and **Non-Access Stratum (NAS)**

- The NAS deals with signaling between the core network and the user
- The AS deals with signaling between the radio access network and the user
The Access Stratum consists of the following layers:
- Radio Resource Control (RRC)
- Radio Link Control (RLC)
- Medium Access Control (MAC)
- Physical Layer (PHY)

Data flow between layers:
- Radio Bearers – carry signaling RRC and RLC or user data between application layers and Layer 2
- Logical channels – carry signaling and user data between RLC and MAC
- Transport channels – carry signaling and user data between MAC and PHY
UTRAN Architecture

- Located in RNC
- Partially located in RNC and Node B
- Located in Node B
Main drivers for the evolution

- Faster radio resource management response (RRM) for channel dependent scheduling
- Reduced packet latencies
- Interworking with other radio access technologies (non-3GPP)
From a centric RNC based RRM (stupid base station and smarter RNCs)
To a decentralized base station based RRM (smarter base stations, less smart RNCs)
From a user packet data forwarding to GGSN through RNC
To direct user packet data forwarding to GGSN
Network Simplification: From 3GPP to 3GPP LTE

- **3GPP LTE architecture**
  - 2 functional entities on the user plane: eNodeB and S-GW
  - SGSN control plane functions → S-GW & MME
  - Less interfaces, some functions will disappear

- **4 layers into 2 layers**
  - Evolve GGSN → integrated S-GW
  - Moving SGSN functionalities to S-GW
  - RNC evolutions to RRM on a IP distributed network for enhancing mobility management.
  - Part of RNC mobility function being moved to S-GW & eNodeB

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S/P-GW: Serving/ PDN Gateway
MME: Mobility Management Entity
eNodeB: Evolved NodeB
Evolved UTRAN Architecture – I/II

- The core network is packet-switched only
- The E-UTRAN consists of one node only
- S1 interface between S-GW/MME and eNB
  - Logical many-to-many interface
  - Supports procedures to establish, maintain and release E-UTRAN Radio Access Bearers
  - Supports transfer of NAS signalling messages between UE and EPC
- X2 interface between eNBs
  - Logical point-to-point interface
  - Seamless mobility
  - Interference management
  - Load management
Evolved UTRAN Architecture – II/II

Located in eNB
**EPS Architecture – Functional Description**

**eNodeB** contains all radio access functions
- Admission Control
- Scheduling of UL & DL data
- Scheduling and transmission of paging and system broadcast
- IP header compression
- Outer ARQ (RLC)

**MME control plane functions**
- Idle mode UE reachability
- Tracking area list management
- S-GW/P-GW selection
- Inter core network node signaling for mobility bw. 2G/3G and LTE
- NAS signaling
- Authentication
- Bearer management functions

**Serving Gateway**
- Local mobility anchor for inter-eNB handovers
- Mobility anchor for inter-3GPP handovers
- Idle mode DL packet buffering
- Lawful interception
- Packet routing and forwarding

**PDN Gateway**
- UE IP address allocation
- Mobility anchor between 3GPP and non-3GPP access
- Connectivity to Packet Data Network

**MME**
- NAS Security
- Idle State Mobility Handling
- EPS Bearer Control

**S-GW**
- Mobility Anchoring

**P-GW**
- UE IP address allocation
- Packet Filtering
EPS Architecture – Control Plane

NAS sub-layer performs:
- Authentication
- Security control
- Idle mode mobility handling
- Idle mode paging origination

RRC sub-layer performs:
- Broadcasting
- Paging
- Connection Mgt
- Radio bearer control
- Mobility functions
- UE measurement reporting & control

PDCP sub-layer performs:
- Integrity protection & ciphering
EPS Architecture – User Plane

**Physical sub-layer performs:**
- DL: OFDMA, UL: SC-FDMA
- FEC
- UL power control
- Multi-stream transmission & reception (i.e. MIMO)

**RLC sub-layer performs:**
- Transferring upper layer PDUs
- In-sequence delivery of PDUs
- Error correction through ARQ
- Duplicate detection
- Flow control
- Segmentation/ Concatenation of SDUs

**MAC sub-layer performs:**
- Scheduling
- Error correction through HARQ
- Priority handling across UEs & logical channels
- Multiplexing/de-multiplexing of RLC radio bearers into/from PhCHs on TrCHs
Serving GW anchors mobility for intra-LTE handover between eNBs as well as mobility between 3GPP access systems → HSPA/EDGE uses EPS core for access to packet data networks

PDN GW is the mobility anchor between 3GPP and non-3GPP access systems (SAE anchor function); handles IP address allocation

S3 interface connects MME directly to SGSN for signaling to support mobility across LTE and UTRAN/GERAN; S4 allows direction of user plane between LTE and GERAN/UTRAN (uses GTP)
Summary

- The RAN architecture was evolved from UMTS to LTE
  - The UTRAN in UMTS consists of RNC and Node B
  - The E-UTRAN consists of eNB only
- Several functionalities of the UMTS RNC have been moved to the LTE eNB
  - Significantly reduced latency
- The network architecture in LTE is very flat
  - Four layers (Node B, RNC, SGSN, GGSN) have been reduced to two layers (eNB, S-GW/MME)
- The core network in UMTS supported circuit-switched and packet-switched operation
- The core network in LTE is packet switched only
- The evolved packet core allows interworking with non-3GPP technologies