UMTS System Architecture and Protocol Architecture

Overview on overall system architecture
- UMTS network architecture and elements
- Mobile station
- High-level functions
- UMTS domains and strata
- UMTS/GPRS protocol architecture

References:
- Kaaranen, Ahtiainen, Laitinen, Naghian, Niemi: UMTS Networks – Architecture, Mobility and Services. 2nd edition, Wiley 2005
  - Ch 5.1: Core Network Architecture Release 3
  - Ch 5.4&5.5: Core Network Architecture Release 4 and 5
  - Ch 6: UMTS Terminal
- Cornelia Kappler: UMTS Networks and Beyond, Wiley, 2009
- 3GPP TS 23.002: UMTS network architecture (CN and AN entities) and procedures
- 3GPP TS 23.101: General UMTS architecture
- 3GPP TS 23.060: GPRS, Service Description
- 3GPP TS 21.101/21.102/21.103: List of standards for Release 3, 4 and 5, respectively
- 3GPP TR 21.905: UMTS vocabulary and abbreviations
UMTS/GSM Network Architecture
UMTS System Architecture

Mobile Station (MS):
- radio interface
- service control and user interface

Radio Access Network (RAN):
- radio-specific functions

Core Network (CN):
- radio-independent functions
  - transport
  - mobility management
  - subscriber data
  - service control

UMTS Subscriber Identity Module (USIM):
- subscriber-specific data
- support of authorized access to network
Mobile-services Switching Centre (MSC)

An exchange performing all the switching and signalling functions (CS only) for mobile stations
MSC controls mobile-originated and mobile-terminated CS calls

Functions
- call management
- mobility management (handling attach and authentication)
- subscriber administration
- maintenance of charging data (for radio network usage)
- CS data services (FAX, modem)
- supplementary call services (call forwarding, etc.)
- SS7-based signaling

Main difference to an exchange in a fixed network: deal with mobility (e.g. location registration, handover) and authentication

Gateway MSC (GMSC)
- Provides interconnection between the UMTS core network and external PSTN/ISDN networks
GPRS Support Node (GSN)

GSNs constitute the interface between the radio access network and the fixed networks for packet switched services (similar to MSC for CS calls)

**Serving GSN (SGSN)**
- session management
- mobility management
- subscriber database management (interface with HLR)
- maintenance of charging data (for radio network usage)
- IP-based transport of user data between SGSN and the UTRAN
- IP- or SS7-based signaling transport

**Gateway GSN (GGSN)**
- gateway for UMTS packet service to external data networks (e.g. the Internet)
- IP interface towards SGSN
- performs user data screening and security
- maintenance of charging data (for external data network usage)
Home Location Register (HLR) now Home Subscriber Server (HSS)

Home (primary) data base in charge of the management of mobile subscribers

Basic information:
- International Mobile Subscriber Identity (IMSI)
- CS subscription information
  - one or more Mobile Subscriber International ISDN number(s) (MSISDN)
- PS subscription information
  - zero or more Packet Data Protocol (PDP) address(es)
  - permission for GGSN to dynamically allocate PDP addresses for a subscriber
- location information enabling the charging and routing of calls towards the MSC or SGSN where the MS is registered (e.g. VLR Number)

Other information:
- teleservices and bearer services subscription information
- service restrictions (e.g. roaming limitation)
- parameters attached to supplementary services
Visitor Location Register (VLR)

(Secondary) data base supporting the management of mobile subscribers currently located within its VLR area

Motivation: minimize load for HLR (i.e. of the primary data base)

Tasks:

• control MSs roaming in an MSC assigned to it
• exchange information with HLR to allow the proper handling of calls

Information maintained by VLR (for call handling):

- International Mobile Subscriber Identity (IMSI)
- Mobile Station International ISDN number (MSISDN)
- Mobile Station Roaming Number (MSRN)
- Temporary Mobile Station Identity (TMSI), if applicable
- location area where the mobile station has been registered
- the last known location and the initial location of the MS
- supplementary service parameters attached to the mobile subscriber (received from the HLR)

Source: 3GPP 23.002-3.5.0
Authentication Centre (AuC)

Stores data for each mobile subscriber
- to authenticate the International Mobile Subscriber Identity (IMSI)
- to support ciphering of the communication over the radio path

The AuC transmits the data needed for authentication and ciphering via the HLR to the VLR, MSC and SGSN which need to authenticate a mobile station

AuC is associated with an HLR, and stores an identity key for each mobile subscriber

The AuC communicates solely with its associated HLR (H-interface)
Equipment Identity Register (EIR)

Logical entity storing the International Mobile Equipment Identities (IMEIs)

Equipment is classified as
- white listed: serie number of equipment
- grey listed: equipment tracked by network
- black listed: barred equipment
- unknown to EIR

Source: 3GPP 23.002-3.5.0
Radio Network System (RNS)

Provide access to the UMTS terrestrial radio interface

Radio Network Controller (RNC)
- (Radio) mobility management
- Management of radio resources

Base Station (Node B)
- Radio coverage of cells
- Physical layer processing
UMTS Functional Entities: Domains

Domain: grouping of physical entities of the system

Source: 3GPP 23.101-4.0.0
Functions of the UMTS Domains

Infrastructure domain
– Access network (AN) domain: functions specific to access technique
– Core network (CN) domain: functions independent of access technique

Access network domain
– physical entities managing the resources of the access network
– provides the user with a mechanism to access the core network domain

Serving network (SN) domain
– part of the CN domain to which the AN domain that provides the user’s access is currently connected
– responsible for routing calls and transport user data/information from source to destination
– provides CN functions that are local to the user’s access point (i.e. SN changes when the user moves)

Home network (HN) domain
– provides CN functions that are conducted at a permanent location regardless of the location of the user’s access point (i.e. does not change due to user mobility)
– contains user-specific data and is responsible for management of subscription information
– handle home-specific services, not offered by the serving network domain

User Services Identity Module domain (USIM)
– related to the home network domain by subscription
UMTS Protocol Architecture

We will focus on the packet switched mode here

References:
- Kaaranen, Ahtiainen, Laitinen, Naghian, Niemi: UMTS Networks – Architecture, Mobility and Services. Wiley 2001, Ch. 5.1
- Walke, et al: UMTS – ein Kurs, Ch. 5 (air interface only)
- 3G TS 23.060: GPRS, Service Description
User Plane Bearer Services – Overview

For each bearer:
- specific attributes (delay, bandwidth, guarantees, etc.)
- specific reservation mechanism
MS-RNS-SGSN-GGSN – User Plane, Rel. 5+

Source: 3GPP 23.060-15.0.0
**GTP-U (GPRS Tunneling Protocol for User plane):**

- tunneling of user data between UTRAN and the 3G-SGSN
- tunneling between the GSNs in the backbone network
- encapsulation of all PDP PDUs
MS-RNS-SGSN-GGSN – User Plane

PDCP (Packet Data Convergence Protocol):

- provides protocol transparency (wrt the underlying radio-interface protocols) for higher-layer protocols
- support for e.g., IPv4, PPP and IPv6 (easy introduction of new higher-layer protocols)
- compression of control information (header compression)
- no user data compression in Iu mode (because the data compression efficiency depends on the type of user data)

Source: 3GPP 23.060-4.1.0
## MS-RNS-SGSN-GGSN – User Plane

<table>
<thead>
<tr>
<th>Application</th>
<th>E.g., IP, PPP</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDCP</td>
<td></td>
</tr>
<tr>
<td>RLC</td>
<td></td>
</tr>
<tr>
<td>MAC</td>
<td></td>
</tr>
<tr>
<td>L1</td>
<td></td>
</tr>
</tbody>
</table>

### RLC (Radio Link Control):  
RLC protocol provides logical link control over the radio interface  
There may be several simultaneous RLC links per MS; each link is identified by a Bearer ID

### MAC (Medium Access Control):  
MAC protocol controls the access signaling (request and grant) procedures for the radio channel

Source: 3GPP 23.060-4.1.0
MS-RNS-SGSN-GGSN – Control Plane, Rel. 5+

GMM: GPRS Mobility Management
SM: Session Management
SMS: short message service support
GTP-C: GPRS Tunneling Protocol for Control plane
RANAP: Radio Access Network Application Protocol
RRC: Radio Resource Control

Source: 3GPP 23.060-15.0.0
MS-RNS-SGSN – Control Plane

GMM (GPRS Mobility Management):
- GMM supports mobility management functionality such as attach, detach, security, and routing area update

SM (Session Management):
- SM supports PDP context activation and deactivation

SMS supports short message service

GTP-C (GPRS Tunneling Protocol for Control plane):
- establish, manage and release GTP tunnels

RANAP (Radio Access Network Application Protocol):
- transport of higher-layer signalling
- handling of signalling between the 3G-SGSN and UTRAN
- management of the GTP connections on the Iu interface

RRC (Radio Resource Control):
- Information Broadcast (AS and NAS)
- RRC connection management (setup, release, reconfiguration)
- Radio Bearers management (setup, release, reconfiguration)
- Management of radio resources for the RRC connection
- RRC connection mobility functions
- Paging/notification

Source: 3GPP 23.060-4.1.0