Aalto University
School of Electrical
Engineering

ELEC-E7230 – Mobile Communication Systems

Prof. Tarik Taleb
School of Electrical Engineering
Aalto University

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1

Content

- **Mobile Network Architectures Evolution**
  - MN Arch. Evolution: 2G to 3G
  - Evolved Packet System
    - Core NW Architecture & components
    - Protocols
  - 5G Core Network
  - Service Based Architecture
- **5G Mobile Networks**
  - Requirements and features
- **Cloud-based Mobile Core Networking**
  - Network Function Virtualization
  - Software Defined Networking
  - Core Network Virtualization
- **Evolved RAN: LTE, LTE-Advanced and LTE-Advanced Pro**

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Grading Policy

- In-class (or after-class) exercises
  - 30% of course grade
- Assignment
  - Presentation of a scientific publication relevant to beyond 5G
  - Nine white papers to be presented by nine groups during the last three sessions of the course
  - Further instructions will be communicated by Dr. Edward Mutafungwa
- Examination (Open Book)
  - 40% of course grade
- Reading Material
  - Material for 4G and 5G
  - Basics vs Advanced

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Important Dates

- Lecture 1: Mon 07.09.20 12:15 - 14:00
- Lecture 2: Fri 11.09.20 12:15-14:00
- Lecture 3: Mon 14.09.20 12:15 - 14:00
- Lecture 4: Mon 21.09.20 12:15 - 14:00
- Lecture 5: Mon 28.09.20 12:15 - 14:00
- Lecture 6: Mon 05.10.20 12:15 - 14:00

- Assignment -
  - Paper presentation day 1: Mon 12.10.2020, 14:00 - 16:00
  - Paper presentation day 2: Wed 16.10.2020, 14:00 - 16:00

- Examination: Tue 20.10.2020 09:00-12:00

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4

Learning Outcome

- Understanding the migration scenarios from 2G/3G to 4G and 5G
- Factual knowledge of EPC, LTE/LTE-Advanced and 5G architecture
- Basic understanding of recent RAN technologies (from LTE towards 5G NR)
- Familiarity with latest developments in NFV, SDN and Network Softwarization
- Development of skills for research and presentation of complex concepts to a general audience
- Development of technical writing skills

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Inquiries about the Course

- Please contact Dr. Edward Mutafungwa edward.mutafungwa@aalto.fi

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6

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Mobile Core Network Systems

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7

TODAY'S LECTURE

- **Content**
  - Mobile Network Architectures Evolution
    - MN Arch. Evolution: 2G, 3G, 4G
    - Evolved Packet System (4G)
      - Core NW Architecture & components
      - Protocols

- **Learning Outcome**
  - Understanding the migration scenarios from 2G/3G to 4G
  - Factual knowledge of EPC

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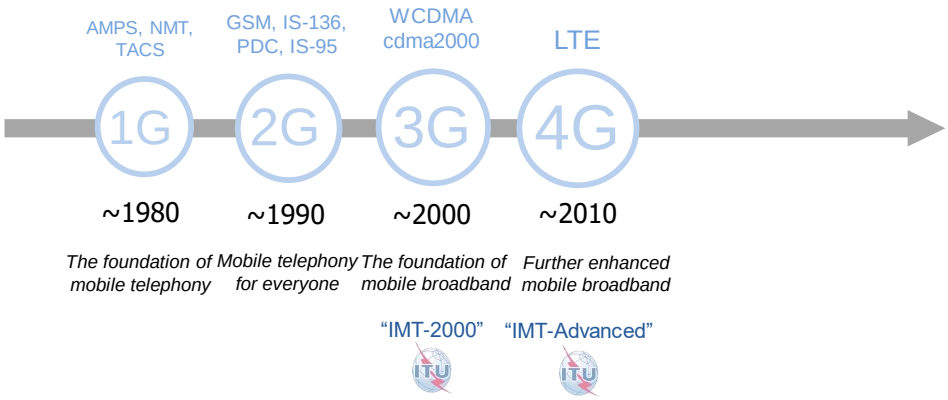
8

Mobile Generations …



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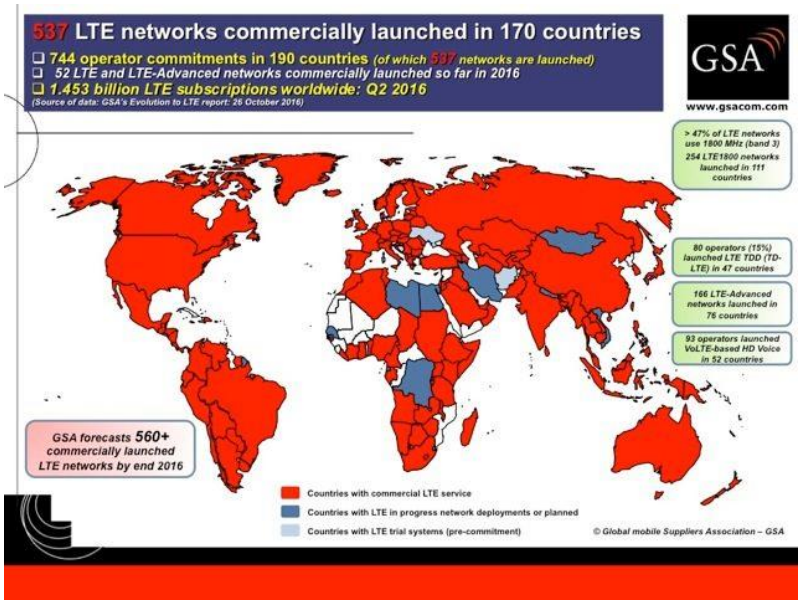
9

Global LTE Commitments



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Why Mobile Communications Systems?

https://www.youtube.com/watch?v=rP6Flfu42Qk

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Migration Scenarios from 2G/3G to 5G?

Interesting commercials of the main services of each technology

- 1G- 1960s (B&W)
  - https://www.youtube.com/watch?v=jwO7Qr-O9OU
- 2G- GSM ADVERTISING
  - https://www.youtube.com/watch?v=l3Oo5vlWNWw
- 3G- iPhone 3GS Ad
  - https://www.youtube.com/watch?v=AcigqYci7Ss
- 4G/LTE - Simply Boosted
  - https://www.youtube.com/watch?v=kf-nAPW4Irw
- 5G as perceived in Japan
  - https://www.youtube.com/watch?v=lDJC_yJTXIc
- Huawei 5G
  - https://www.youtube.com/watch?v=UzMu0DCElII

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12

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Mobile Network Architecture Evolution

13

Outline

- **Legacy Networks:**
  - GSM
  - GPRS
  - UMTS
- **System Architecture Evolution**
  - Background & requirements
  - Motivation
  - Basic principles
  - Network elements and high level functions
- **Architectural enhancements for E-UTRAN and interoperability with 3GPP and non-3GPP accesses**
  - Interoperability Mobility and handover management
  - Policy Control and Charging (PCC)
  - QoS Provisioning

Main References:

1- 3GPP Technical Specifications 23.401
2- 3GPP Technical Specifications 23.402

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Major Standardization Groups

- 3rd Generation Partnership Program (3GPP)
  - In existence since 1998
  - Is the most prominent standardization group for mobile networks
    - Developed legacy GSM, GPRS, UMTS,
    - e-UTRAN
    - 5G
- WIMAX Forum Networking Group (WMF NWG)
  - In existence since 2001
  - Developed WIMAX
    - Competitor to 3GPP's EPS
    - Integration between the two systems is also considered
- Telecom & Internet Converged Services & Protocols for Advanced Networks (TISPAN)
  - Focuses on network interconnection and evolution as part of Next Generation Networks (NGN)
  - IMS
- 3rd Generation Partnership Project Nr. 2 (3GPP2)
  - Counterpart of 3GPP for the American, Pacific and partially Asian market
  - Developed several specifications
    - CDMA2000 ©, 1xRTT, EV-DO or HRPD
  - Interworking between 3GPP2 and 3GPP networks are considered

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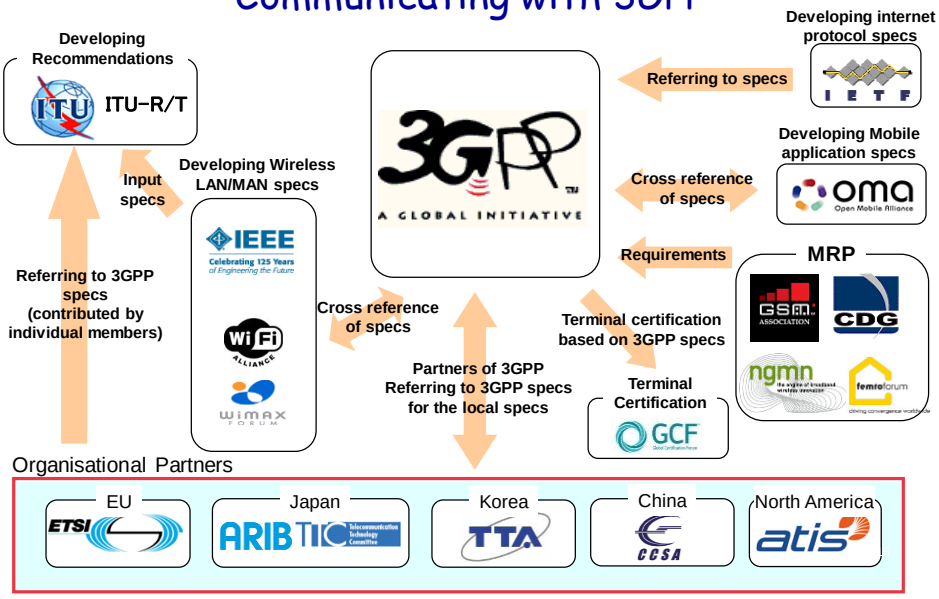
Standardization Organizations Communicating with 3GPP



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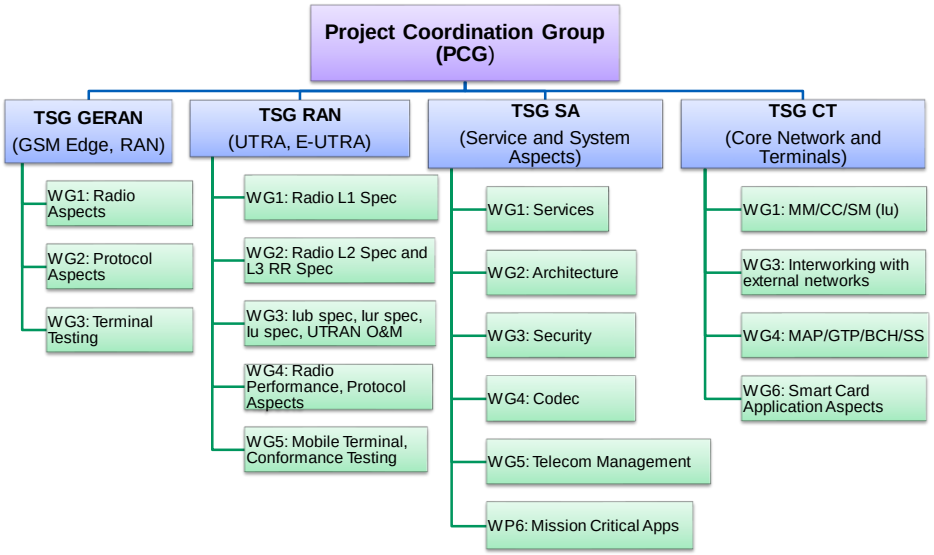
16

3GPP TSG Structure



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17

3GPP Access Evolution

- **2G or GSM/CS**
  - Voice communication
    - narrowband, real-time, circuit switched
  - WAP or HSCSD as extensions to enable data communications but limited success
- **2.5G (GPRS/PS, Enhanced Data Rates for GSM Evolution EDGE)**
  - Adding Packet Services
  - Theoretical data rates up to 384 Kbps
  - Not "always-on" IP connectivity:
    - IP address is assigned only when "PDP context" is established for data transmission
- **3G or UMTS**
  - Built on WCDMA
    - High peak data rates: 2Mbps
    - Extended by HSDPA (Rel. 5), HSUPA (Rel. 6), and HSPA+ (Rel. 7)

  IMS as service control layer for PS core network
- **4G**
  - Long Term Evolution (LTE)
  - LTE-Advanced
- **Beyond 4G**
  - 5G SBA
  - 5G NR

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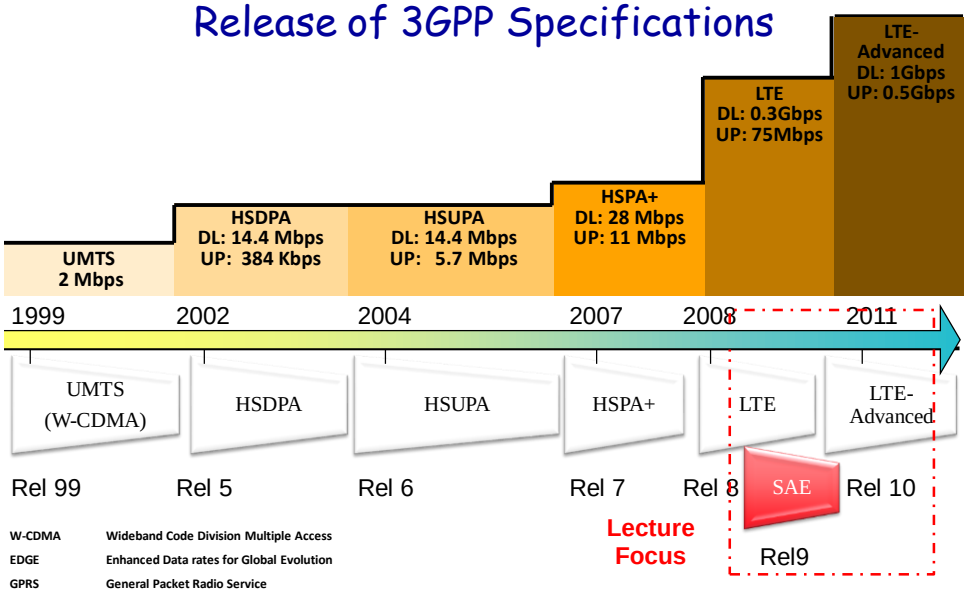
Release of 3GPP Specifications



W-CDMA	Wideband Code Division Multiple Access
EDGE	Enhanced Data rates for Global Evolution
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
LTE	Long Term Evolution
HSUPA	High Speed Uplink Packet Access
HSDPA	High Speed Downlink Packet Access
UMTS	Universal Mobile Telecommunications System

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Nomenclature (1)

Long Term Evolution

- Evolved UMTS Radio Access (E-UTRA) (Physical and link layers)

E-UTRA Network (E-UTRAN)

- Radio Network's Functions

Evolved Packet Core

- System Architecture

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Nomenclature (2)

Evolved 3GPP System

System Architecture Evolution (SAE)

Evolved Packet System (EPS)

EPS = Evolved UTRAN + Evolved Packet Core

3G+, 3.5G, 4G, 5G,etc

- Advanced phases of the system design
- Marketing terms

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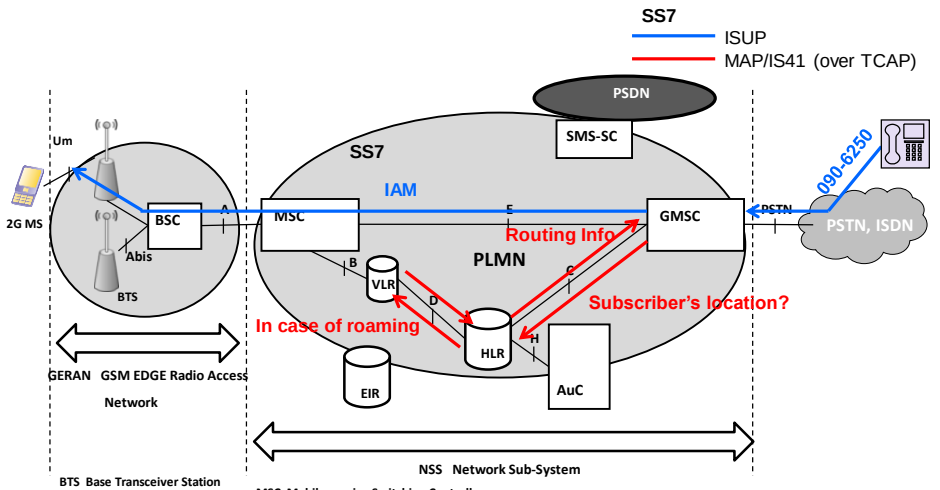
Legacy 3GPP Networks

22

GSM 2G Architecture



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Circuit Switch vs Packet Switch

- Reserved bandwidth
- Time based billing
- Fixed access time

- Suitable to real-time applications

- Lower bit rates (14.4 kbps)
- Inefficient use of resources

- Shared bandwidth
- Traffic based billing
- Variable access times

- Ideal for "data" traffic

- Higher bit rates (up to 170 kpbs)

2.5 G (GPRS)

GPRS General Packet Radio Service

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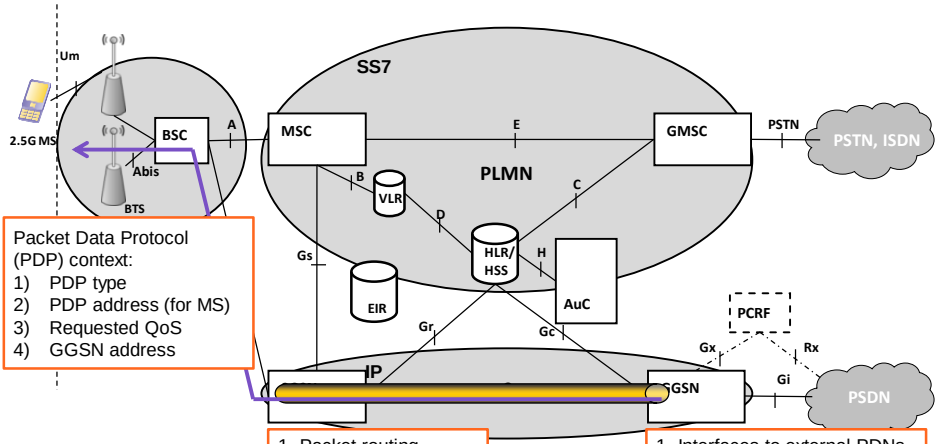
GPRS Architecture



GPRS General Packet Radio Service
SGSN Serving GPRS Support Node
GGSN Gateway GPRS Support Node
HSS Home Subscriber Server
PCRF Policy Charging & Rules Function

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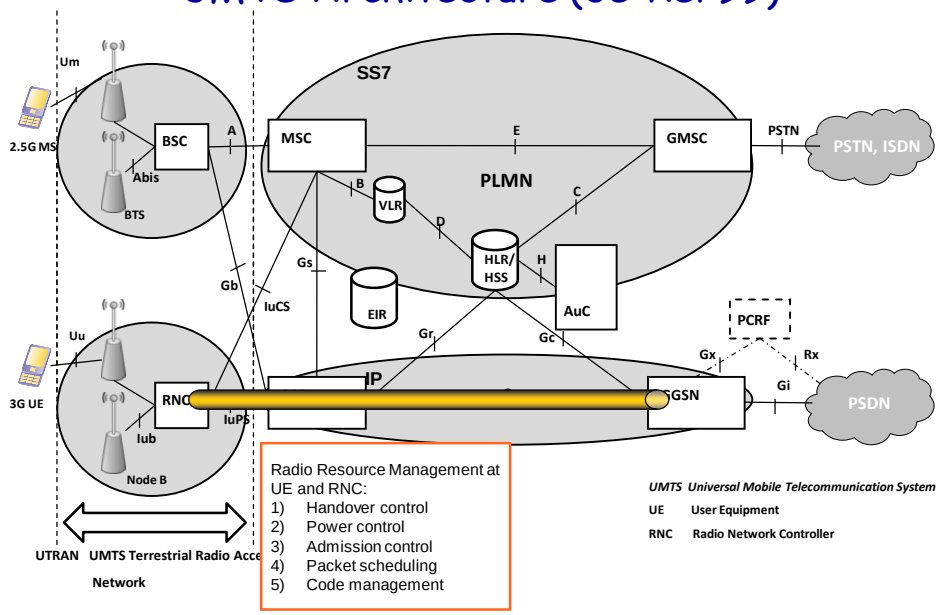
25

UMTS Architecture (3G Rel 99)



UMTS Universal Mobile Telecommunication System
UE User Equipment
RNC Radio Network Controller

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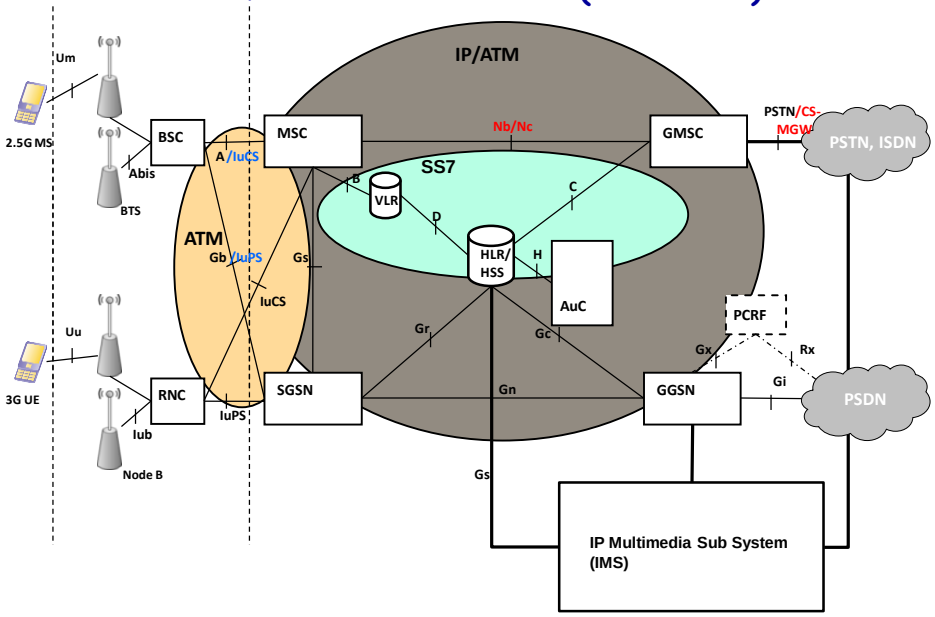
26

UMTS Architecture (3G Rel 5)



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27

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Long Term Evolution

28

LTE Features & Requirements (1/2)

- **"Always on" IP connectivity**
- **All-IP Network (AIPN)**
  - Providing economy of scale and spectrum reuse
  - Supporting full mobility and global roaming
  - Ensuring seamless service across different radio access
  - Efficiently interworking with non-3GPP accesses
  - Compatible with legacy 3GPP networks
  - Ensuring high QoS
  - Affording high user data rates for both uplink and downlink
  - Lower latencies in user data and control planes
  - Supporting diverse mobile network services, both unicast and multicast
- System with **reduced cost (CAPEX and OPEX)**
  - Reduced number of network elements – flatter architecture
  - Less complexity in RAN and economic usage of backhaul capacity
- System with **improved capacity and coverage**
  - Usage of the orthogonal frequency-division multiplexing (OFDM)
  - Spectrum efficiency and reuse
- System with **high level of security**

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Key Features/Requirements (2/2)

- **Simple protocol architecture**
  - Shared channel based
  - PS mode only with VoIP capability (No CS)
- **Simple Architecture**
  - eNodeB as the only E-UTRAN node
  - Fully meshed approach with tunneling mechanism over IP transport network
  - Iu Flex approach
  - Smaller number of RAN interfaces
    - eNodeB ←→ MME/SAE-Gateway (S1)
    - eNodeB ←→ eNodeB (X2)
- **Compatibility and inter-working with earlier 3GPP Releases**
- **Inter-working with other systems, e.g. cdma2000**
- **FDD and TDD within a single radio access technology**
- **Efficient Multicast/Broadcast**
  - Single frequency network by OFDM
- **Support of Self-Organizing Network (SON) operation**

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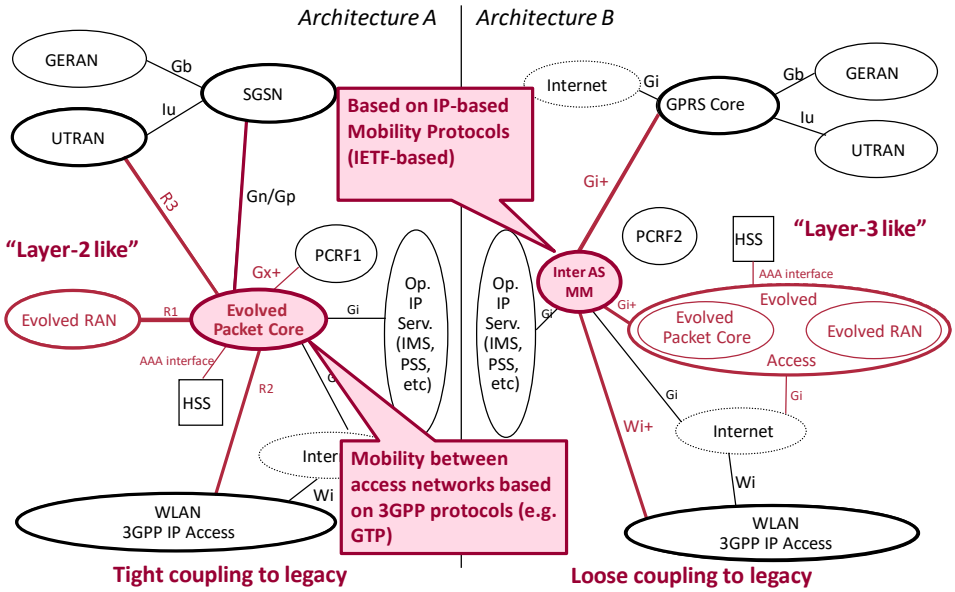
3GPP TS 22.278 Tech. Spec., "Service Requirements for Evolution of the 3GPP System, Stage 1, Release 8," June 2008

History on Architecture "Battles" (1)



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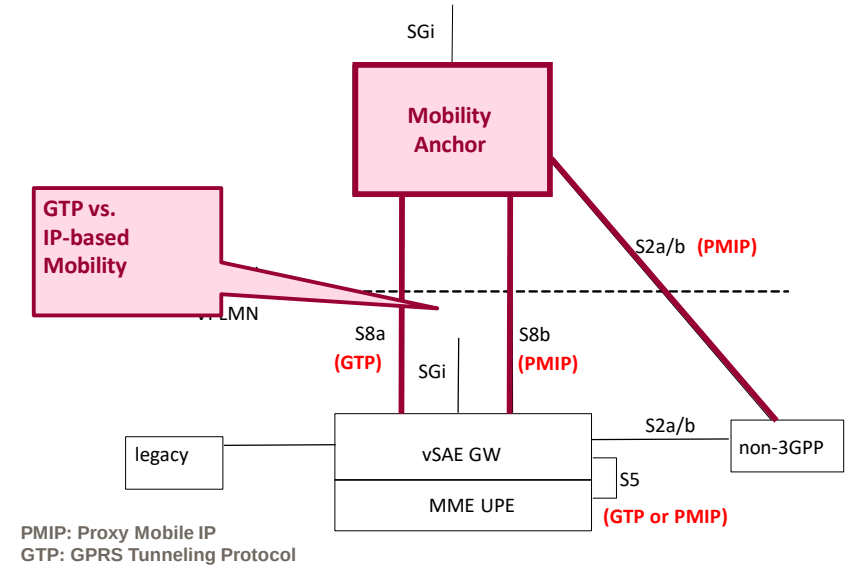
35

History on Architecture "Battles" (2)



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Architectural Aspects of EPC

- 3GPP accesses
- non-3GPP accesses
  - Untrusted non-3GPP
    - Requirement for a special gateway (evolved Packet Data Gateway) for a secure access of UE to EPC
  - Trusted non-3GPP
    - ePDG not required

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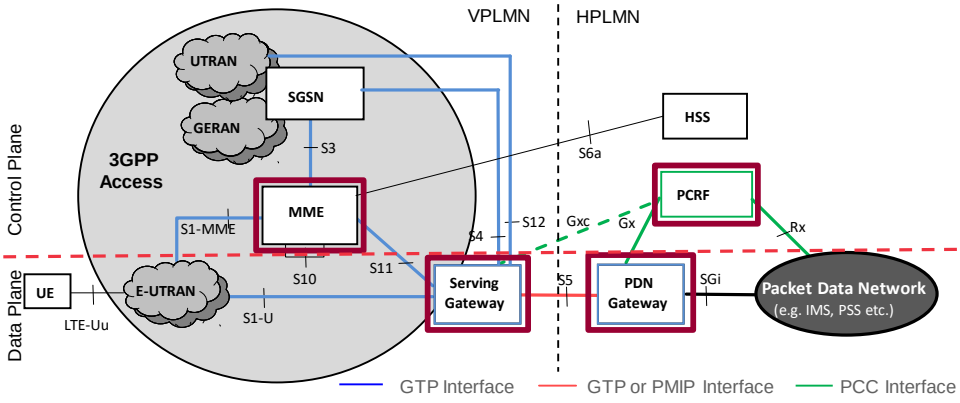
EPS for 3GPP Accesses

- **PDN GW:** IP address allocation, charging and enforces QoS
- **Serving GW:** Local mobility anchor for intra-3GPP HO
- **MME:** Mobility management entity for intra-3GPP mobility, paging, authentication, bearer management, etc.
- **PCRF:** QoS and charging rule provisioning



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EPS for 3GPP Accesses

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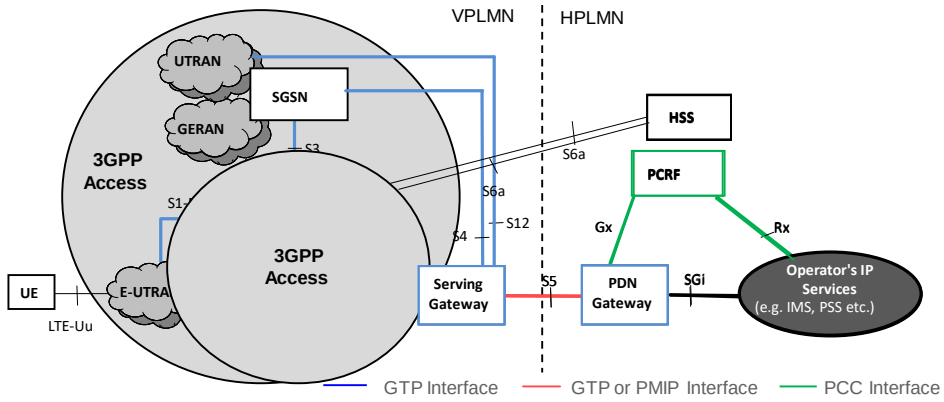

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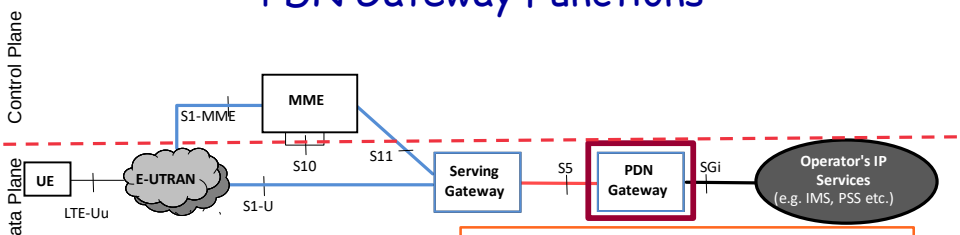
39

PDN Gateway Functions



- **UE IP address allocation**
- **UE data anchoring**
- **Per user packet filtering**
- **Lawful interception**
- **Transport level packet marking**
- **Service level charging**
- **Service level gating control**
- **Rate enforcement based on**
  - Aggregate Maximum Bit Rate for an APN
  - Accumulated Maximum Bit Rates of the aggregate of service data flows with the same guaranteed bit rate
- **DHCPv4 & DHCPv6 functions**

GTP-based S5

- **Up/Downlink bearer binding**
- **Uplink bearer binding verification**
- **IP neighborhood detection**

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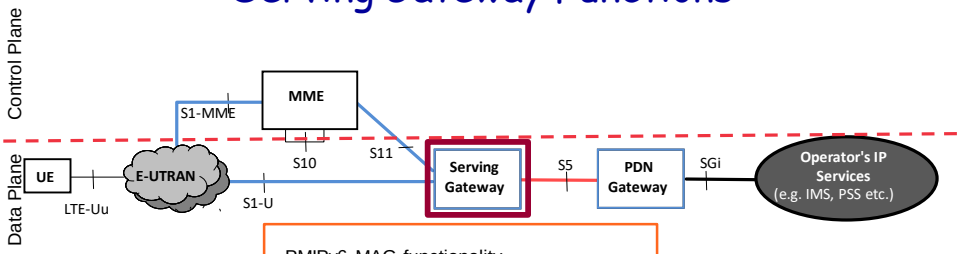
Serving Gateway Functions



- PMIPv6 MAG functionality
- Inter-eNB handover
- Downlink packet buffering in idle mode
- Service Request
- Lawful Interception
- Packet routing and forwarding
- Up/Downlink packet marking
- Accounting for inter-operator charging
- Up/Downlink charging

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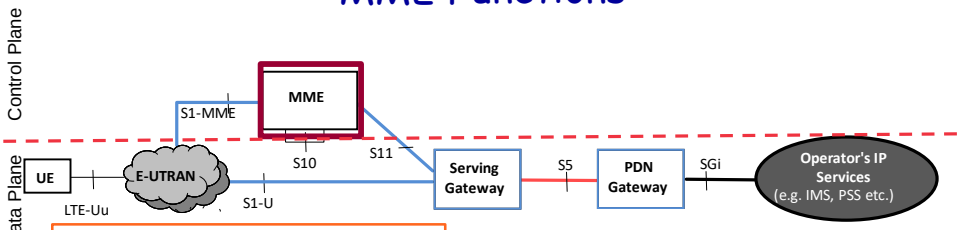
41

MME Functions



- Handling of NAS signaling
  - En/decryption and authentication of messages
- Support of UE Reachability in “idle” state
- Tracking Area management;
- PDN/S-GW selection
- Target MME selection
- Subscriber authentication
- Bearer management
- Lawful Interception of signaling traffic

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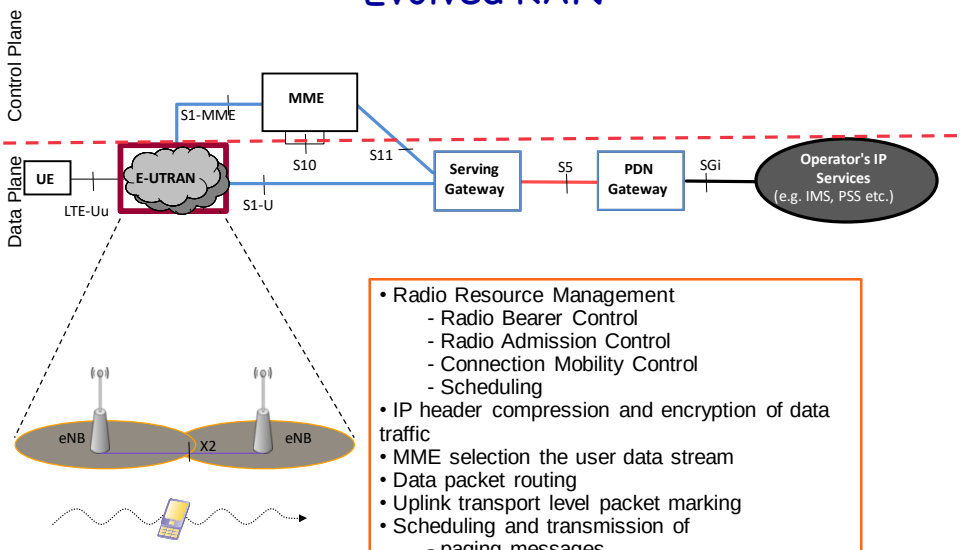
42

Evolved RAN



- Radio Resource Management
  - Radio Bearer Control
  - Radio Admission Control
  - Connection Mobility Control
  - Scheduling
- IP header compression and encryption of data traffic
- MME selection the user data stream
- Data packet routing
- Uplink transport level packet marking
- Scheduling and transmission of
  - paging messages
  - broadcast information
- Measurement for mobility and scheduling

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Summary (1)

- **Migration scenarios from legacy NWs to EPS**
- **LTE Requirements & History**
- **EPS Architecture, Components, and Protocols**
  - **To be continued!**

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