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Towards Broadband Wireless Access Integration - Understanding the Role of the 3GPP Evolved Packet Core (EPC)

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Open EPC Evolved Packet Core

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About the Speakers

Prof. Dr. Ing. habil Thomas Magedanz

Thomas Magedanz (PhD) is professor in the electrical engineering and computer sciences faculty at the Technical University of Berlin, Germany, leading the chair for next generation networks (Architektur der Vermittlungsknoten – AV) supervising Master and PhD Students

In addition, he is director of the "NGNI" division at the Fraunhofer Institute FOKUS, which provides toolkits for NGN/IMS as well as NGMN/EPC test and development tools for global operators and vendors. Prof. Magedanz is one of the founding members of FOKUS (1988) and member of the management team.

Furthermore he is principal consultant of Direct Link Consult e. V., a FOKUS Consulting spin off focussing on professional services, strategic studies and technology coaching.

Prof. Magedanz is a globally recognised technology expert, based on his 18 years of practical experiences gained by managing various research and development projects in the various fields of today´s convergence landscape (namely IT, telecoms, internet and entertainment).

He acts often as invited tutorial speaker at major telecom conferences and workshops around the world.

Prof. Magedanz is senior member of the IEEE, editorial board member of several journals, and the author of more than 200 technical papers/articles. He is the author of two books on IN standards and IN evolution.

Abstract

Broadband wireless access network technologies are evolving towards all IP networks. Today the 3GPP Long-term Evolution (LTE) is gaining momentum globally, as it considered as a cornerstone for the realization of the Next Generation Mobile Network (NGMN). As LTE initially can only be deployed in islands, the related 3GPP Evolved Packet System (EPS) specifications define the Evolved Packet Core (EPC) as a general NGMN control platform across different broadband radio access networks. The EPC should provide seamless IP connectivity to different operator service delivery platforms, such as the IP Multimedia Subsystem (IMS) or more internet-based platforms.

This talk will introduce the 3GPP Evolved Packet System and compare LTE and WIMAX networks as basic NGMN broadband wireless access networks. Subsequently, the Evolved Packet Core is introduced, where we look at its basic architecture and its functions, such as cross access network mobility management, security, QoS and Charging. We will illustrate its operation above 3GPP networks (e.g. LTE, 3G) as well as non-3GPP networks (WLAN, Wimax). In addition, we will outline the major NGMN and EPC challenge, namely the provision of voice based services. Finally we will introduce the OpenEPC NGMN testbed toolkit (www.openepc.net), which enables industry, namely network operators, equipment manufacturers, and service providers, as well as academia to investigate the technical potentialities of this key enabling technology for NGMN implementation.

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Agenda

- Motivation for Next Generation Mobile Networks (NGMNs)
- NGMN related Fora and Standards
- NGMN access network technologies
- EPS and EPC Overview
- NGMN Services: the Role of IMS over EPC – Voice and more
- Introducing the FOKUS OpenEPC NGMN toolkit
- Summary

Introduction

- The introduction of IP technology in telecommunication networks started in the fixed network domain, known as Next Generation Network (NGN)
  - The IP Multimedia System (IMS) – although proposed for the mobile domain - has become the common control overlay network for fixed, mobile, and cable networks
  - IMS is considered key for NGNs, and it particuarly supports Fixed Mobile Convergence (FMC) across different access networks, by common QoS, security, charging and session mobility management
- These days the Next Generation Mobile Network (NGMN) concept is emerging, driven by the hype around Long-term Evolution (LTE)
- But LTE is just one promising mobile access network technology, there are much more WAN out there, such as WIMAX and WLAN etc.
- Therefore, 3GPP defined the Evolved Packet Core (EPC) as the new mobile core network, suporting seamless mobility, QoS and charging across multiple IP access networks, incl. 3GPP and non-3GPP access networks
- EPC shares a lot of concepts with IMS, e.g. overlay architecture concept, HSS, PCC, etc.
- Early prototyping of NGMN environments will be crucial to gain practical experiences
- Similar to Open IMS Core for NGN, the OpenEPC toolkit is designed for NGMN prototyping

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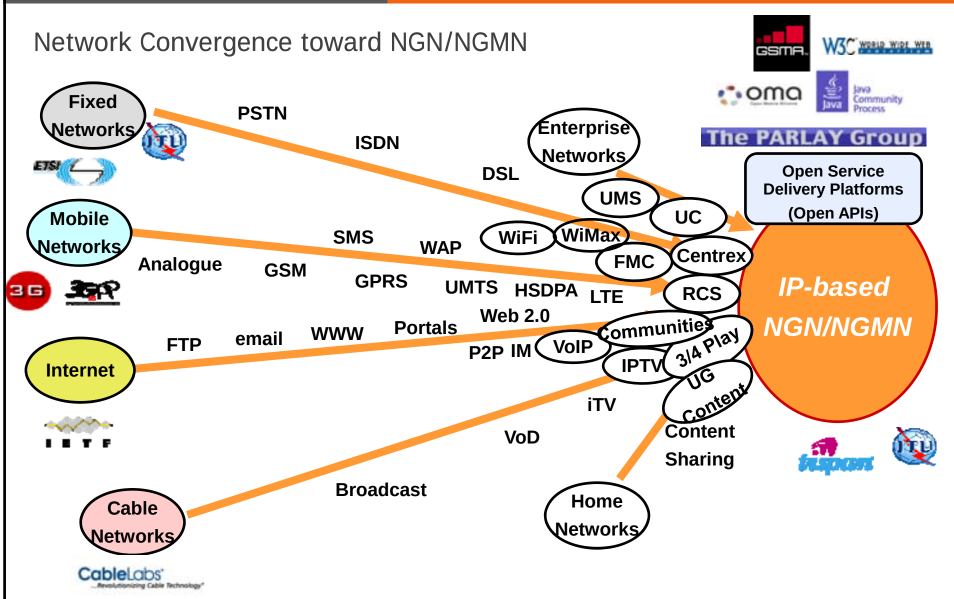
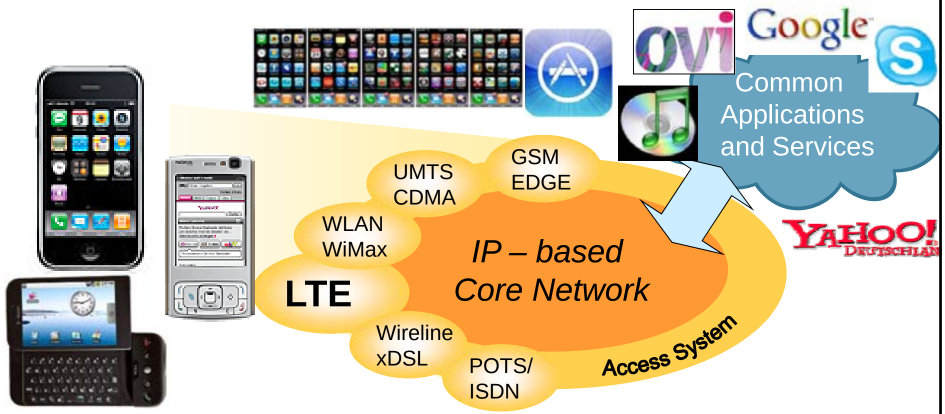
Network Convergence toward NGN/NGMN



Content and Apps over Bitpipes – Where is the Money??

- Network convergence based on IP has led to high competition
- Connectivity Services (QoS) versus Multimedia Services (Content)



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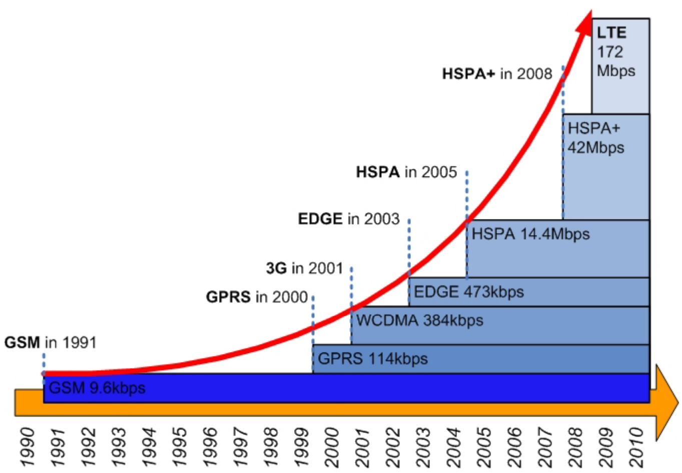
Evolution Path of 2G and 3G Technologies



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Wireless Broadband enables new Services

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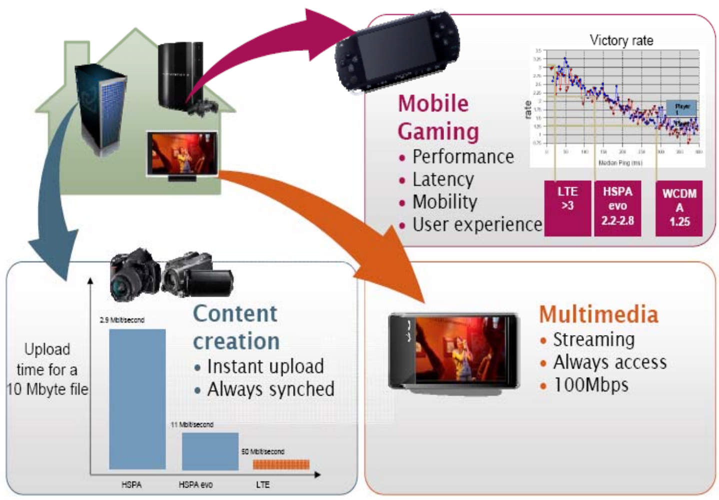
Coming up soon: The Digital Home on the Move (e.g. DTAG Connected Life & Work)



Source: DTAG

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Expected NGMN Services (Just Examples ….)

- VoIP alternatives to expensive tariffs
  - e.g., avoiding international roaming charges
- Video/Music on demand while mobile
- Multicast and broadcast service offerings
- Life IPTV (in HD)
- Interactive gaming (graphics, twitch games)
- Downloaded applications
- Larger, multi-media, graphically intensive ones
- High quality/definition audio/video services
- Superior encoding options
- Cloud computing functions and features (all user data is in the cloud)

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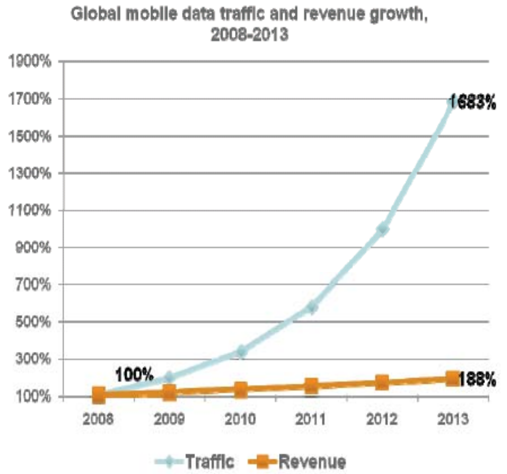
Traffic vs. Revenues Forecast

Global mobile data traffic volumes to grow to 17x 2008 levels by 2013, whilst revenues grow by factor of 1.8x



Source: Informa's Global Content & Services Traffic Forecast, 2009

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Motivation for NGMN

- NGMN stands for ***Next Generation Mobile Network***
- NGMN is a new paradigm for mobile networks which:
  - Drives customer-centric innovation
  - Is primarily business driven
  - Provides end-to-end perspective for future technology needs
  - Bundles operators expertise to develop viable ecosystem
  - Wants to prevent fragmentation
  - Is not another standardisation organisation!
- NGMN Alliance (www.ngmn.org) intends to complement and support the work within standardization bodies by providing a coherent view of what the operator community is going to require in the decade beyond 2010.
- The initial objective of the NGMN Alliance is the commercial launch of a new experience in mobile broadband communications and to ensure a long and successful cycle of investment, innovation and adoption of new and familiar services that would benefit all members of the mobile ecosystem.

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Who is Who in Next Generation Mobile Network context?

- NGMN Alliance defines LTE/EPC Requirements
  - http://www.ngmn.org
- 3GPP developes LTE/EPC Specifications
  - http://www.3gpp.org/Highlights/LTE/LTE.htm
  - http://www.3gpp.org/Specification-Numbering
- LTSI performs Proof of Concept / Interoperability Tests
  - http://www.lstiforum.org/file/news/Latest_LSTI_Results_Feb09_v1.pdf

NGMN Alliance Recommendations

- The target architecture defined by these recommendations will be an optimized Packet Switched (PS) network architecture, which will provide a smooth migration of existing 2G and 3G networks towards an IP network with improved cost competitiveness and broadband performance.
- The NGMN initiative introduces a platform for innovation, and therefore there are recommendations for the envisaged platform.
- The key NGMN functional characteristics are (drivers for performance) :
  - QoS support
  - Mobility support
  - Uplink/downlink data rates
  - Always-on support
  - Core, RAN and E2E Latency
  - Spectrum efficiency
  - Authentication support

Source: White Paper "Next Generation Mobile Networks Beyond HSPA & EVDO“ Available at http://www.ngmn.org

NGMN Alliance Recommendations

- The key NGMN non-functional characteristics are (drivers for efficier
  - Integrated Network
    - support for different access technologies that provide
      - higher bandwidth
      - higher peak rates
      - lower latency
  - Inter-working
    - coexistence with legacy networks
  - Simplicity
    - minimization of overall complexity (architecture and protocols)
  - Reduced Total Cost of Ownership (TCO)
  - Reliability
    - deliver correct systems operation

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3GPP Standard Releases

- 2000 - Release 3 (Release 98): Initial 3G UMTS release
- 2001 - Release 4 (Release 99): BICN (Bearer Independent Core Network)
- 2002 - Release 5: HSDPA und IMS introduction
- 2004 - Release 6: HSUPA, MBMS and WLAN interworking
- 2006 - Release 7: HSPA+ and IMS Evolution
- 2007 - Release 8: LTE and SAE Introduction, Common IMS

UMTS Long Term Evolution (LTE)

- Concepts for UMTS Long Term Evolution (LTE) have been introduced in 3GPP Release 8
  - in order to ensure the competitiveness of UMTS for the next 10 years and beyond
- Objective is a high-data-rate, low-latency and packet-optimized radio access technology
- LTE is also referred to as
  - EUTRA (Evolved UMTS Terrestrial Radio Access) or
  - E-UTRAN (Evolved UMTS Terrestrial Radio Access Network)
- LTE uses new multiple access schemes on the air interface:
  - OFDMA (Orthogonal Frequency Division Multiple Access) in downlink and
  - SC-FDMA (Single Carrier Frequency Division Multiple Access) in uplink
- Furthermore, MIMO (Multiple Input Multiple Output) antenna schemes form an essential part of LTE

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LTE (cont.)

- LTE brings some major changes to the existing UMTS protocol concepts!
- Impact on the overall network architecture including the core network is referred to as 3GPP System Architecture Evolution (SAE)
- SAE is also known as Evolved Packet Core (EPC)
- LTE includes an FDD (Frequency Division Duplex) mode of operation and a TDD (Time Division Duplex) mode of operation.
  - LTE TDD which is also referred to as TD-LTE provides the long term evolution path for TD-SCDMA based networks.
- LTE is focusing on optimum support of Packet Switched (PS) services
- Main requirements for the design of an LTE system were identified in the beginning of the standardization work on LTE and have been captured in 3GPP TR 25.913

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LTE Requirements (see 3GPP TR 25.913)

- Data Rate: Peak data rates target 100 Mbps (downlink) and 50 Mbps (uplink) for 20 MHz spectrum allocation, assuming 2 receive antennas and 1 transmit antenna at the terminal.
- Throughput: Target for downlink average user throughput per MHz is 3-4 times better than release 6. Target for uplink average user throughput per MHz is 2-3 times better than release 6.
- Spectrum Efficiency: Downlink target is 3-4 times better than release 6. Uplink target is 2-3 times better than release 6.
- Latency: The one-way transit time between a packet being available at the IP layer in either the UE or radio access network and the availability of this packet at IP layer in the radio access network/UE shall be less than 5 ms. Also C-plane latency shall be reduced, e.g. to allow fast transition times of less than 100 ms from camped state to active state.
- Bandwidth: Scaleable bandwidths of 5, 10, 15, 20 MHz shall be supported. Also bandwidths smaller than 5 MHz shall be supported for more flexibility, i.e. 1.4 MHz and 3 MHz.
- Interworking: Interworking with existing UTRAN/GERAN systems and non-3GPP systems shall be ensured. Multimode terminals shall support handover to and from UTRAN and GERAN as well as inter-RAT measurements. Interruption time for handover between E-UTRAN and UTRAN/GERAN shall be less than 300 ms for real time services and less than 500 ms for non real time services.
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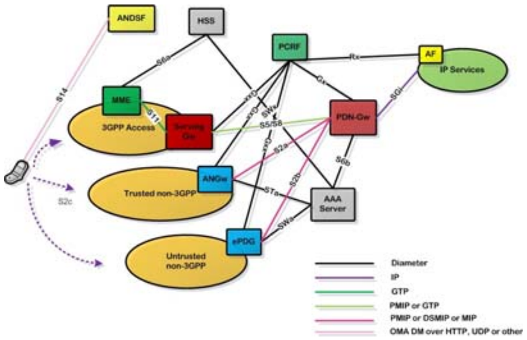
LTE Requirements (cont.)

- Multimedia Broadcast Multicast Services (MBMS): MBMS shall be further enhanced and is then referred to as E-MBMS.
- Costs: Reduced CAPEX and OPEX including backhaul shall be achieved. Cost effective migration from release 6 UTRA radio interface and architecture shall be possible. Reasonable system and terminal complexity, cost and power consumption shall be ensured. All the interfaces specified shall be open for multi-vendor equipment interoperability.
- Mobility: The system should be optimized for low mobile speed (0-15 km/h), but higher mobile speeds shall be supported as well including high speed train environment as special case.
- Spectrum allocation: Operation in paired (Frequency Division Duplex / FDD mode) and unpaired spectrum (Time Division Duplex / TDD mode) is possible.
- Co-existence: Co-existence in the same geographical area and colocation with GERAN/UTRAN shall be ensured. Also, co-existence between operators in adjacent bands as well as cross-border coexistence is a requirement.
- Quality of Service: End-to-end Quality of Service (QoS) shall be supported. VoIP should be supported with at least as good radio and backhaul efficiency and latency as voice traffic over the UMTS circuit switched networks

EPS architecture (3GPP TS 23.401 and 3GPP TS 23.402)

- Interconnection with UTRAN and GERAN through SGSN, MME and Serving Gw
- In roaming scenarios PDN-Gw can be in the visited (local breakout) or in the home network (home routed)
- Serving-Gw and PDN-Gw could be deployed together



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What is 4G ?

- ITU-R defines IMT-Advanced (4G) with the following requirements:
  - *A high degree of commonality of functionality worldwide while retaining the flexibility to support a wide range of services and applications in a cost efficient manner;*
  - *Compatibility of services within IMT and with fixed networks;*
  - *Capability of interworking with other radio access systems;*
  - *High quality mobile services;*
  - *User equipment suitable for worldwide use;*
  - *User-friendly applications, services and equipment;*
  - *Worldwide roaming capability*
  - *Enhanced peak data rates to support advanced services and applications (100 Mbit/s for high and 1 Gbit/s for low mobility were established as targets for research)*
- Both LTE Advanced and Mobile WiMAX (802.16m) are candidate technologies

Source : ITU-R Background on IMT-Advanced (2008)

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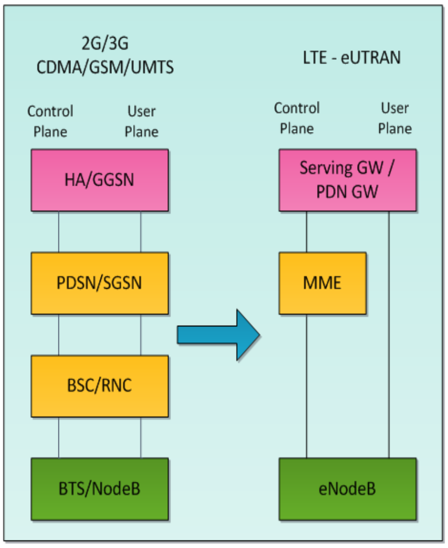
LTE/SAE/EPC – Towards a flat architecture

- System Architecture Evolution (SAE) is the core network architecture of 3GPP's future LTE wireless communication standard.
- SAE / EPC is the evolution of the GPRS Core Network, with some differences:
  - simplified architecture
  - all IP Network only
  - support for higher throughput and lower latency radio access networks (RANs)
  - support for multiple, heterogeneous RANs, including legacy systems as GPRS, but also non-3GPP systems (e.g. WiMAX)
  - mobility between heterogeneous RANs, including legacy systems as GPRS, but also non-3GPP systems (e.g. WiMAX)



Access technologies to NGMN

- Main advantages of NGMN
  - high capacity & data rates
  - ubiquitous coverage
  - low cost
- These factors are limited by spectrum usage
- Technologies evolution provides more bandwidth and spectrum efficiency

	GSM	GPRS	EDGE	WCDMA	HSPA	HSPA+	LTE	Mobile WiMAX	IMT-Advanced
Generation	2	2.5	2.75	3	3.5	3.9	3.9	3.9	4
Year	1992	1997	2003	2000	2006	2009	2011	2008	2015?
Peak Data Bitrates	9.6-14.4 kbps	114-171 kbps	474 kbps	2 Mbps	14.4 Mbps	42 Mbps	100-326 Mbps	23-46 Mbps	1 Gbps
Normalized efficiency	2.1-3.2	4.7	13.3	26.6	187	560	333-1087	200-300	667?

Source : Agilent Technologies (2008)

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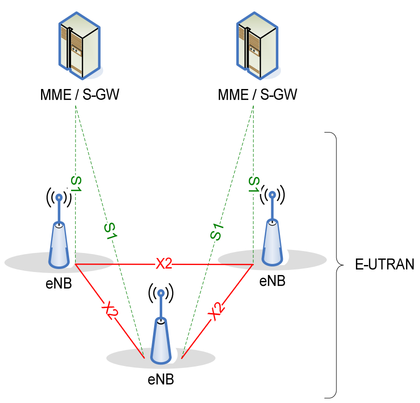
Evolved-UTRAN (eUTRAN)

- Simplified Radio Access Network (RAN) architecture with less nodes
- Evolved Node B (eNB) includes the functions
  - Radio Resource Management
  - Selection of MME
  - Routing user plane data to S-Gw
  - Scheduling
  - Measurement & Reporting



Source : 3GPP TS 36.300 Stage 2 Release 8 V8.0.0 (2009)

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LTE PHY-Layer Improvements

- Downlink OFDM (Orthogonal Frequency Division Modulation)
- Uplink SC-FDMA (Single Carrier Frequency Division Multiple Access) for better "Peak to average" relation as OFDMA
- Support for both FDD and TDD
- Support for many different frequency bands
- 3 Modulation schemes: QPSK / 16 QAM / 64 QAM
- MIMO Spatial Multiplexing, Beam forming, Antenna Diversity
- Up to 326 Mbps in the downlink (with MIMO 4x4 and 20MHz Bandwidth without error rate coding)
- Latency reduction for initial connection from 2s to 50ms and subsequent from 50ms to 5ms

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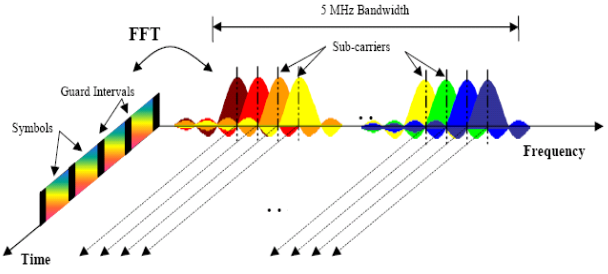
LTE Downlink Coding: OFDMA

- The downlink transmission scheme for E-UTRA FDD and TDD modes is based on conventional OFDM (Orthogonal Frequency Division Modulation)
- In an OFDM system, the available spectrum is divided into multiple carriers, called subcarriers. Each of these subcarriers is independently modulated by a low rate data stream
- OFDM is used as well in WLAN, WiMAX and broadcast technologies like DVB. OFDM has several benefits including its robustness against multipath fading and its efficient receiver architecture



LTE Downlink Coding: SC-FDMA

- During the study item phase of LTE, alternatives for the optimum uplink transmission scheme were investigated.
- While OFDMA is seen optimum to fulfil the LTE requirements in downlink, OFDMA properties are less favourable for the uplink.
  - This is mainly due to weaker peak-to-average power ratio (PAPR) properties of an OFDMA signal, resulting in worse uplink coverage.
- Thus, the LTE uplink transmission scheme for FDD and TDD mode is based on SC-FDMA (Single Carrier Frequency Division Multiple Access) with cyclic prefix.
- SC-FDMA signals have better PAPR properties compared to an OFDMA signal.
  - This was one of the main reasons for selecting SCFDMA as LTE uplink access scheme.
  - The PAPR characteristics are important for cost-effective design of UE power amplifiers.
- SC-FDMA signal processing has some similarities with OFDMA signal processing, so parametrization of downlink and uplink can be harmonized.

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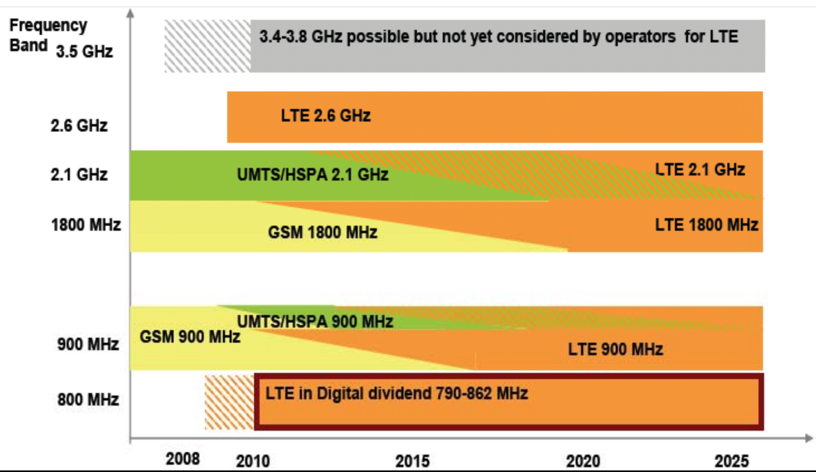
LTE Spectrum Options

- New band @ 800MHz for early Mobile Broadband introduction in rural areas
- Re-farming 900 MHz and 1.8 GHz frequency bands for coverage and capacity expansion



3G vs. LTE

	Existing Paradigm (3G)	LTE
Voice	Circuit Switched	VoIP only
Broadband Services	Best effort, limited and expensive	Real-time, interactive, low latency, true broadband QoS
Multisession Data	Limited	All about bearers, sessions, data flows
QoS	No true e2e guarantees	e2e guaranteed, strictly defined parameters, classification
Policy Management	Not widely adopted	True network wide policy control and management
Mobility Management	Hidden in the RAN	Visible and moved to the core

NGMN : WiMAX or LTE ?

- The features of an access system to NGMN (Higher capacity, lower latency, improved coverage, lower cost) can be reached with both LTE or Mobile WiMAX access technologies
- WiMAX access is standardized by IEEE while LTE is standardized by 3GPP
- Both define an All-IP architecture and may connect to IMS

	WiMAX	LTE
Downlink	**OFDMA**	**OFDMA**
Uplink	**OFDMA**	**SC-FDMA**
Architecture	**All-IP**	
Spectrum	**TDD and FDD (802.16m)**	**FDD and TDD**
Spectrum Flexibility	**Fixed bandwidth**	**Flexible bandwidth**

Source : Alcatel-Lucent (2009)

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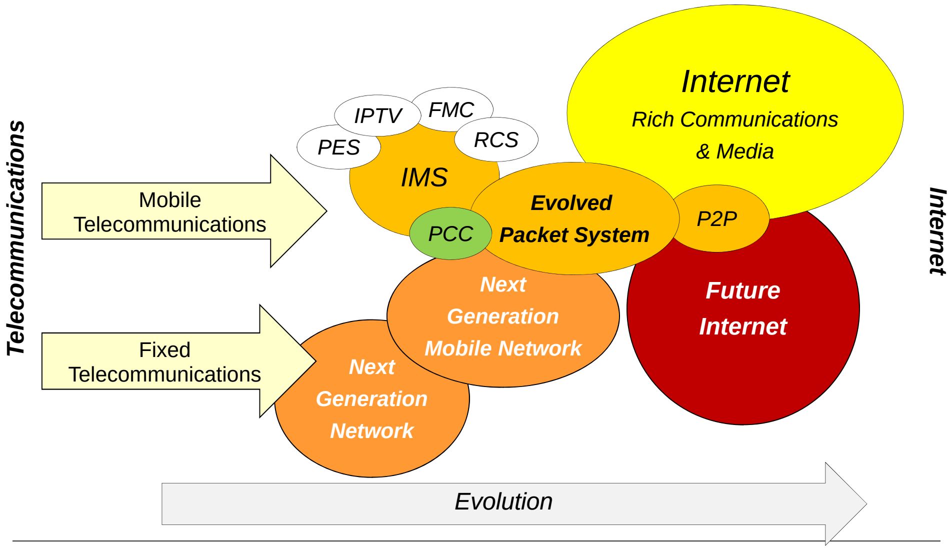
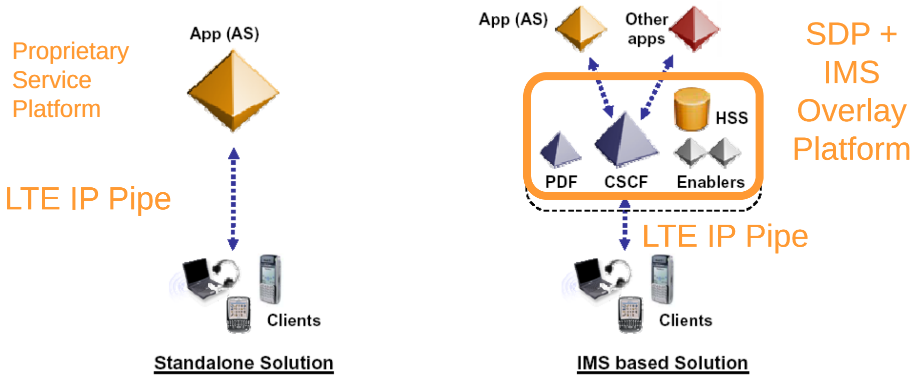
From NGN to NGMN: an important step towards the Future Internet



NGMN Over the Top (OTT) vs. Standardised IMS Service Platform



Fast one-off deployment
Optimised one-off CAPEX (but repeated)
OPEX for each standalone solution
Fragmented end-user experience

Faster integration of subsequent apps
Re-use deployed infrastructure
OPEX shared across whole solution
Integrated end-user experience

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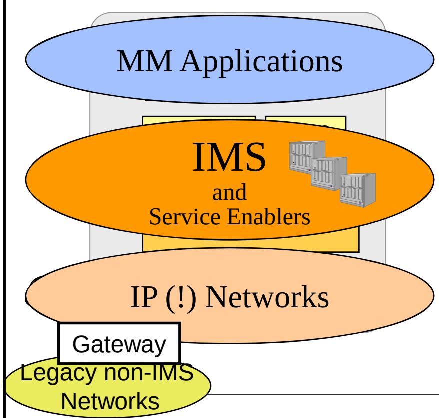
IMS Architecture Principles

- IMS does NOT standardise specific services, but enablers
- BUT supports inherently multimedia over IP, VoIP, IM, presence (SIP)
- IMS enables the flexibility in providing IP-based applications !!



- Horizontal Architecture defining a “docking station” for applications
- Defines service enabler capabilities
- Build on existing IETF and telco SDP standards
- Provides compared to standard internet
- Better security, Service based QoS, flexible charging and single sign on

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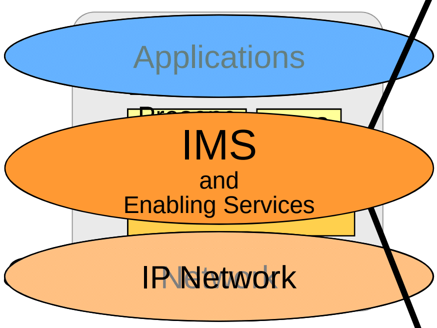
IMS Control Capabilities

IMS Applications are provided by Application Server



- Multiparty / Multimedia Session handling based on SIP Control
- Multimedia Content Pull & Push
- Messaging Support
- Conferencing and Group Com. Support
- Fixed Mobile Convergence / 3P
- Single-Sign-On User-Authentication
- High Secure Service Access and Provision
- Service based Bearer QoS
- Flexible Charging
- Legacy Network Interworking Support
- *Docking Station for Service Enablers*
- *Docking Station for Applications*

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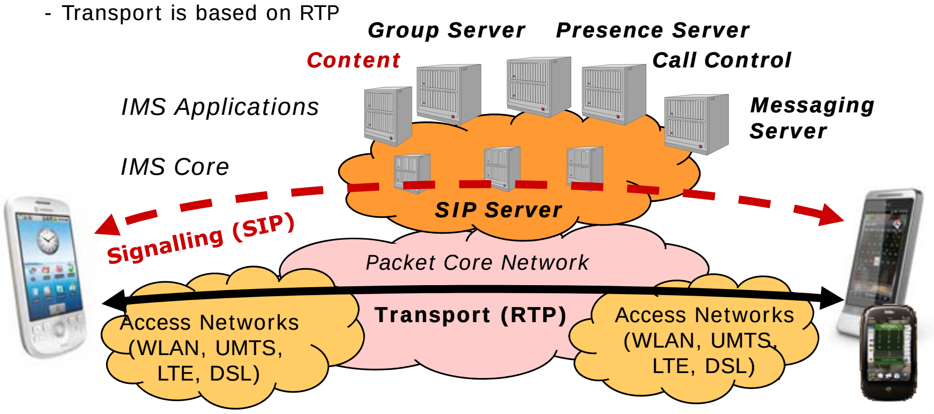
IMS – Flexible & Controlled Service Provision on IP Networks

- IMS Core provides session signalling based on SIP and AAA capabilities based on Diameter
- IMS control and content Application Servers can be dynamically connected to IMS Core for signalling
- Transport is based on RTP



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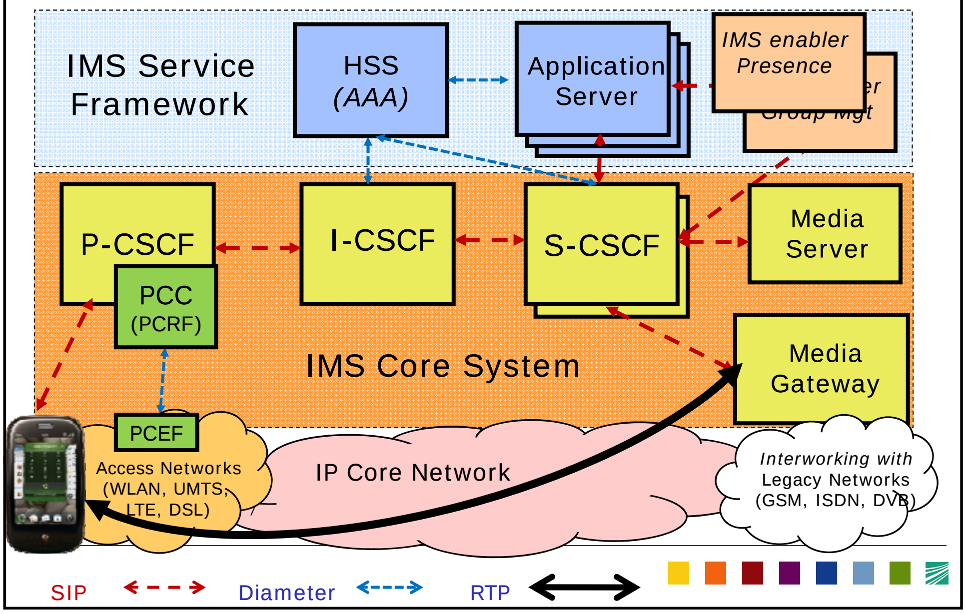
3GPP IMS Architecture: IMS Core and Application Layer



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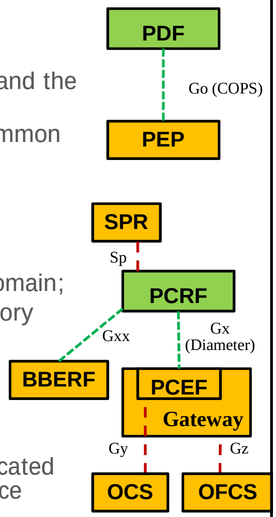
IMS Major Components

- The IMS is an Overlay Session/Service Control Architecture on top of the Packet domain based on IP technologies and protocols:
  - IMS Core
    - S-CSCF (Serving Call Session Control Function) the IMS anchor point in the home network
    - I-CSCF (Interrogating Call Session Control Function) provides topology hiding
    - P-CSCF (Proxy Call Session Control Function) entry point into IMS world
    - MRF (Media Resource Function) – Media Server hosting special resources
    - MGCF (Media Gateway Control Function) for interworking with legacy networks
    - PCC (Policy Charging & Control) for integrated QoS Control and Charging
  - IMS Application Layer
    - HSS (Home Subscriber System) for maintaining subscriber and AS profiles
    - AS (Application Server Function) for specific applications or enabling services
- The main new protocols used are (IETF's) SIP and DIAMETER (but 3GPP MAP and CAP are also important).
- *Note that all Online and Offline Charging components and interfaces (Ro, Rf) are not shown in the previous slide!*

PCC's Architecture Evolution (R6-R7-R8-onwards)

- Release 6 Policy Control (only QoS and gate control)
  - was developed to cope with IMS based services
  - two components: the Policy Decision Function (PDF) and the Policy Enforcement Point (PEP).
  - Policy decisions transferred by Go Interface using Common Open Policy Service (COPS) protocol.
- Release 7 PCC (Policy and Charging control)
  - More complex architecture; it unifies QoS, policy and charging control; Diameter protocol replaced COPS
  - Provides separation from the entities from the IMS domain;
  - A new component is added Subscriber Profile Repository (SPR) for subscription related policy control.
- Release 8 PCC
  - New Bearer Binding and Event Reporting Function (BBERF);
  - The BBERF is specific to each IP-CAN type and is allocated in the corresponding Gateway though the Gxx interface



PCC's Architecture Scope

- The Policy and Charging Control functionality encompasses the following high level functions for IP CANs (e.g. GPRS, WLAN, Fixed Broadband, etc.):
  - Flow Based Charging, including charging control and online credit control to allow for more granularity for end-user charging, accounting and online credit control;
  - Enhanced Policy control (e.g. gating control, QoS control, QoS signalling, etc.) to allow the operator to perform service based QoS policy control.
- The PCC architecture is an evolution of Flow Based Charging (FBC) as defined in TS 23.125 and a replacement for Service Based Local Policies (SBLP) as defined in TS 23.207. From Release 7 onwards PCC supersedes FBC and replaces the SBLP architecture and functionality.

IP CAN: IP Connectivity Access Network

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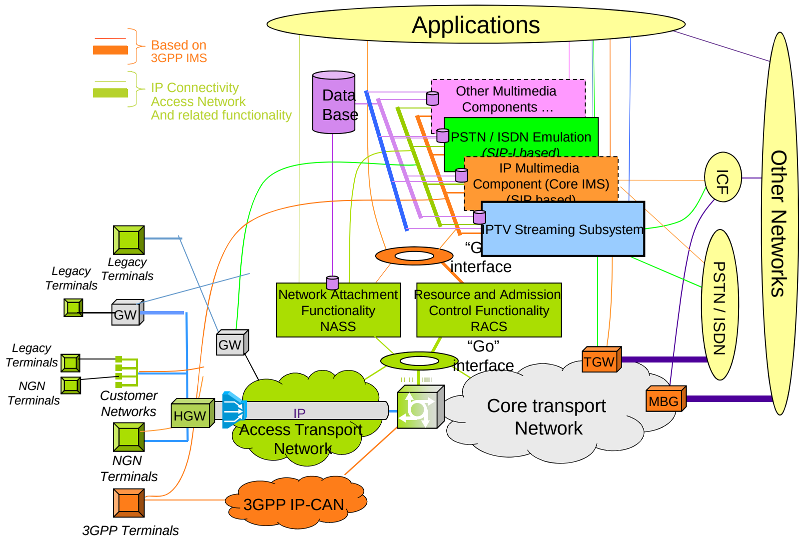
Overall TISPAN NGN Architecture



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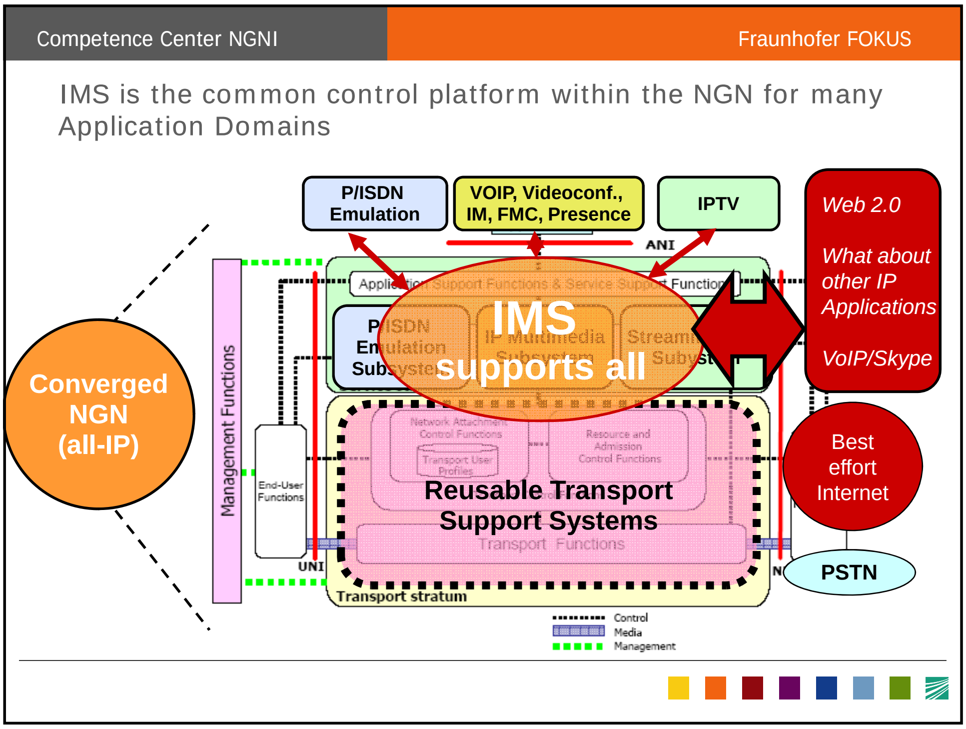
Overall TISPAN NGN Architecture

- NGN as a modular system for independence of subsystems evolution
  - Transfer Functions
  - Network Attachment Subsystem (NASS)
  - Resource Admission and COntrol Subsystem (RACS)
  - PSTN / ISDN Emulation Subsystem (PES)
  - IP Multimedia Subsystem (IMS)
  - NGN Common Functions
  - Applications (out of scope)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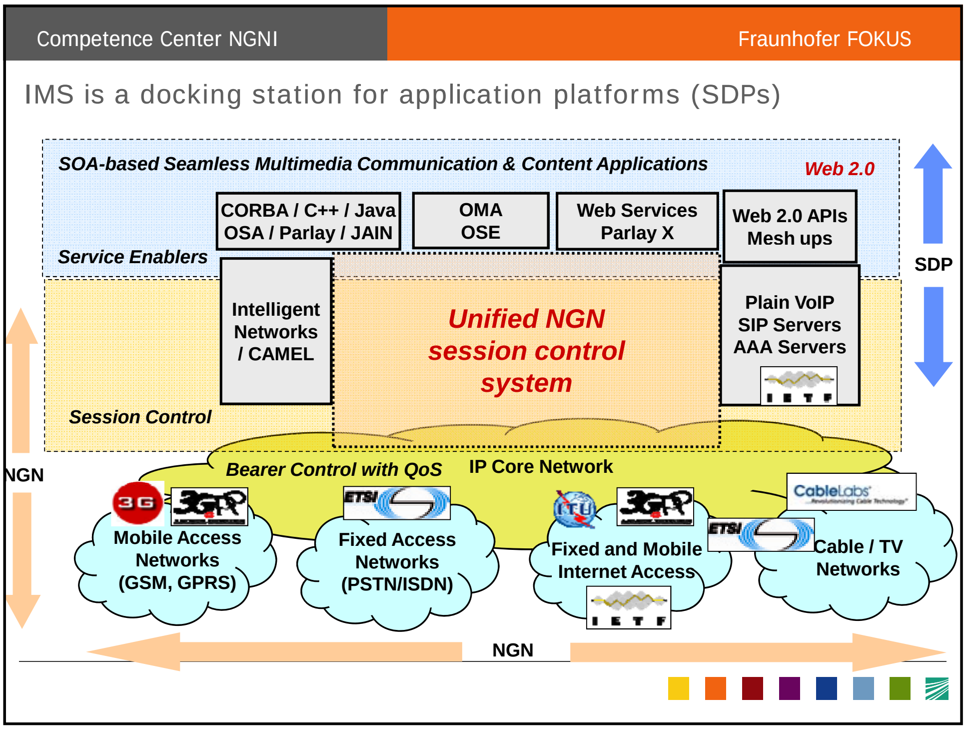
IMS is the common control platform within the NGN for many Application Domains
P/ISDN Emulation
VOIP, Videoconf., IM, FMC, Presence
IPTV
Web 2.0
What about other IP Applications
VoIP/Skype
ANI
IMS supports all
Converged NGN (all-IP)
Management Functions
End-User Functions
Reusable Transport Support Systems
Transport Functions
Best effort Internet
PSTN
UNI
Transport stratum
Control
Media
Management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IMS is a docking station for application platforms (SDPs)
SOA-based Seamless Multimedia Communication & Content Applications
Web 2.0
CORBA / C++ / Java OSA / Parlay / JAIN
OMA OSE
Web Services Parlay X
Web 2.0 APIs Mesh ups
Service Enablers
SDP
Intelligent Networks / CAMEL
Unified NGN session control system
Plain VoIP SIP Servers AAA Servers
Session Control
NGN
Bearer Control with QoS
IP Core Network
Mobile Access Networks (GSM, GPRS)
Fixed Access Networks (PSTN/ISDN)
Fixed and Mobile Internet Access
Cable / TV Networks
NGN

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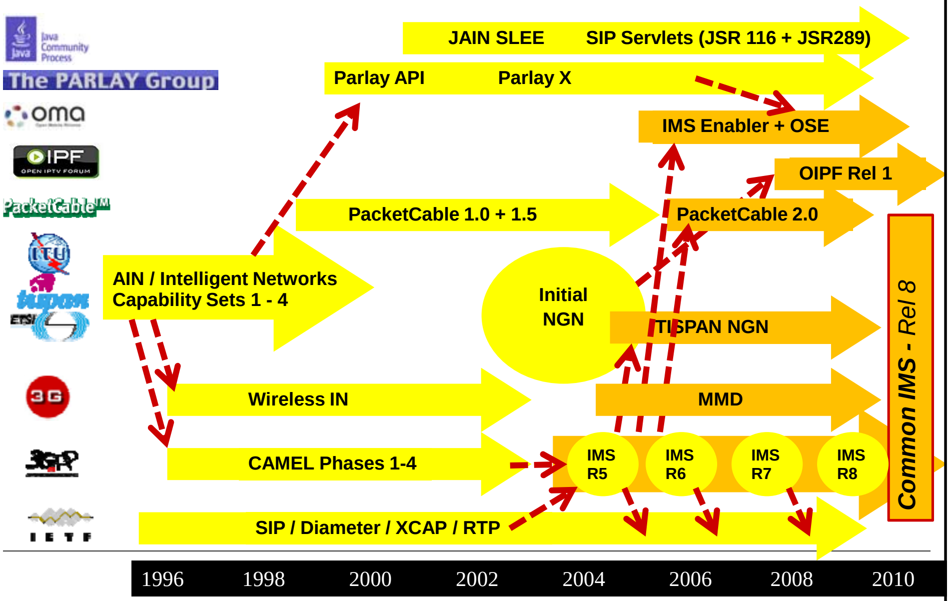
From IN to IMS / SDP Standardisation



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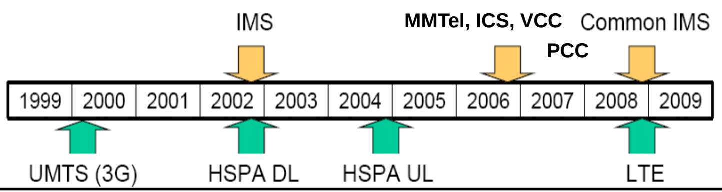
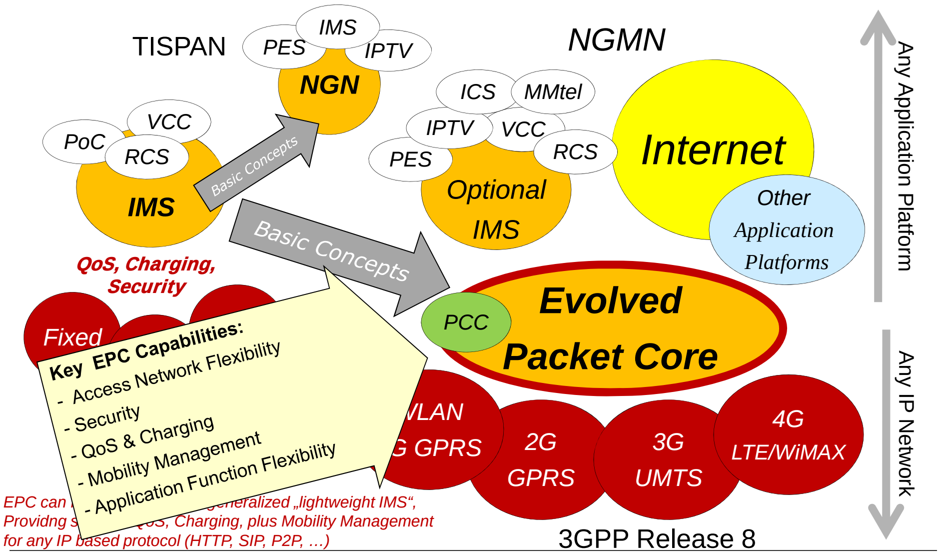
IMS Standards Evolution in regard to Access Network Evolution

- IMS developed as part of 3GPP Release 5 as an application development environment based on IN/CAMEL and VoIP (IETF) concepts and protocols
  - Encourage new applications on top of 3G networks
  - Greater operator policing than native SIP/SDP
  - Home control allowing service customization
- IMS retargeted in Release 7 for telephony replacement
  - Standardized multimedia suite developed (ICS, MMTel, VCC)
  - Optimizations for QoS and Charging (PCC)
  - Access independence
- Common IMS specified in Release 8
  - Extension of Session Mobility support
  - Integration of IMS variants and requirements from 3GPP2, TISPAN, and Cablelabs



Concept Reuse: From IMS for NGN to EPC for all-IP



Evolved Packet System (EPS)

- 3GPP required a network architecture able to support the characteristics of E-UTRAN
- The study point to generate such network architecture was called the "System Architecture Evolution" (SAE)
- *SAE objective was:*

  "to develop a framework for an evolution or migration of the 3GPP system to a higher-data-rate, lower-latency, packet-optimized system that supports, multiple RATs. The focus of this work is on the PS domain with the assumption that voice services are supported in this domain"
- The result of that study is a new simplified All-IP architecture which fulfills the requirements of NMGN: the "Evolved Packet Core" (EPC)
- The Evolved Packet System (EPS) is the term used to refer to the combination of EPC + E-UTRAN
- The EPS is an IP network and uses the standard routing and transport mechanisms of the underlying IP network.

EPS Objectives

- Provide higher data rates, lower latency, high level of security and enhanced QoS
- Support a variety of different access systems (existing and future), ensuring mobility and service continuity between these access systems
- Support access system selection based on a combination of operator policies, user preference and access network conditions
- Realize improvements in basic system performance whilst maintaining the negotiated QoS across the whole system
- Provide capabilities for co-existence with legacy systems and migration to the Evolved Packet System
- *See also 3GPP TS 22.278: Service requirements for the Evolved Packet System (EPS)*

EPS Functional Split between E-UTRAN and EPC

- Target was the enhancement of Packet Switched technology to cope with higher data rates, lower latency, packet optimized system with support for multiple Radio Access Technologies
- This lead to a simplified IP-based overlay architecture with distributed control
- Functionality is divided between E-UTRAN (LTE radio access) and EPC (NAS and IP functionality)

Evolved Packet System		
Evolved UTRAN (E-UTRAN)	**Evolved Packet Core (EPC)**	
eNodeB (eNB) Inter Cell Radio Resource Management, Radio Bearer Control, Connection Mobility Continuity, Radio Admission Control, Dynamic Resource Allocation	**Mobility Management Entity (MME)** NAS, Idle State control, Security, EPS Bearer Control	
	S-Gw Mobility Anchoring for intra-3GPP	**PDN-Gw** IP address allocation, Packet Filtering, inter 3GPP mobility anchoring

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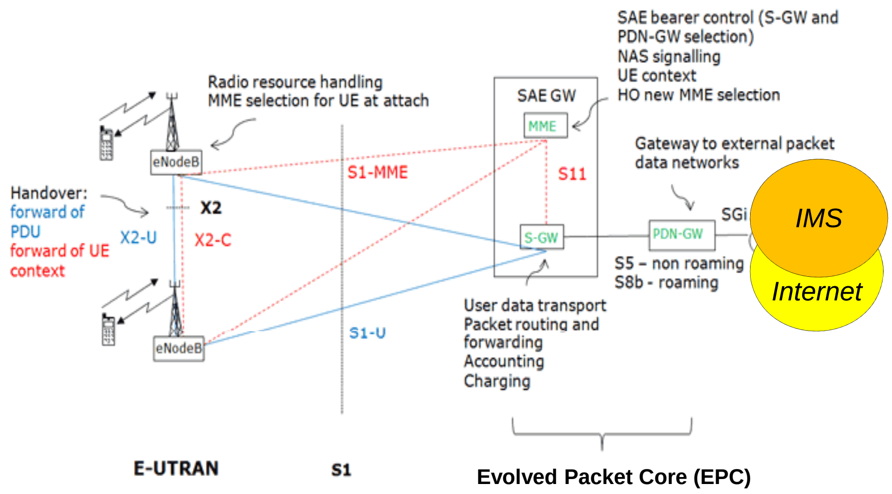
3GPP Evolved Packet System = E-UTRAN + EPC



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EPS Features

- Support for IP traffic with QoS
- Support for IP multicast
- IP session control including mobility, session adaption to terminal capabilities, user preferences, subscriber priorities, network conditions etc.
- Support for scalable multi-party sessions
- Support simultaneous active Packet Data Network connections for the same User Equipment
- Support for emergency calls
- Support for multi-access and seamless mobility

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EPS Mobility and Connectivity Concepts

- The EPS Mobility Management (EMM) states describe the Mobility Management states that result from the mobility management procedures e.g. Attach and Tracking Area Update procedures.
- The EPS Connection Management (ECM) states describe the signalling connectivity between the UE and the EPC.
- In general, the ECM and EMM states are independent of each other.
- Transition from EMM-REGISTERED to EMM-DEREGISTERED can occur regardless of the ECM state, e.g. by explicit detach signalling in ECM-CONNECTED or by implicit detach locally in the MME during ECM-IDLE.
  - However there are some relations, e.g. to transition from EMM-DEREGISTERED to EMM-REGISTERED the UE has to be in the ECM-CONNECTED state.

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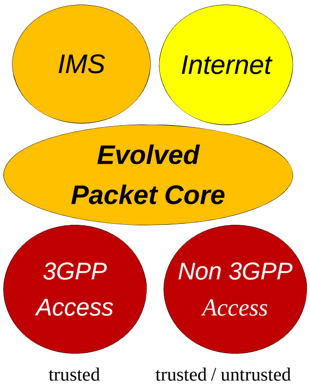
Evolved Packet Core (EPC)

- is an evolution of the legacy GPRS architecture to improve performance and reducing costs
- is the new, all-IP only, mobile core network introduced with LTE in 3GPP release 8
- EPC is motivated by the fact that LTE is just one access network technology, and mobile applications have to interoperate with various access network technologies
- LTE access and EPC overlay form together the **Evolved Packet System (EPS),** formerly known as System *Architecture Evolution (SAE)*
- EPC is based on end-to-end IP only connectivity (no circuit switched connections!)
  - Clear delineation of control plane and data plane
  - Simplified architecture: flat IP architecture with a single core network
  - EPC is based entirely on IETF protocols
- EPC allows the operator to realize a truly converged packet core supporting different wireless access technologies (3GPP and non-3GPP)
- EPC maintains seamless mobility , QoS and unified charging and thus provides the foundation for seamless, consistent and optimized services provision independent of the access network type

Evolved Packet Core (EPC)

- The EPC is a multi-access core network based on the Internet Protocol (IP) one common packet core network for both
  - trusted networks including
    - 3GPP Access (LTE-E-UTRAN, UMTS-UTRAN, GPRS-GERAN)
    - Non 3GPP Access (WIMAX, CDMA2000/HRPD)
  - and untrusted networks including
    - Non-3GPP Access (WLAN)
- EPC provides connection to IP service domains
  - IMS
  - Internet (or others, e.g. P2P etc.)
- Important EPC functions include:
  - NAS and security (AAA)
  - mobility and connectivity management
  - policy QoS control and charging (PCC)



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Evolved Packet Core Logical Functions

- As defined in 3GPP TS 23.401 V9.2.0 the EPC supports the following logical functions:
  - Network Access Control Functions are covering network selection, authentication, authorization, admission control, lawful interception, and optionally policy control and charging (PCC)
  - Packet Routeing and Transfer Functions, where the EPC is using the standard routeing and transport mechanisms of the underlying IP network.
  - Mobility Management Functions are used to keep track of the current location of a UE
  - Security Functions comprise authentication of the UE by the network and service request validation, encryption, etc.
  - *Radio Resource Management Functions* are concerned with the allocation and maintenance of radio communication paths, and are performed by the radio access network.
  - *Network Management Functions* provide mechanisms to support O&M functions related to the Evolved Packet System.

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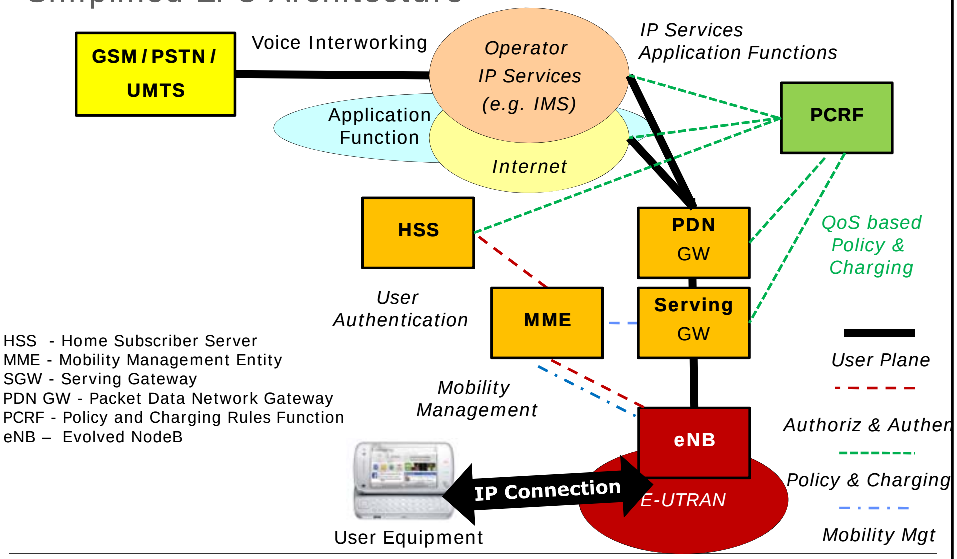
Simplified EPC Architecture



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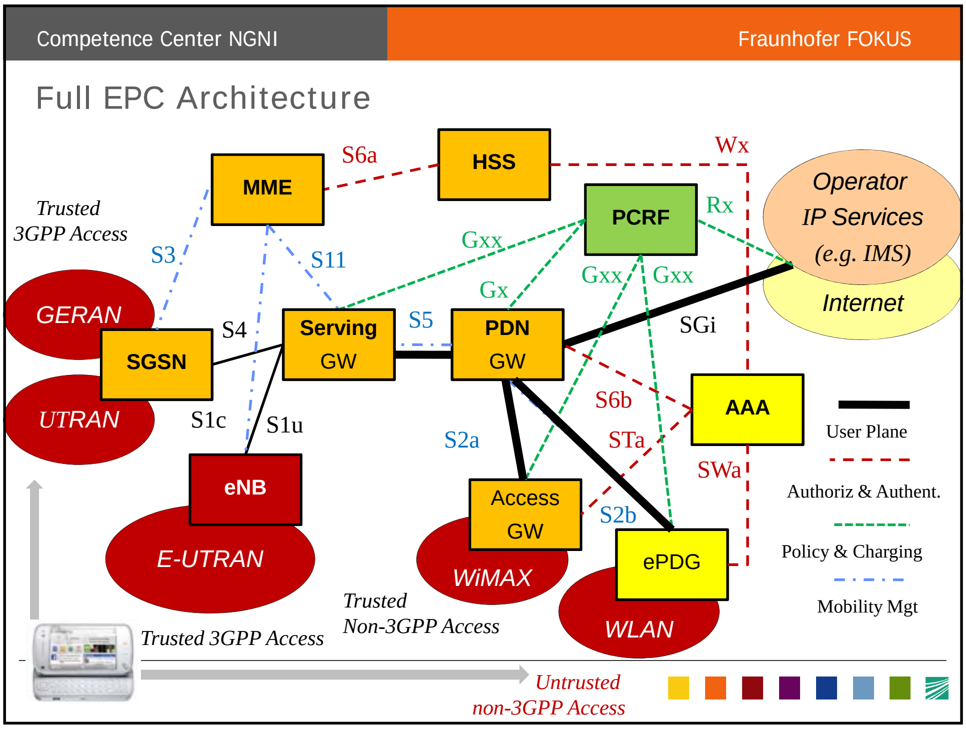
EPC Key Elements

- Home Subscriber Server (HSS)
- Mobility Management Entity (MME)
- Serving Gateway (Serving GW)
- Packet Data Network Gateway (PDN GW)
- Policy and Charging Rules Function (PCRF)
- *Application Function (AF)*
- *User Equipment (UE)*
- Additional EPC Components (see later slides):
  - 3GPP AAA Server (for non-3GPP access networks)
  - evolved Packet Data Gateway (ePGW) for untrusted access networks (WLAN)
  - Trusted non-3GPP accesses (Access GW) for WiMax, etc.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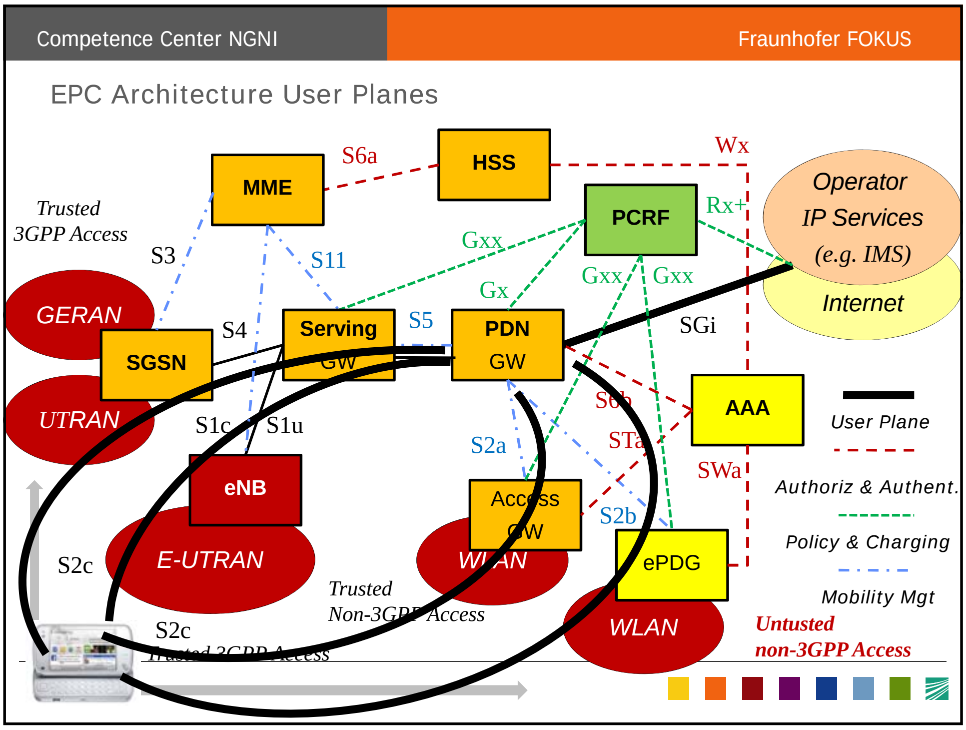
Full EPC Architecture
MME
S6a
HSS
Wx
PCRF
Rx
Operator
IP Services
(e.g. IMS)
Internet
Trusted
3GPP Access
S3
S11
Gxx
Gx
Gxx
Gxx
GERAN
SGSN
S4
Serving
GW
S5
PDN
GW
SGi
UTRAN
S1c
S1u
S2a
S6b
STa
AAA
User Plane
eNB
Access
GW
SWa
Authoriz & Authent.
S2b
E-UTRAN
WiMAX
ePDG
Policy & Charging
Trusted
Non-3GPP Access
WLAN
Mobility Mgt
Trusted 3GPP Access
Untrusted
non-3GPP Access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EPC Architecture User Planes
MME
S6a
HSS
Wx
PCRF
Rx+
Operator
IP Services
(e.g. IMS)
Internet
Trusted
3GPP Access
S3
S11
Gxx
Gx
Gxx
Gxx
GERAN
SGSN
S4
Serving
GW
S5
PDN
GW
SGi
UTRAN
S1c
S1u
S2a
AAA
User Plane
eNB
SWa
Authoriz & Authent.
S2b
S2c
E-UTRAN
ePDG
Policy & Charging
Trusted
Mobility Mgt
S2c
WLAN
Untusted
non-3GPP Access

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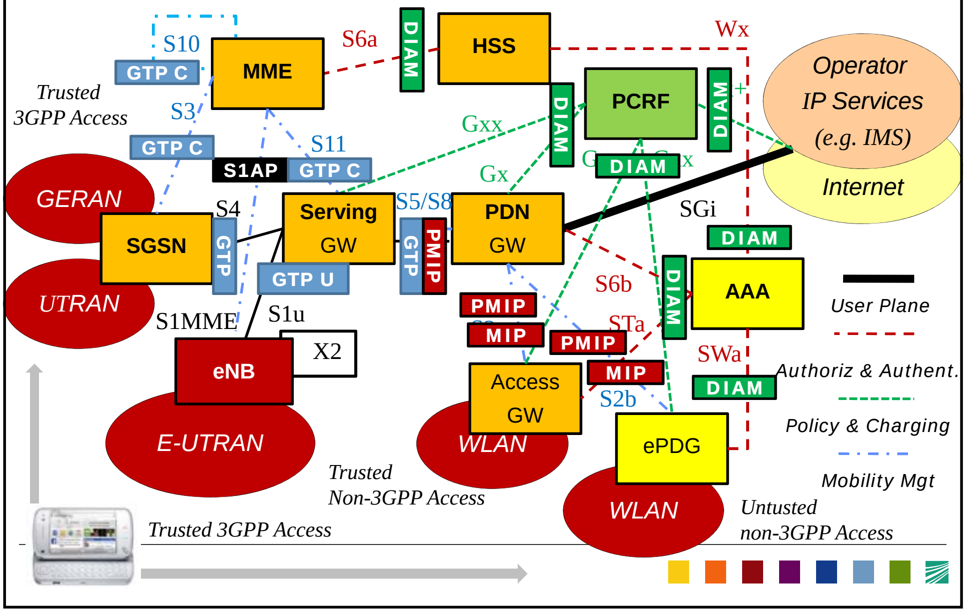
Full EPC Architecture Reference Points & Protocols



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Protocols Classification

- Network Layer Protocols
  - IP
  - Mobile IP and variations
  - PMIPv6
  - GTP
- Transport Layer Protocols
  - SCTP
  - TCP/UDP
- Application Level Protocols
  - OMA DM over HTTP or UDP or other
  - Diameter
  - S1-AP

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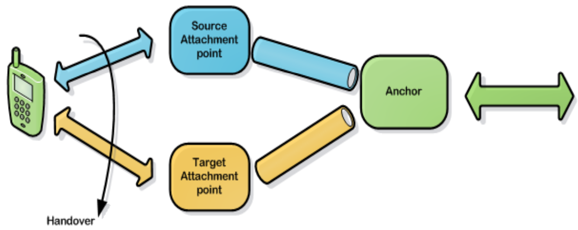
Mobility Management in EPC

- Mobility Management refers to the need of the UE to change the point of attachment to the EPC as it moves
- In the EPC mobility management involves the preservation of IP address of the UE during an attachment point modification
- Tunnels are established between an anchor point and the attachment point
- A signaling protocol is used for tunnel control
- On change of attachment a new tunnel is established and the anchor forwards packets through it



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QoS and Charging in EPC

- QoS control and Charging control is done in the EPC following the architecture of the ***Policy and Charging Control (PCC)*** which has been available since 3GPP Release 7
- The PCC (Release 7) comprises the
  - *Subscriber Profile Repository (SPR),*
  - *Policy and Charging Rules Function (PCRF) , and*
  - *Policy and Charging Enforcement Function (PCEF)*
- The deployment of the PCC architecture is optional for the EPC as the operator may decide to perform profile based QoS control (static)
- In Release 8 the PCC also includes the *Bearer Binding and Event Reporting Function (BBERF)* and two modes of operation of the PCRF for roaming scenarios Home-PCRF and Visited-PCRF with an interface (S9) between them
- The PCRF keeps control of the bearers and sessions established by the users and the treatment the network gives to them
- The QoS control in the PCC level is independent of the access network used as a standard set of parameters is used which are later translated to specific access parameters in the gateways

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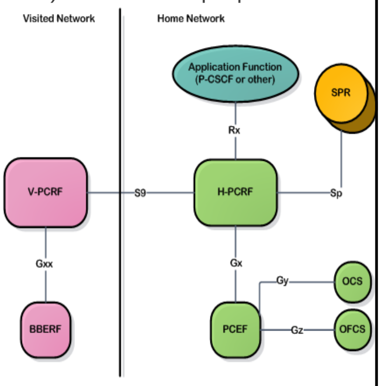
QoS and Charging in EPC (2)

- The Policy and Charging Enforcement Function (PCEF) is co-located in the PDN-Gw and does firewall control and QoS enforcement, credit management and reporting
- The Bearer Binding and Event Reporting Function (BBERF) is located in a peripheral gateway and does QoS control and event reporting
- Two modes of operation exist:
  - **PULL:** the BBERF and PCEF inform the PCRF upon bearer level establishment, modification or release
  - **PUSH:** the Application Function informs the PCRF upon new session establishment, modification or release

  The Bearer Binding and Session Binding mechanisms perform the adequate matching



PCC architecture with home routed roaming

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Agenda

- Motivation for Next Generation Mobile Networks (NGMNs)
- NGMN related Fora and Standards
- NGMN access network technologies
- EPS and EPC Overview
- NGMN Services: the Role of IMS over EPC – Voice and more
- Introducing the FOKUS OpenEPC NGMN toolkit
- Summary

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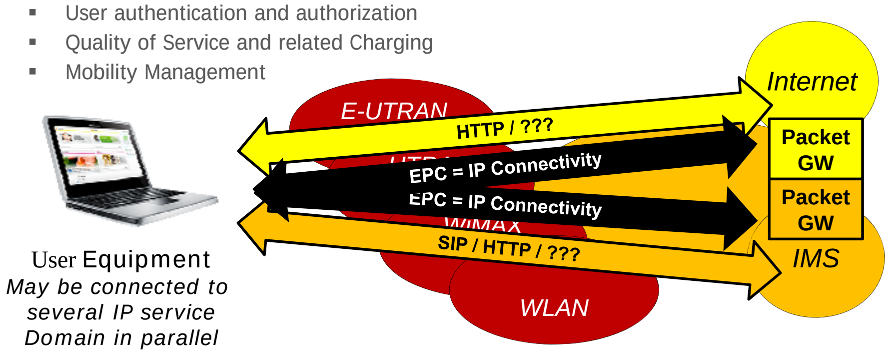
EPC Capabilities = Seamless IP Connectivity

- The EPC allows multiple access networks to be connected in a controlled way (secure, QoS, seamless) to either
  - the operator IP cloud (e.g. IMS or any intranet)
  - the internet or others
- Note that the EPC provides controlled IP connectivity, in regard to
  - User authentication and authorization
  - Quality of Service and related Charging
  - Mobility Management



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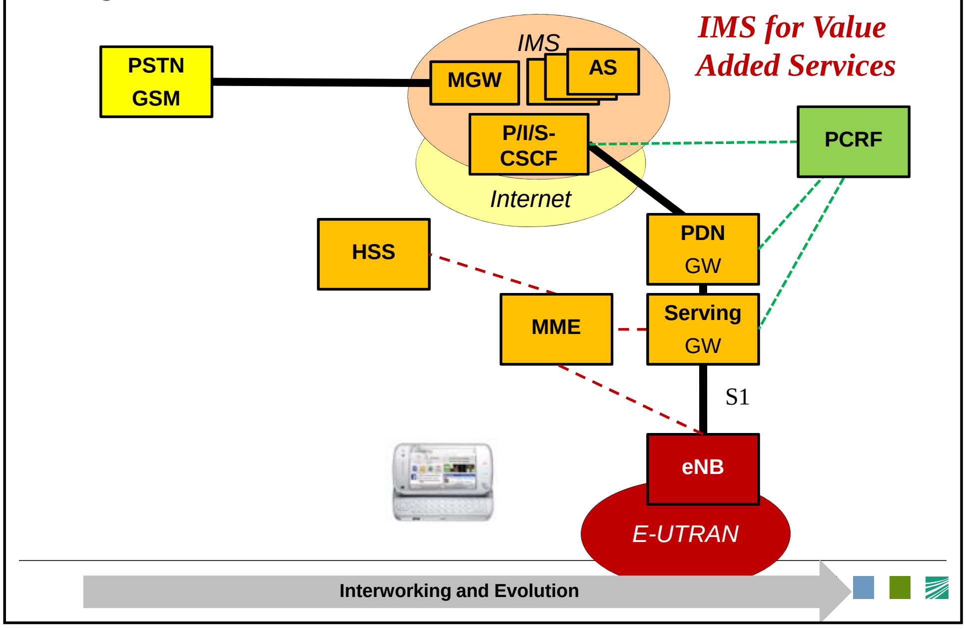
Long term View: IMS over LTE/EPC Architecture



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IMS Standards Evolution in regard to Access Network Evolution

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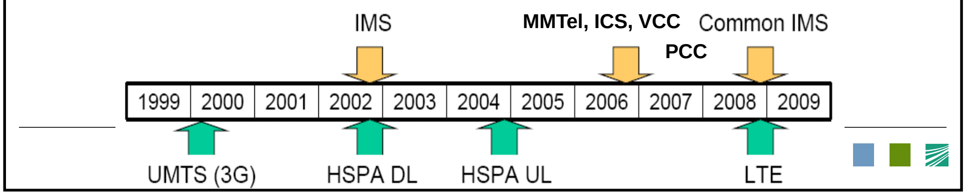

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IMS Standards

- 3GPP Release 7 provides major extensions for Voice Services and Multiple Accesss Network support:
  - Voice service enabled IMS (CSI, MMTel, Emergency, call performance improvements, VCC)
  - Support for IMS based emergency calls
  - Support for multi-service environment and mass-market reachability →IMS Communication Service
  - Policy & Charging Control (PCC)
  - Enabling fixed (e.g. DSL, Cable) access to IMS
  - Parlay-X / Webservices (SOA) enabling value add services (”northbound interface”)

IMS Standards (cont.)

- 3GPP Release 8 extends Session Mobility / Handover Capabilities
- Common IMS aligning TISPAN, 3GPP2 and PacketCable requirements into 3GPP
  - IMS Centralised Services (ICS) and session / service continuity (extension to and replacement of VCC), SRVCC
  - IMS NNI interconnect profile
  - ISC/iFC enhancements (increased flexibility)
  - Recovery Procedures
  - Local Breakout for IMS
  - IMS based Mobile TV

Common IMS

- 3GPP members, 3GPP2, WiMAXforum, ETSI TISPAN and CableLabs contribute to 3GPP common IMS specifications
  - Different requirements are supported in common implementation
- All IMS specifications are harmonized to 3GPP specifications
  - Common parts are defined in 3GPP specifications only
  - Core IMS entities (CSCFs, AS, UE IMS client,...) + agreed common functions
    - Other organisations either reference or re-use 3GPP specification as it stands
    - Any changes or additions in the Common IMS area are made in 3GPP
  - All 3GPP members can contribute on their favourite work items
  - Ongoing work initiated by 3GPP members, CableLabs, 3GPP2 and ETSI TISPAN
    - The scope and coverage of Common IMS have been agreed by the SDOs
- Common version of IMS specifications in Rel-8
  - Business or architecture specific additions to 3GPP Common IMS are possible outside the agreed Common IMS area

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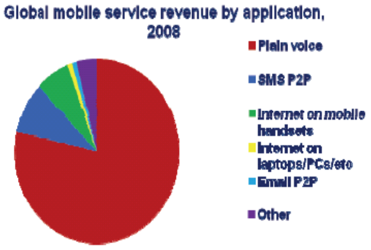
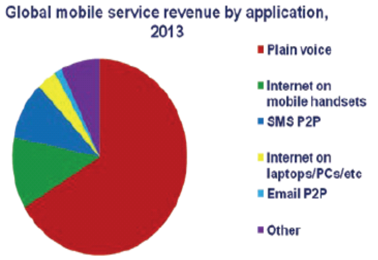
Forecast Predictable Revenue Sources

- Plain voice and SMS will still account for 70%+ of global service revenue in 2013
- New, successful revenue streams (e.g. mobile BB, mobile email) enjoy heavy support (subsidisation, marketing, sales), but only once revenue potential identified
- In the short-term, LTE business case will be driven more strongly by cost-reduction versus revenue-generation
- An operator mindset shift required to open up new business models





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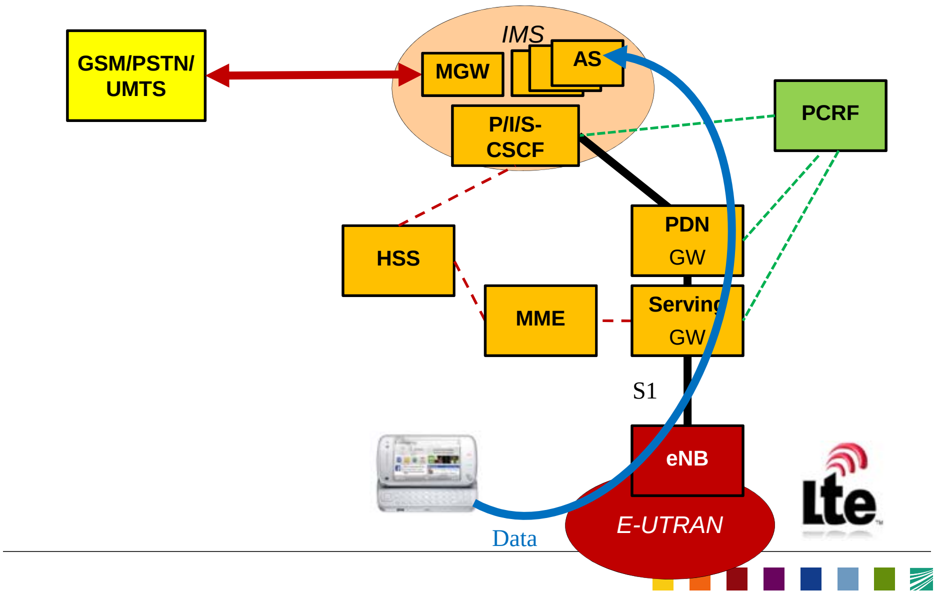
The Challenge: Voice over LTE

- LTE being packet only does not include a solution for how to provide voice calls over the new network
- Such a solution should include also handover to UTRAN/GERAN
- Several solutions have been proposed but no final agreement has been reached

Data in EPC Architecture



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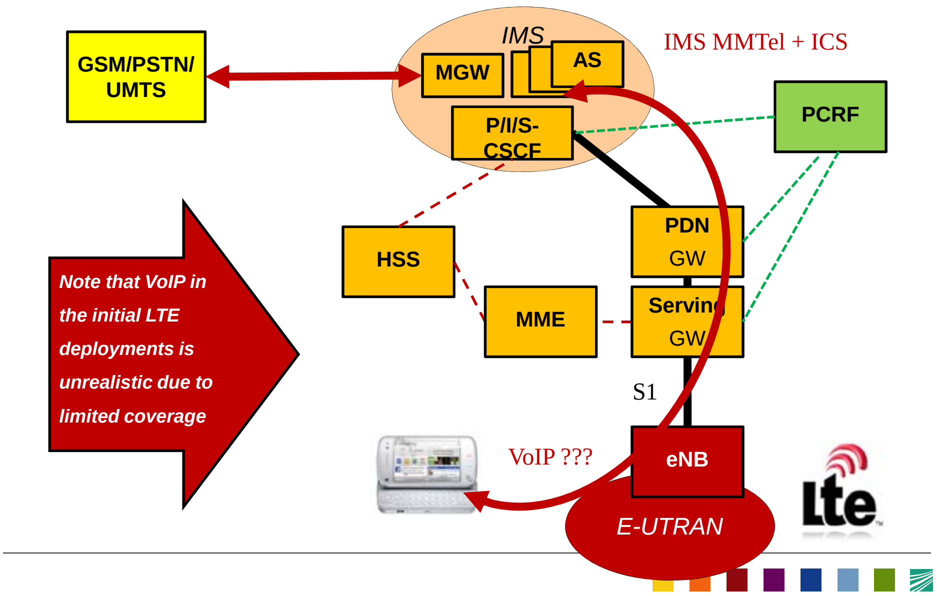
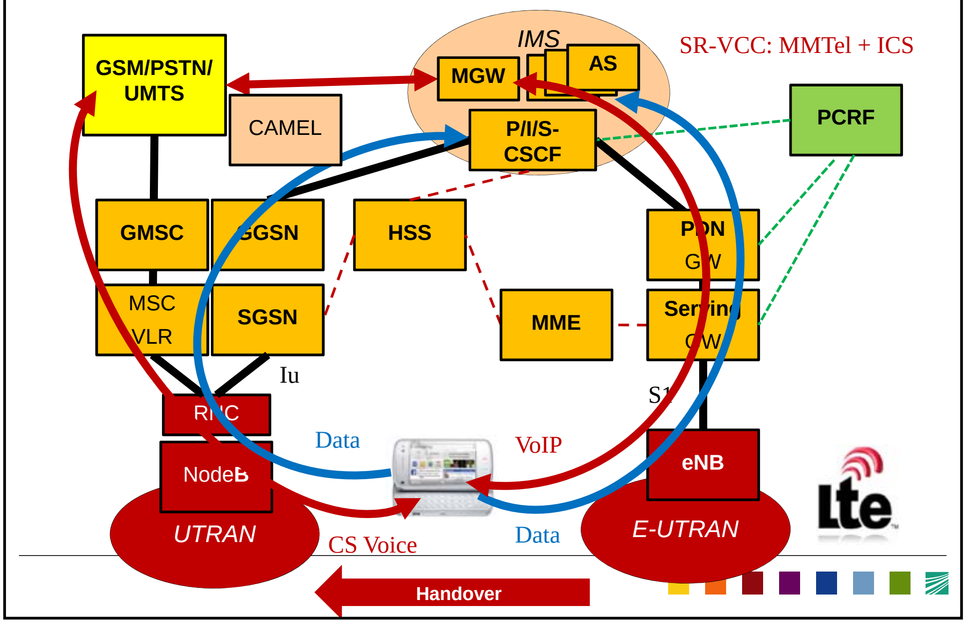
IMS VoIP in EPC Architecture



Handover from E-UTRAN to GERAN/UTRAN

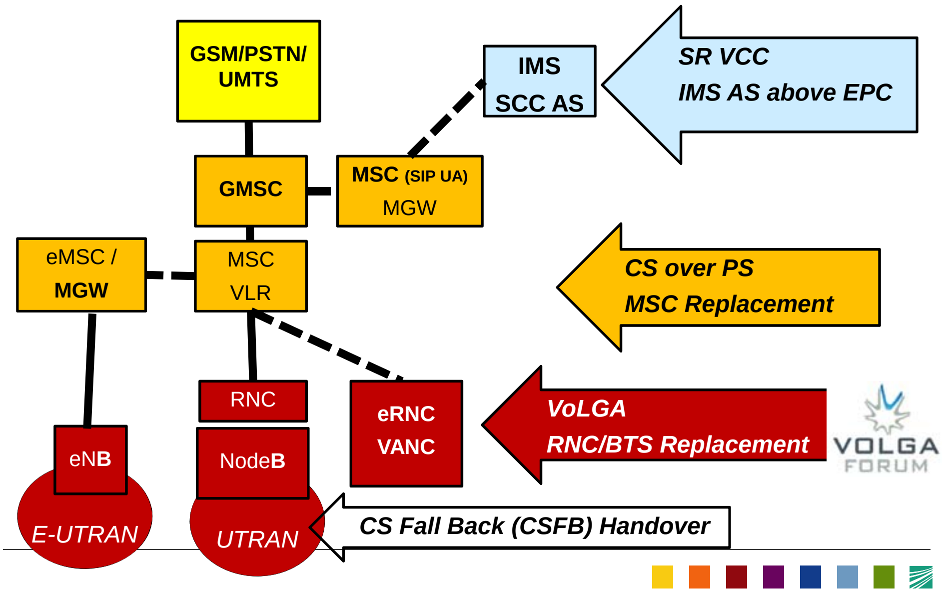


Voice in LTE Options

- LTE being packet only does not include a final solution for providing voice calls over the new network in the near future ;-(
- Several solutions have been proposed and are under discussion:
  - *Single Radio Voice Call Continuity (SR-VCC):* IMS ICS based call control and handover from LTE to 2G/3G via dedicated IMS AS (SCC AS)
    - *IMS Centralized Services (ICS):* IMS based solution evolved from older device centric Voice Call Continuity (VCC) and MMtel, MSC has to host IMS Client and MGw
    - *MMTel:* IMS based solution for providing PSTN supplementary services for VoIP plus multimedia session handling capabilities (RCS)
  - *Circuit Switched Fallback (CSFB):* all incoming/outgoing voice calls are immediately handed over from LTE to 2G/3G before call setup
  - *CS over EPS:* MCS replacement by special EPS AS (still a study point)
  - *Voice over LTE using Generic Access Network (VoLGA):* EPS behaves like an RNC or a BSC (CS over IP re-using UMA) → no MSC changes!

IMS

Voice in LTE Options (cont.)



Voice over LTE Comparison

Approach	3GPP	IMS	Additional Component		Modified Components	Main Advantage	Main Disadvantage
			Name	Function			
SR-VCC	X	X	VCC AS	Anchor sessions in the IMS domain	MME,MSC,UE	VCC is an existing method, which has been improved for Single Radio	Requires IMS and improvements in MSC and MME
ICS	X	X	SCC AS	Anchor and control sessions	MSC,UE	Handover to 2G, can be used by GSM mobiles as well, Supplementary services Compatible with SR-VCC	Requires IMS and complex AS
MMTel	X	X			UE	Only defines an interoperable way to handle speech sessions for IMS	IMS centric solution

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Voice over LTE Comparison II

Approach	3GPP	IMS	Additional Component		Modified Components	Main Advantage	Main Disadvantage
			Name	Function			
CSFB	X				MSC,MME,UE	No support for voice in E-UTRAN under the supposition that it coexists with GERAN/UTRAN	Additional delay, suboptimal option
CS over EPS	X		eMSC	MSC with new interface towards UE and MME AS behavior towards PCRF and PDN-Gw	UE	CS signaling encapsulated over IP towards new eMSC	Not yet completed. Not PS native solution.
VOLGA			VANC	BSC or RNC behavior (A or Iu mode) towards CS, AS behavior towards PS	UE	CS signaling encapsulated over IP towards VANC. Follows the structure of already existing GAN specifications of 3GPP	Not yet 3GPP solution. Not PS native solution
			HOSF	Handover target selection			

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Agenda

- Motivation for Next Generation Mobile Networks (NGMNs)
- NGMN related Fora and Standards
- NGMN access network technologies
- EPS and EPC Overview
- NGMN Services: the Role of IMS over EPC – Voice and more
- Introducing the FOKUS OpenEPC NGMN toolkit
- Summary

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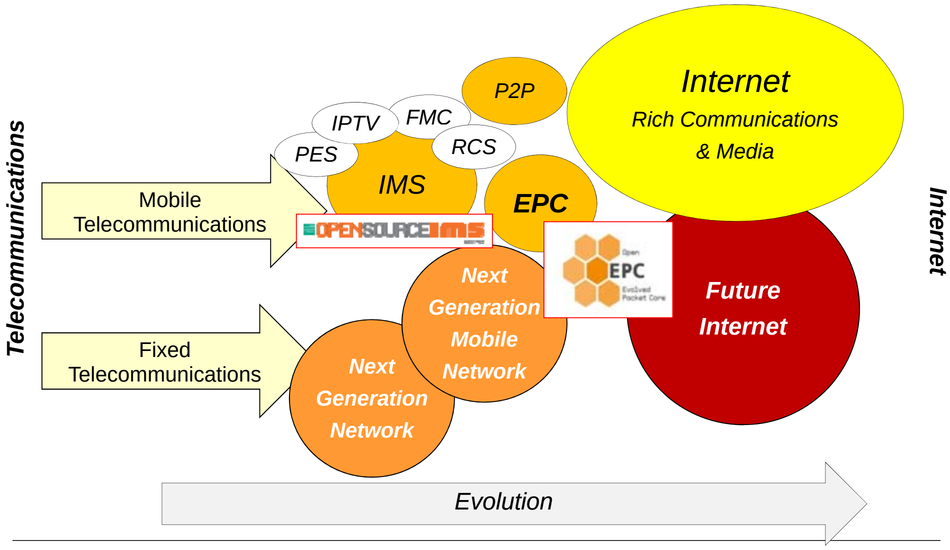
From Open IMS to Open EPC: an important step towards the FI



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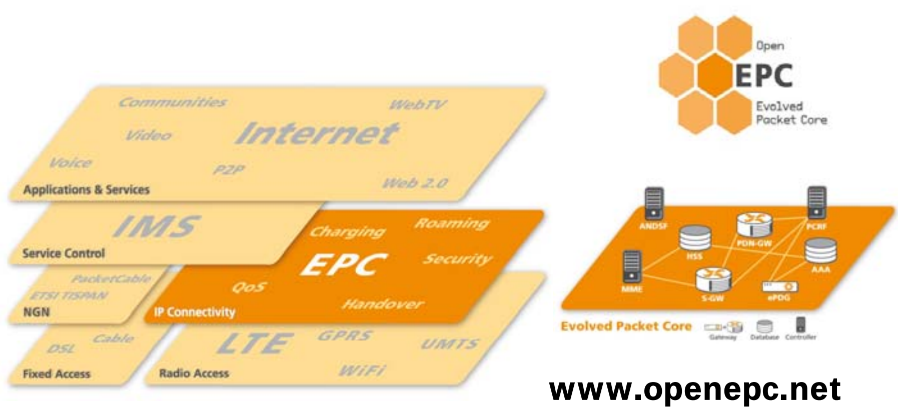
From the Open IMS Core to an Open EPC platform

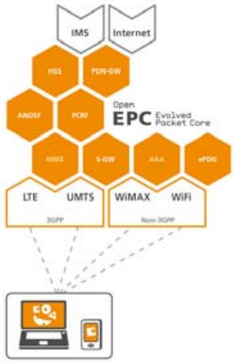


www.openepc.net

"Open IMS Core made the NGN world possible. OpenEPC will bring about the NGMN ecosystem"

What is the FOKUS OpenEPC platform

- In NGN/NGMN multi access network support (fixed, mobile, cable) and multi application domain support (OTT, P2P, IMS, etc.) will become key for multimedia service delivery
- Based on the Open IMS Core success, FOKUS is developing a NON-OPEN SOURCE EPC platform, enabling academia and industry to
  - integrate various network technologies and
  - integrate various application platforms
- into a single local testbed, lowering development costs
- This platform can be used to perform R&D in the fields of
  - QoS, Mobility, Security, Management
- Open EPC is conformant to 3GPP specifications (Rel 8)
  - High performant
  - Adaptable to different deployments
  - Extensible to specific research needs
  - Configurable



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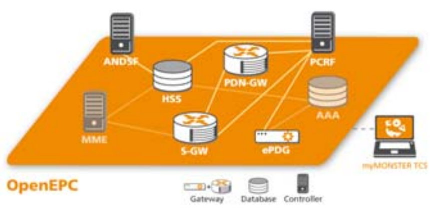
OpenEPC Components I

- The **Home Subscriber Server** (**HSS**): is the main subscriber information repository
- **Mobility Management Enabler** (**MME**): handles the Non-Access-Stratum (NAS) functions and coordinates mobility in LTE and other 3GPP access networks (UMTS, GPRS)
- **Serving Gateway** (**S-Gw**): is the anchor point in 3GPP access networks and includes access and QoS control functions
- **Packet Data Network Gateway** (**PDN-Gw**): is the main gateway of EPC performing anchoring for heterogeneous non-3GPP and 3GPP mobility and data forwarding control including QoS control
- **Policy and Charging Control** (**PCC**) architecture: performs QoS and charging control and encloses the Policy and Charging Rules Function (**PCRF**) and functionality integrated in gateways



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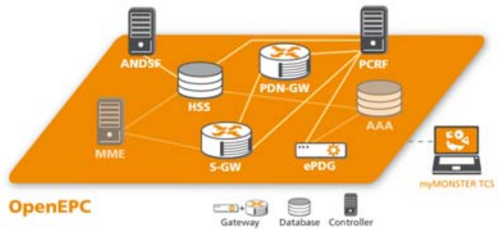
OpenEPC Components II

- **AAA** Server and Proxy: is the repository of subscribers profile needed to authenticate and secure non-3GPP accesses connections
- **evolved Packet Data Gateway** (**ePDG**): is the gateway towards the non-3GPP untrusted accesses (Wi-Fi access) which performs security, mobility and QoS control functionality.
- **Access Network Discovery and Selection Function** (**ANDSF**): provides information of access networks and operators preference to the User Equipment
- Other peripheral gateways (**ASN-Gw** & **HRPD-Gw**): interconnect the WiMAX access network and the High Rate Packet Data access network from 3GPP2 to EPC performing authentication, mobility and QoS control functions



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OpenEPC Technical Aspects

- OpenEPC is a software implementation of a set of standard EPC components which permits the cost efficient establishment of NGMN testbeds to prototype, measure, monitor, test, and perform research developments in the area of NGMNs.
- OpenEPC is both IPv4 and IPv6 compatible and its components have been developed in C under Linux for high performance.
- The specific components that are part of the current release 1 of OpenEPC are:
  - a S-Gw and ePDG (including a BBERF from PCC Release 8), PDN-Gw (including a PCEF from PCC Release 8), PCRF, HSS, ANDSF, and a corresponding EPCclient.
- All these components have been designed to be:
  - Configurable – allowing easy modification of the behavior of components and the inclusion of optional features.
  - Customizable and extensible – permitting the set-up of different environments and adapting to new requirements that may appear within standardization process
  - Reliable – based on the know-how gained in previous component development like the Open IMS Core project
  - Conformant to standards - can be used for testing other commercial components as well

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OpenEPC for Research and Development

- OpenEPC enables a quick start on the heart of emerging NGMNs, namely the Evolved Packet Core architecture, because of its:
  - **Standards conformance:** OpenEPC has been done with the standards in mind; being an independent organization and having commercial deployment out of scope constitutes a great advantage
  - **Configurability:** OpenEPC can be configured to match your needs for testing only some components or use cases
  - **Extensibility:** adding new functionality whether new mobility schemes or QoS protocols or other functionality added to the components is as easy as it gets with the modular, standard based OpenEPC architecture
- Open EPC aims to provide its users with a basic understanding and practical hands on experiences with EPC, as well as conformance testing. With OpenEPC it is possible to develop functional extensions of individual and/or multiple EPC components and new NGNM showcases.
- In addition, OpenEPC supports research and development of challenging aspects of upcoming NGMN infrastructures and services, like the integration of new fixed and wireless access technologies, new approaches to mobility and QoS, or optimizations of the architecture, design of new seamless wireless applications, and the investigation of new business models in the NGMN world.

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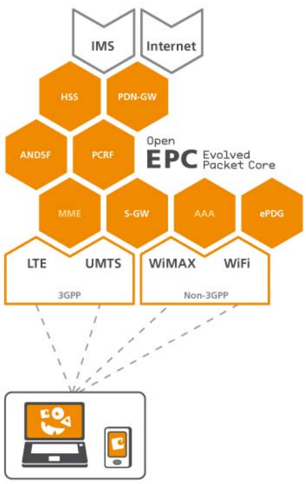
OpenEPC Use Cases

- **Operators** are using OpenEPC to prepare for the upcoming all-IP NGN and NGMN world and have an open and vendor independent test-bed infrastructure.
- **Manufacturers** of individual EPC components are using OpenEPC to test their products in concert with a standards based NGMN environment.
- **Manufacturers** of full EPC platforms are using OpenEPC for practical research on new concepts and protocols in an easier to maintain platform.
- **Application developers** are using OpenEPC to certify that their applications work in NGMNs and take advantage of the functional capabilities offered by EPC to the applications domains.
- **Research institutions and universities** are using OpenEPC for practical NGMN research, including usage of OpenEPC as black box for applications prototyping, or extending individual or multiple EPC components and/or developing new EPC components and protocols to provide new capabilities for integrating new networks or enabling new applications.



OpenEPC Releases and Roadmap

- OpenEPC is available under license either as a complete testbed or as individual components for research and development purposes. OpenEPC integrates with various access networks and different services platforms to provide a complete NGMN solution.
- The planned releases of OpenEPC are as follows:
  - **November 2009:** First demonstration of OpenEPC and availability for partners at 5th FOKUS IMS Workshop
  - **Spring 2010:** First Release of OpenEPC: will include more mobility options, roaming configurations support, and support for security procedures
  - **End of Summer 2010:** Second Release and full OpenEPC
- We are able to provide on-site coaching, local deployment and integration activities, support, as well as extensions to OpenEPC components to meet specific customer requirements.
- In the same way Fraunhofer FOKUS and TU Berlin are interested in setting up joint R&D projects based on the OpenEPC platform.

And we showed the prototype live ... so stay tuned for more!

Agenda

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Summary

- There is a lot of hype around LTE and its commercial deployment
- LTE roll out will require interworking with other existing and emerging wireless access network technologies
- The 3GPP EPC is the new mobile core network suporting seamless mobility, QoS and charging across multiple IP access networks, incl. 3GPP and non-3GPP access
- EPC shares a lot of concepts with IMS, e.g. overlay architecture concept, HSS, PCC, etc.
- EPC maintains seamless IP connectivity and thus supports multiple application domains, including IMS and internet platforms
- LTE provides IP services only, thus voice services, representing still the operator cash cow, are currently a potential show stopper
- IMS provides a lot of needed capabilities in the voice domain and value added multimedia services domain (e.g. RCS, IPTV, etc)
- Early prototyping of NGMN environments will be crucial to gain practical experiences
- OpenEPC toolkit from FOKUS has been designed for this purpose

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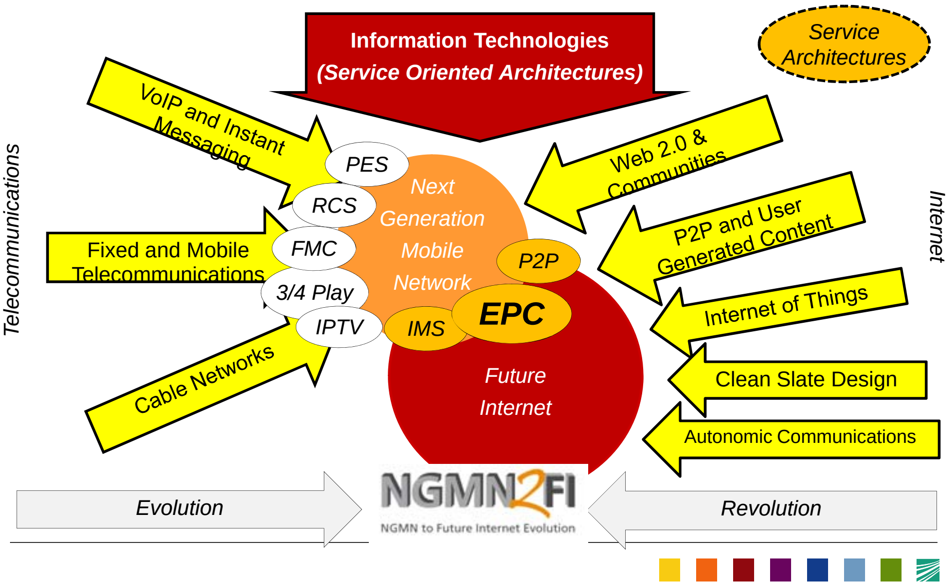
Current R&D Focus: NGMN Evolution towards Future Internet



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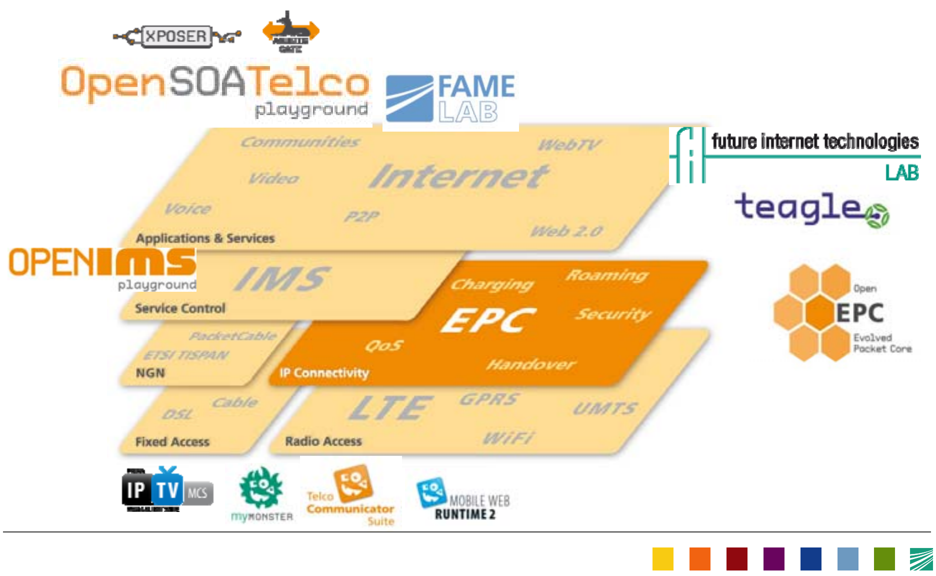
NGN/NGMN and FI Research, Tools and Testbeds at FOKUS



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Questions ???

Open
EPC
Evolved
Packet Core

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Do you want to see more? Look at our Event Minutes!

Fraunhofer FOKUS | www.fokus.fraunhofer.de/go/ims-event

5th FOKUS IMS Workshop

Next Generation Networks in Face of the Future Internet – Towards Rich Communications and Interactive Media

Berlin, November 11–12, 2009

More than 200 people from 29 nations attended the event

www.fokus.fraunhofer.de/go/ims-event/

Featuring:

- *Four tutorials and interactive Workshops on Day 1 related to Rich Communications, Rich Media, Future Internet and Open NGN / IMS Testbeds*
- *Social evening event for Networking*
- *Full day NGN2FI Conference on Day 2*
- *Many Operator Talks and Vendor Exposition*
- *FOKUS Playground Visits and Technology Demonstrations*

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Please mark your Calendar

TridentCom 2010

The 6th International Conference on Testbeds and Research Infrastructures for the Development of Networks & Communities

18-20 May 2010, Berlin, Germany

Sponsored by:	Technically co-sponsored and supported by:
ICST	CELTIC, CREATE-NET, FEDERICA, FIREWORKS, G-Lab, geni, OneLab, Panlab, VITAL++, WISEBED

Important Dates

Papers due:	30 October 2009
Demo and workshop proposals due:	27 November 2009
Notification of paper acceptance:	15 January 2010
Submission of camera-ready papers:	15 February 2010

More details can be found at: www.tridentcom.org

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More information about OpenEPC can be found at

- www.openepc.net

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