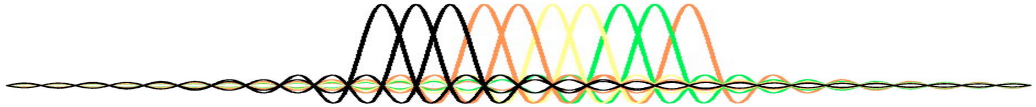


EHB 453, Introduction to Mobile Communications

Lecture 9: 4.5G LTE

Prof. Mustafa Ergen

Abstract

- The 3GPP Long Term Evolution (LTE) represents a major advance in cellular technology. LTE is designed to meet carrier needs for high-speed data and media transport as well as high-capacity voice support well into the next decade. LTE is well positioned to meet the requirements of next-generation mobile networks. It will enable operators to offer high performance, mass-market mobile broadband services, through a combination of high bit-rates and system throughput – in both the uplink and downlink – with low latency.

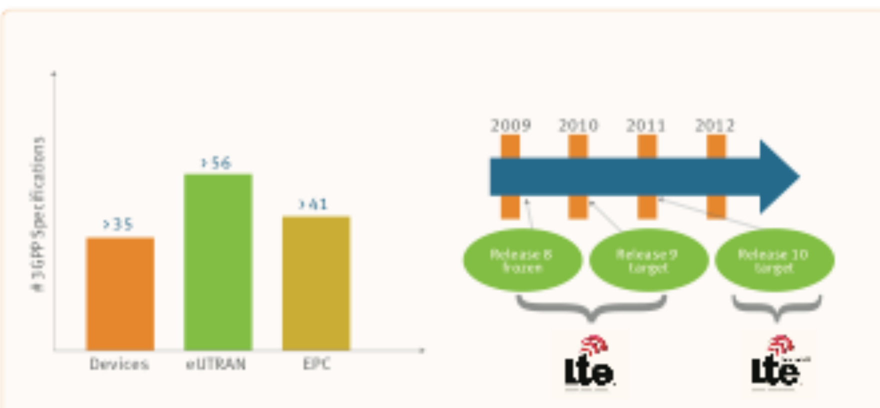
- LTE infrastructure is designed to be as simple as possible to deploy and operate, through flexible technology that can be deployed in a wide variety of frequency bands. LTE offers scalable bandwidths, from less than 5MHz up to 20MHz, together with support for both FDD paired and TDD unpaired spectrum. The LTE–SAE architecture reduces the number of nodes, supports flexible network configurations and provides a high level of service availability. Furthermore, LTE–SAE will interoperate with GSM, WCDMA/HSPA, TD-SCDMA and CDMA.

Overview

- LTE by Numbers
- Introduction
- 3GPP Evolution
- Motivation
- LTE performance requirements
- Key Features of LTE
- LTE Network Architecture
- System Architecture Evolution (SAE)
- Evolved Packet Core (EPC)
- E-UTRAN Architecture
- Physical layer
- LTE Frame Structure
- Layer 2
- OFDM
- SC-FDMA
- Multiple Antenna Techniques
- Services
- Conclusions
- LTE vs WiMAX
- References

LTE SPECIFICATIONS

- DRIVEN BY 3GPP- NUMBER OF SPECIFICATIONS FOR LTE IS OVER 130
  - 35 FOR DEVICES
  - 56 FOR ENODEB
  - 41 ON EPC

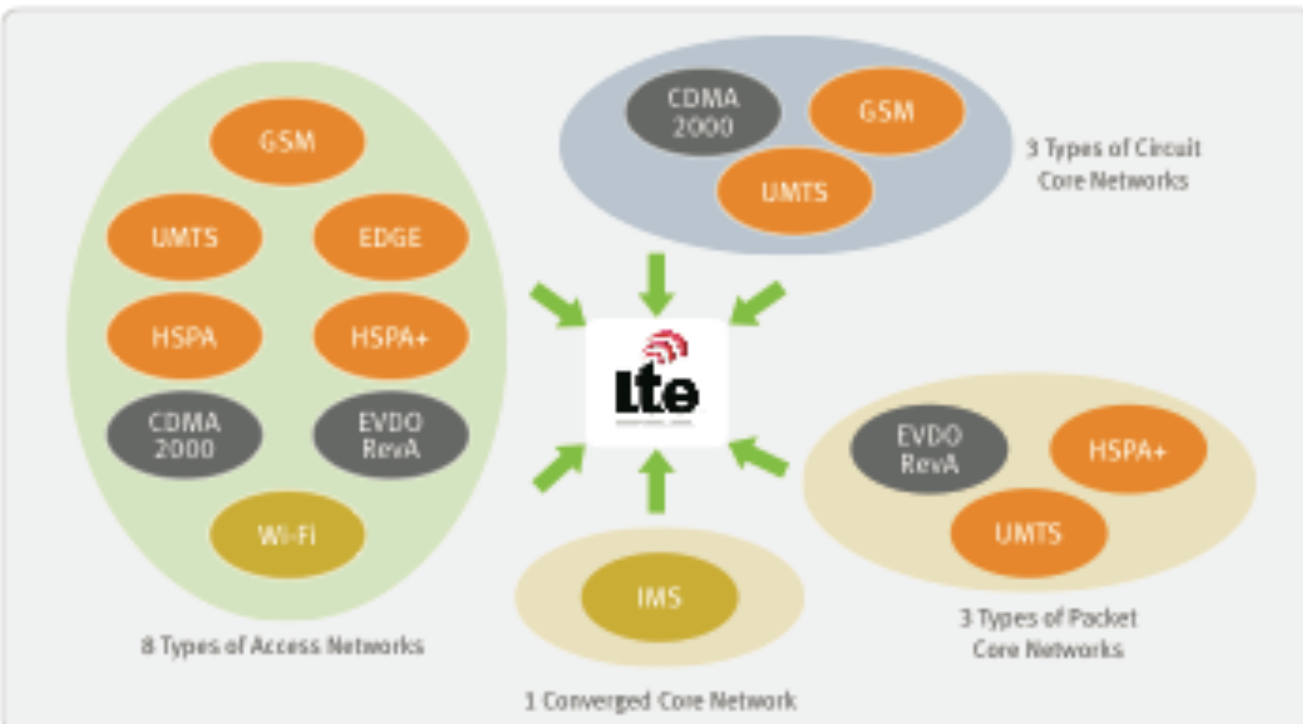


ABIresearch January 2009

"More than 18 operators globally have announced LTE deployment plans, with at least 12 wireless operators committed to deploying LTE networks and offering LTE-based services to their subscribers in 2010"

LTE INTEROPERABILITY

- Unlike previous versions of technology which needed to interoperate with only its predecessor technology, LTE needs to coexist with at least 15 networks as shown below. The combinations of devices, network equipment and network interfaces that can exist in LTE deployments increase the complexity of both IOT and end-to-end functionality testing. This is further exacerbated by the lack of availability of products and devices to test these various network elements.
- There will be at least 15 types of networks LTE will need to interoperate with



LTE voice and SMS

- A big concern with LTE is its lack of support for circuit switched applications such as voice and SMS. These services account for 85% of the services revenue currently, and according to Heavy Reading, they are expected to still account for around 77% of the revenue by the time LTE gains mass adoption.
- This issue had previously received limited attention as initial LTE deployments are expected to be data-only, based on USB dongles and data cards, with voice services planned for much later – by which time IMS networks should be ready and deployed.
- However, as operators near LTE deployment, it is quite clear that these networks will need to co-exist with legacy 2G/3G networks for a few years and, thus, voice and SMS support is needed for a viable business case.
- Additionally, while voice services over LTE may still be a few years out, SMS support is needed at the initial deployment stage, as it has been traditionally used for a lot of network-related services such as subscriber management and provisioning.

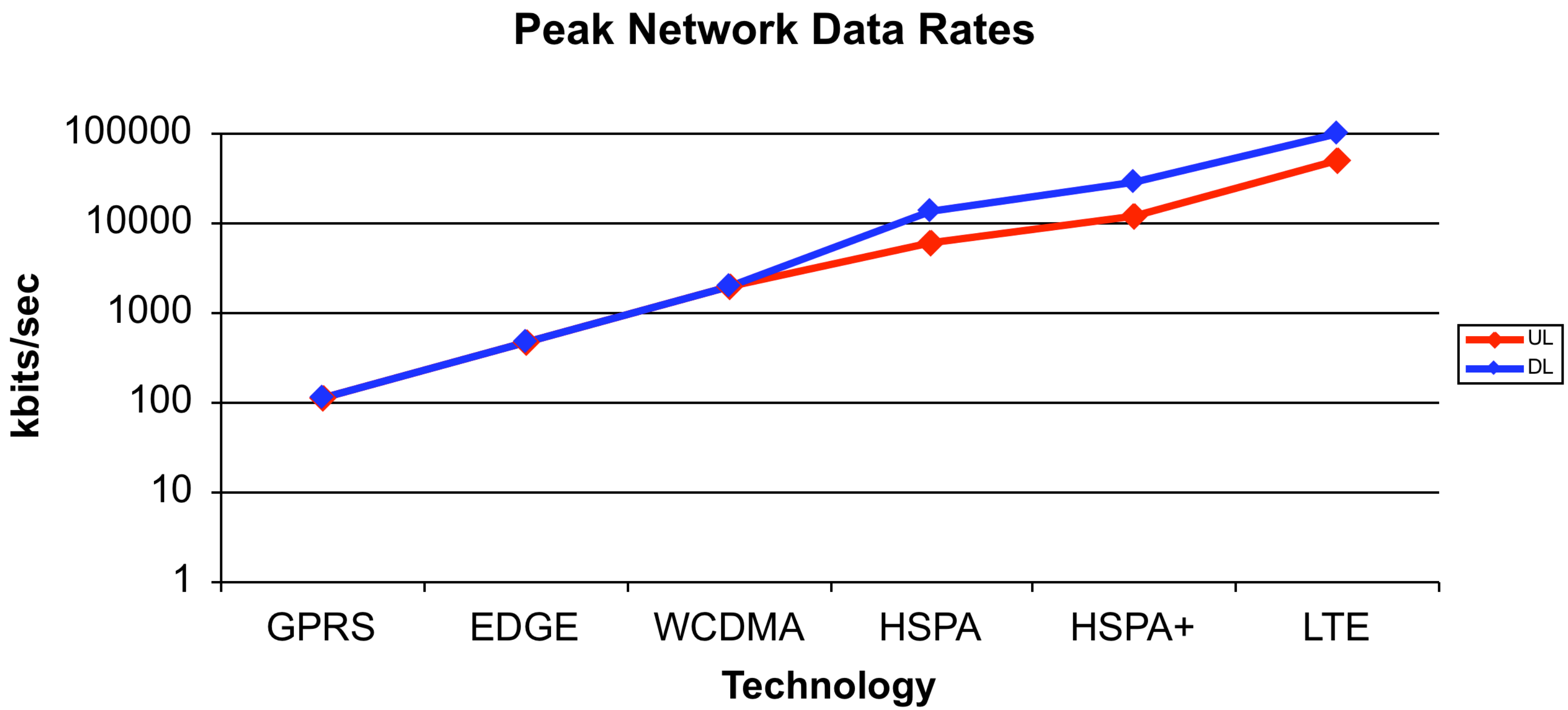
LTE Numbers

The "Numbers"	Implications
2010	LTE systems must be developed to at least "field trial ready" status • Significant interoperability testing must be completed Aggressive development schedules must be committed with risks mitigated
$1 billion	Given their significance, LTE investments must be timed closely to carrier procurement cycles • Overall LTE development costs must be reduced via 3rd party software frameworks and elastic NPI services like testing • Internal resources will need to be freed up from other engineering activities, typically from sustaining projects
130	Modular 3rd party software components can help mitigate continued LTE specification creation and evolution • Significant interoperability testing complexity must be overcome • Regular 3GPP engagement is required
15+	Substantial IOT must be planned, performed and documented • Deep understanding of pre-4G networks is required • Partners with advanced tools, highly automated testing services, and detailed processes and documentation must be leveraged
85%	Identify near term solutions for critical services like Voice and SMS • Constant engagement with bodies like IMS forum and VOLGA forum is required • Incorporate a highly modular and flexible architecture to address future specifications
2 Billion	With carriers rolling out LTE in 2010, initial products must be commercially available in 12 months or less • Carefully balance R&D resources between existing products and LTE • Substantial IOT must be planned, performed and documented

3G Evolution

- Radio Side (LTE – Long Term Evolution)
  - Improvements in spectral efficiency, user throughput, latency
  - Simplification of the radio network
  - Efficient support of packet based services: MBMS, IMS, etc.
- Network Side (SAE – System Architecture Evolution)
  - Improvement in latency, capacity, throughput
  - Simplification of the core network
  - Optimization for IP traffic and services
  - Simplified support and handover to non-3GPP access technologies

Evolution of 3GPP Radio Rates



LTE (Long Term Evolution)

- LTE focus is on:
  - enhancement of the Universal Terrestrial Radio Access (UTRA)
  - optimisation of the UTRAN architecture
- With HSPA (downlink and uplink), UTRA will remain highly competitive for several years
- LTE project aims to ensure the continued competitiveness of the 3GPP technologies for the future

LTE Requirements (1)

- Reduced cost per bit
  - Improve spectrum efficiency (e.g. 2-4 x Rel6)
  - Reduce cost of backhaul (transmission in UTRAN)
- Increased service provisioning – more services at lower cost with better user experience
- Focus on delivery of services utilising ”IP”
- Reduce setup time and round trip time
- Increase the support of QoS for the various types of services (e.g. Voice over IP)
- Increase “cell edge bit rate” whilst maintaining same site locations as deployed today
- Increase peak bit rate (e.g. above 100Mbps DL and above 50Mbps UL)
- Enhance the bit rate for MBMS (e.g. 1-3 Mbps)
- Allow for reasonable terminal power consumption

LTE Requirements (2)

- Flexibility of use of existing and new frequency bands
- Allow to deploy in wider and smaller bandwidths than 5 MHz (e.g. ranging from 1.25 to 20MHz)
- Allow variable duplex technology within bands as well as between bands
- Non-contiguous spectrum allocations to one UE should not be precluded

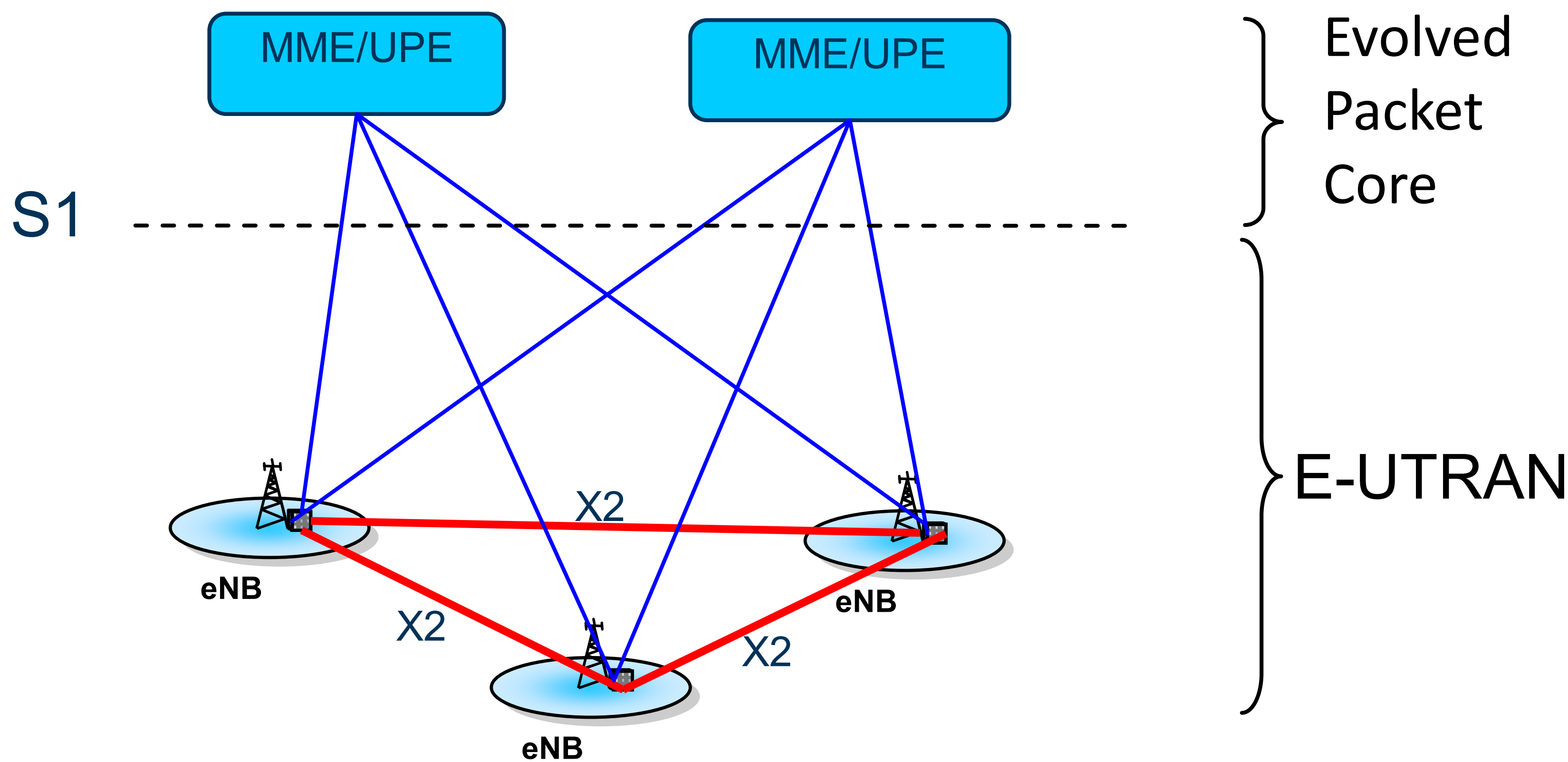
LTE Requirements (3)

- Architecture and Mobility
  - Need to consider UTRAN Evolution and UTRA Evolution at the same time aiming at simplifying the current architecture
  - Shall provide open interfaces to support Multi-vendor deployments
  - Consider robustness – no single point of failure
  - Support multi-RAT with resources controlled from the network
  - Support of seamless mobility to legacy systems as well as to other emerging systems including inter RAT Handovers and Service based RAT Selection
  - Maintain appropriate level of security

LTE Key agreements (1)

- 2 main issues have been investigated:
  - The physical layer
  - The access network internal architecture
- Physical layer
  - Downlink based on OFDMA
    - OFDMA offers improved spectral efficiency, capacity etc
  - Uplink based on SC-FDMA
    - SC-FDMA is technically similar to OFDMA but is better suited for uplink from hand-held devices
    - (battery power considerations)
  - For both FDD and TDD modes
    (User Equipment to support both)
    - With Similar framing + an option for TD SCDMA framing also
- Access Network consideration
  - For the access network it was agreed to get rid of the RNC which minimized the number of nodes

LTE Architecture



MME/UPE = Mobility Management Entity/User Plane Entity
eNB = eNodeB

LTE Key agreements (2)

- On the UTRAN Architecture the following working assumptions were agreed in TSG RAN:
  - RRC Terminates in the eNode B
  - Outer ARQ terminates also in the eNode B
  - Currently Ciphering and integrity for signaling is inside the eNode B while Ciphering for the User plane is in the AGW

LTE Key agreements (3)

- Requirements satisfaction
  - The LTE concept has the potential to fulfil both the system capacity and user throughput targets
  - Evaluated uplink peak data rate is a bit smaller than the requirements, however, it is expected that the peak data rate can be increased by some optimisations, e.g. higher TTI values and/or by reducing the amount of control signalling information.
  - It was confirmed that the requirements of C-plane and U-plane latency can be satisfied.
  - Fulfilments without any issues are identified for requirements on deployment scenarios, spectrum flexibility, interworking, mobility, E-UTRAN architecture and RRM.

LTE Key agreements (4)

- Regarding system and device cost and complexity work needs to continue in the future. As evolved UTRA and UTRAN system will provide significantly higher data rates than Release 6 WCDMA and, as a consequence hereof, the physical layer complexity will increase accordingly compared to lower-rate systems. This complexity is not seen as evolved UTRA and UTRAN specific, but is similar to the complexity experienced in any high data rate system.
- According to these evaluation results, it can be concluded that system concepts captured in this TR are feasible for evolved UTRA and UTRAN.
- For Broadcast/Multicast services it is assume that network synchronization will improve greatly the performance

SAE (System Architecture Evolution)

- To ensure competitiveness of 3GPP systems for the next 10 years and beyond
- Optimization of the network for IP traffic and its expected growth
- Performance improvements
  - reduced latency,
  - higher user data rates,
  - improved system capacity and coverage, and reduced overall cost for the operator.
  - Potential network and traffic cost reduction
- Flexible accommodation and deployment of existing and new access technologies with mobility by a common IP-based network

3GPP SAE – status

- Large number of active companies (30+)
- Reasonable progress on 3GPP parts (including LTE support)
- As of October 2006, SA has given a directive to SA2 to ensure that LTE 3GPP access aspects can meet the time line required by 3GPP RAN
- Some Key areas being addressed – agreements remaining
  - MME-UPE split or merged
  - 3GPP anchor-SAE anchor split or merged
  - Interconnection/mobility for non-3GPP access technologies
  - Roaming aspects
  - PCC architecture & QoS model
  - Simultaneous access to multiple data networks
- Timeline
  - Report to be ready for SA plenary approval Dec 2006
  - Majority of Specifications to be ready end 2007/early 2008

Introduction

- LTE is the latest standard in the mobile network technology tree that previously realized the GSM/EDGE and UMTS/HSxPA network technologies that now account for over 85% of all mobile subscribers. LTE will ensure 3GPP's competitive edge over other cellular technologies.

- Goals include
- Significantly increase peak data rates, scaled linearly according to spectrum allocation
- improving spectral efficiency
- lowering costs
- improving services
- making use of new spectrum opportunities
- Improved quality of service
- better integration with other open standards

3GPP Evolution

- Release 99 (2000): UMTS/WCDMA
- Release 5 (2002) : HSDPA
- Release 6 (2005) : HSUPA, MBMS(Multimedia Broadcast/Multicast Services)
- Release 7 (2007) : DL MIMO, IMS (IP Multimedia Subsystem), optimized real-time services (VoIP, gaming, push-to-talk).
- Release 8(2009?) :LTE (Long Term Evolution)

- Long Term Evolution (LTE)
- 3GPP work on the Evolution of the 3G Mobile System started in November 2004.
- Currently, standardization in progress in the form of Rel-8.
- Specifications scheduled to be finalized by the end of mid 2008.
- Target deployment in 2010.

Motivation

- Need for higher data rates and greater spectral efficiency
  - Can be achieved with HSDPA/HSUPA
  - and/or new air interface defined by 3GPP LTE
- Need for Packet Switched optimized system
  - Evolve UMTS towards packet only system
- Need for high quality of services
  - Use of licensed frequencies to guarantee quality of services
  - Always-on experience (reduce control plane latency significantly)
  - Reduce round trip delay
- Need for cheaper infrastructure

LTE performance requirements

- Data Rate:
- Instantaneous downlink peak data rate of 100Mbit/s in a 20MHz downlink spectrum (i.e. 5 bit/s/Hz)
- Instantaneous uplink peak data rate of 50Mbit/s in a 20MHz uplink spectrum (i.e. 2.5 bit/s/Hz)
-
- Cell range
- 5 km - optimal size
- 30km sizes with reasonable performance
- up to 100 km cell sizes supported with acceptable performance

- Cell capacity
- up to 200 active users per cell(5 MHz) (i.e., 200 active data clients)

LTE performance requirements

- Mobility
- Optimized for low mobility(0-15km/h) but supports high speed

- Latency
- user plane < 5ms
- control plane < 50 ms

- Improved spectrum efficiency
- Cost-effective migration from Release 6 Universal Terrestrial Radio Access (UTRA) radio interface and architecture
- Improved broadcasting
- IP-optimized
- Scalable bandwidth of 20MHz, 15MHz, 10MHz, 5MHz and <5MHz
- Co-existence with legacy standards (users can transparently start a call or transfer of data in an area using an LTE standard, and, when there is no coverage, continue the operation without any action on their part using GSM/GPRS or W-CDMA-based UMTS)

Key Features of LTE

- Multiple access scheme
- Downlink: OFDMA
- Uplink: Single Carrier FDMA (SC-FDMA)

- Adaptive modulation and coding
- DL modulations: QPSK, 16QAM, and 64QAM
- UL modulations: QPSK and 16QAM
- Rel-6 Turbo code: Coding rate of 1/3, two 8-state constituent encoders, and a contention- free internal interleaver.

- Bandwidth scalability for efficient operation in differently sized allocated spectrum bands

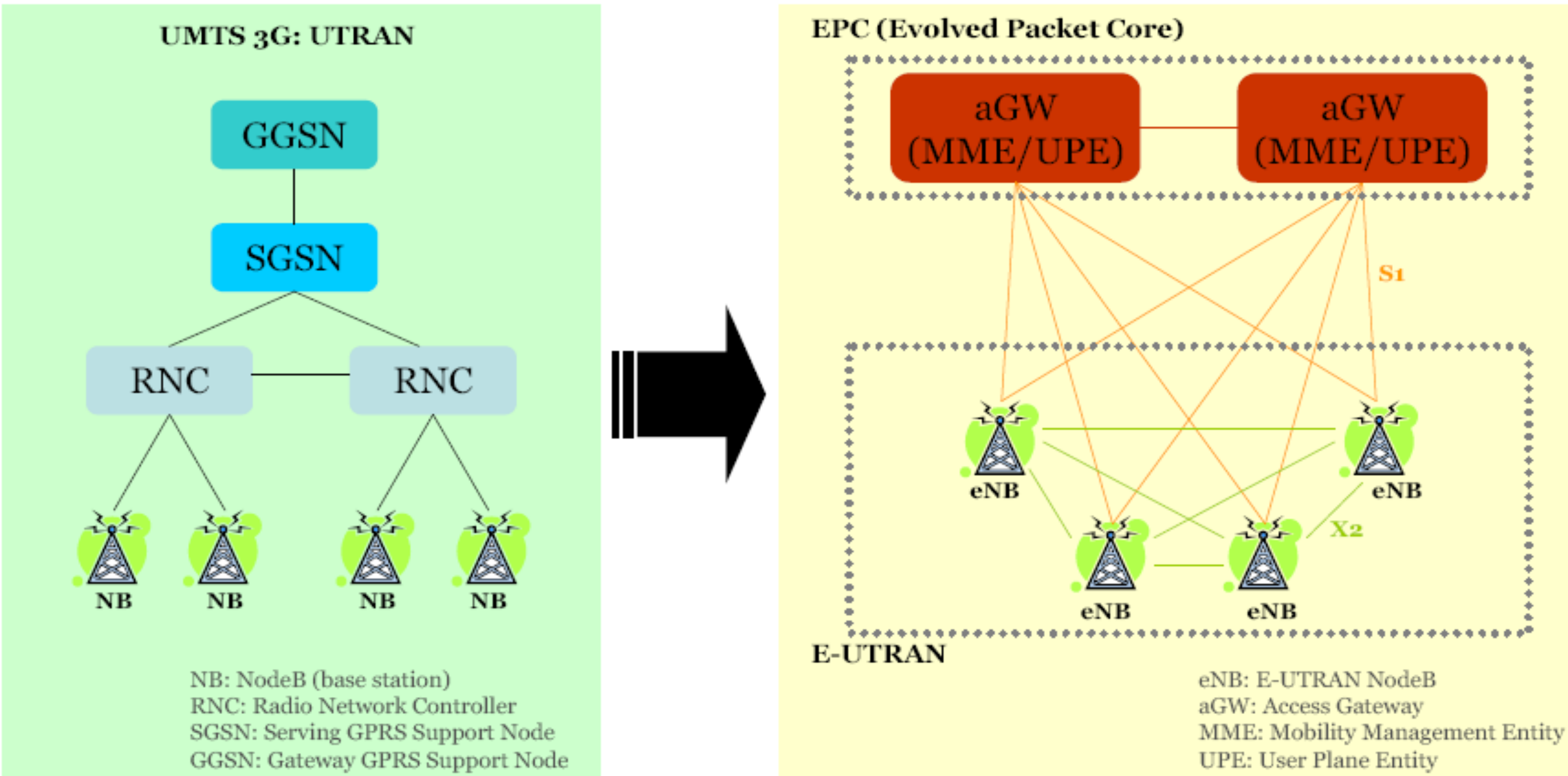
- Possible support for operating as single frequency network (SFN) to support MBMS

Key Features of LTE(contd.)

- Multiple Antenna (MIMO) technology for enhanced data rate and performance.
- ARQ within RLC sublayer and Hybrid ARQ within MAC sublayer.
- Power control and link adaptation
- Implicit support for interference coordination
- Support for both FDD and TDD
- Channel dependent scheduling & link adaptation for enhanced performance.
- Reduced radio-access-network nodes to reduce cost,protocol-related processing time & call set-up time

[Source:Technical Overview of 3GPP Long Term Evolution (LTE) Hyung G. Myung]

LTE Network Architecture



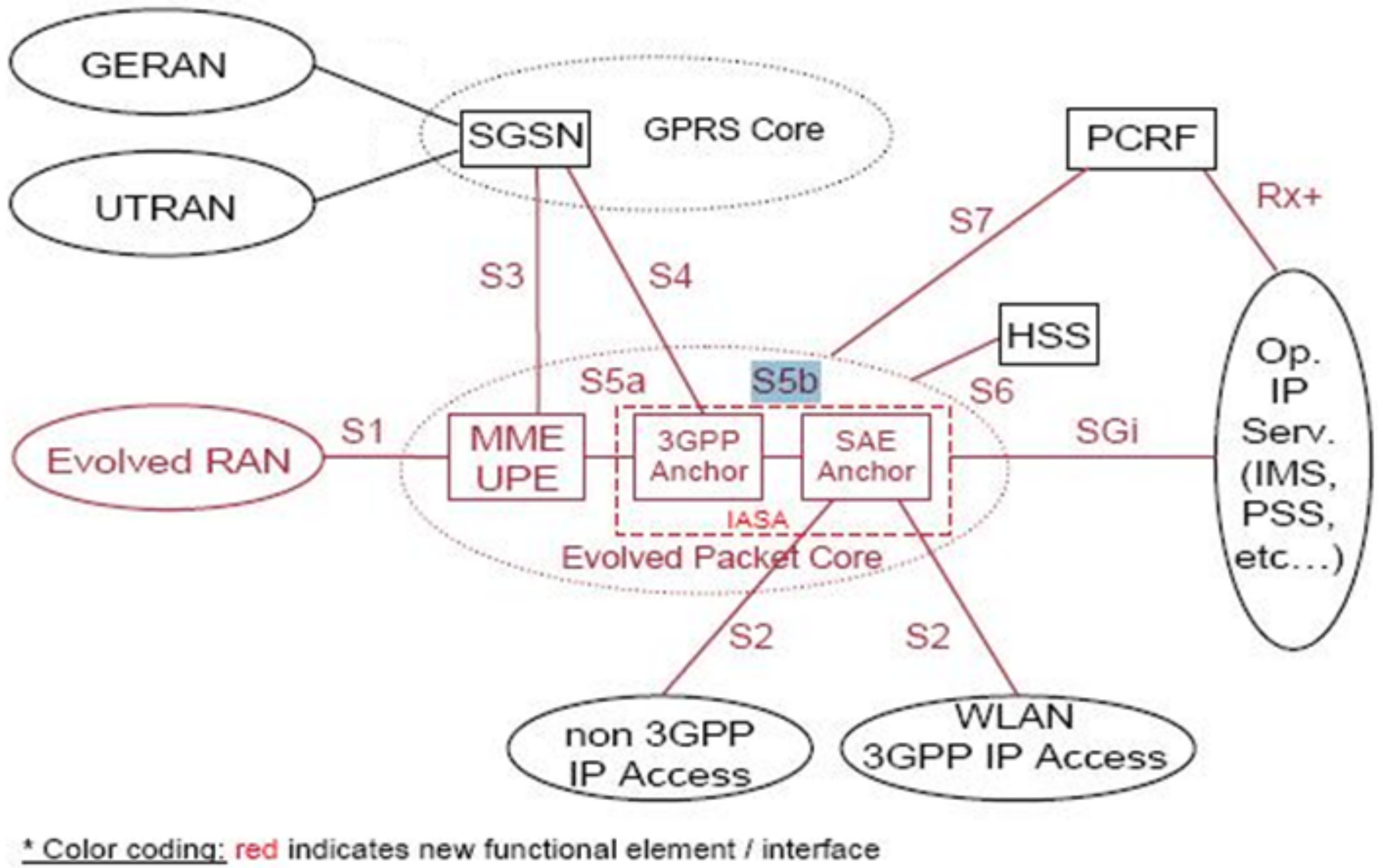
[Source:Technical Overview of 3GPP Long Term Evolution (LTE) Hyung G. Myung
http://hgmyung.googlepages.com/3gppLTE.pdf

System Architecture Evolution(SAE)

- System Architecture Evolution (aka SAE) is the core network architecture of 3GPP's future LTE wireless communication standard.
- SAE is the evolution of the GPRS Core Network, with some differences.

- The main principles and objectives of the LTE-SAE architecture include :
- A common anchor point and gateway (GW) node for all access technologies
- IP-based protocols on all interfaces;
- Simplified network architecture
- All IP network
- All services are via Packet Switched domain
- Support mobility between heterogeneous RATs, including legacy systems as GPRS, but also non-3GPP systems (say WiMAX)
- Support for multiple, heterogeneous RATs, including legacy systems as GPRS, but also non-3GPP systems (say WiMAX)

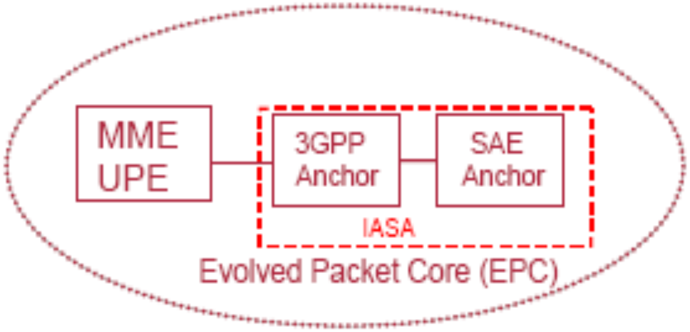
SAE



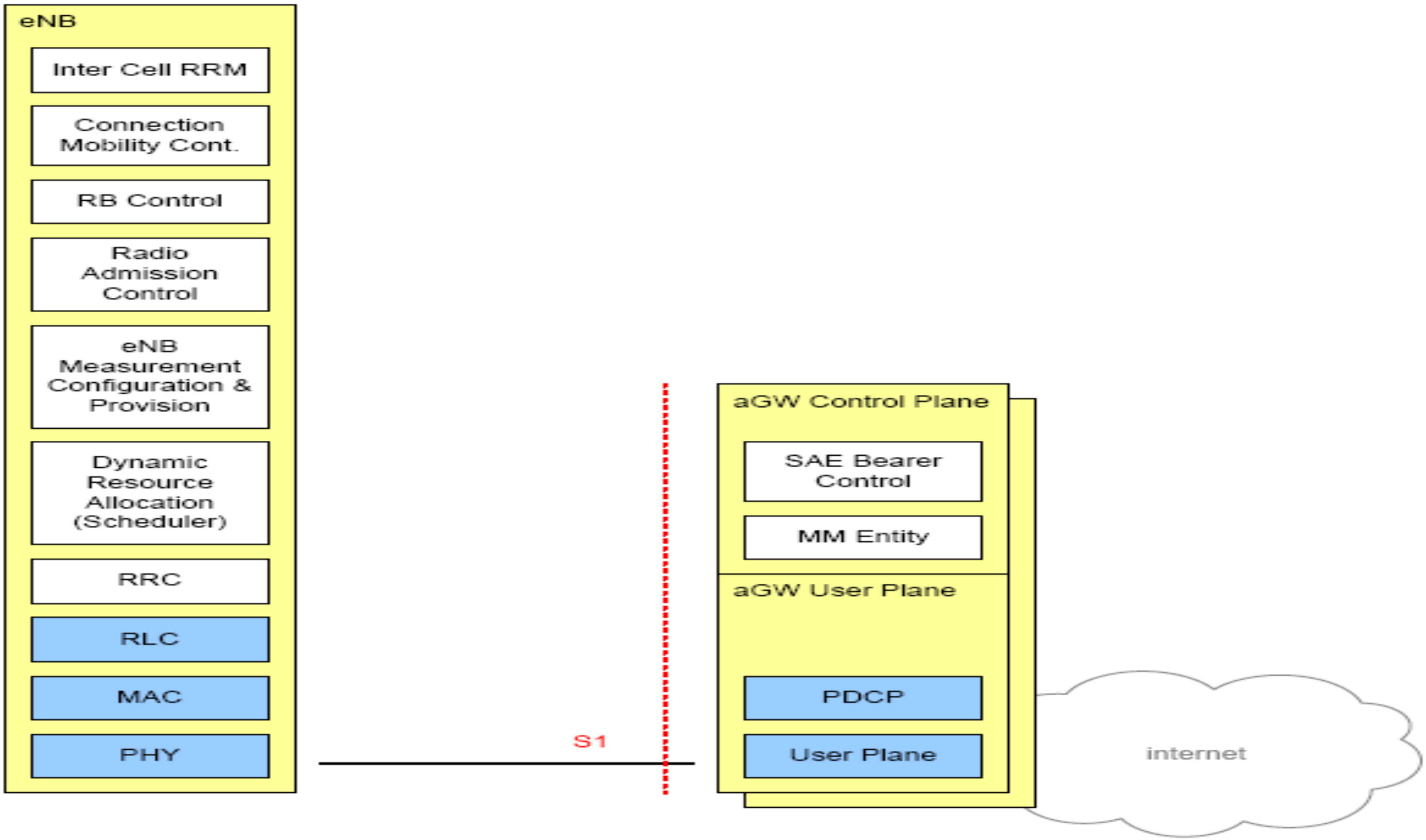
[Source:http://www.3gpp.org/Highlights/LTE/LTE.htm]

Evolved Packet Core(EPC)

- MME (Mobility Management Entity):
- -Manages and stores the UE control plane context, generates temporary Id, provides UE authentication, authorization, mobility management
- UPE (User Plane Entity):
- -Manages and stores UE context, ciphering, mobility anchor, packet routing and forwarding, initiation of paging
- 3GPP anchor:
- -Mobility anchor between 2G/3G and LTE
- SAE anchor:
- -Mobility anchor between 3GPP and non 3GPP (I-WLAN, etc)



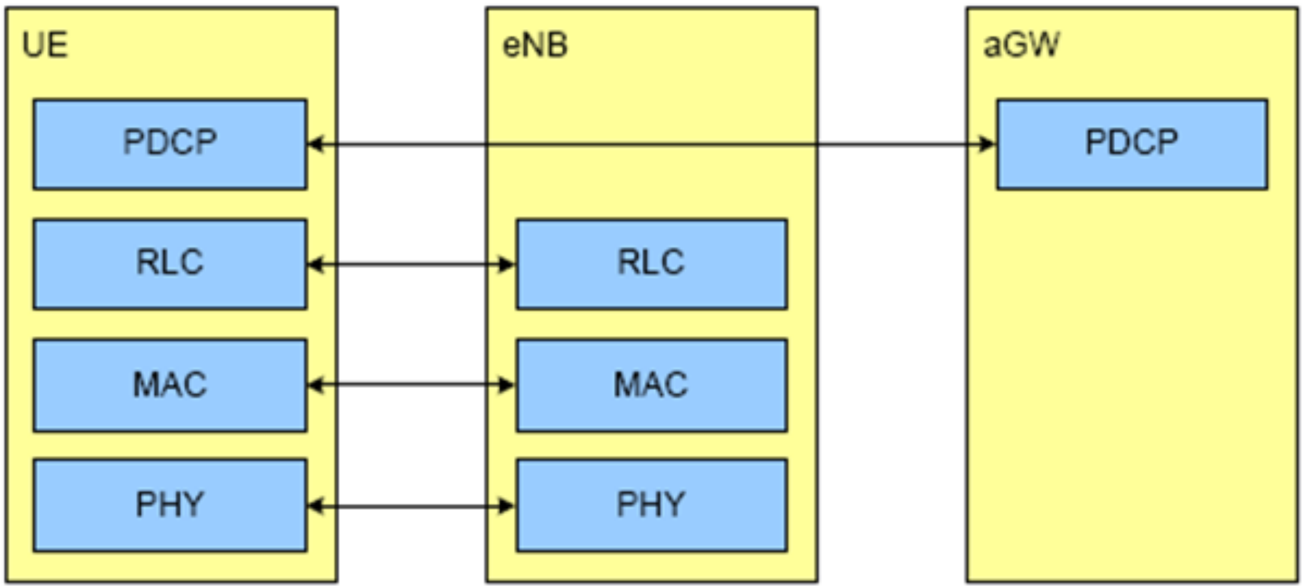
E-UTRAN Architecture



E-UTRAN Architecture

[Source: E-UTRAN Architecture(3GPP TR 25.813]7.1.0 (2006-09))]

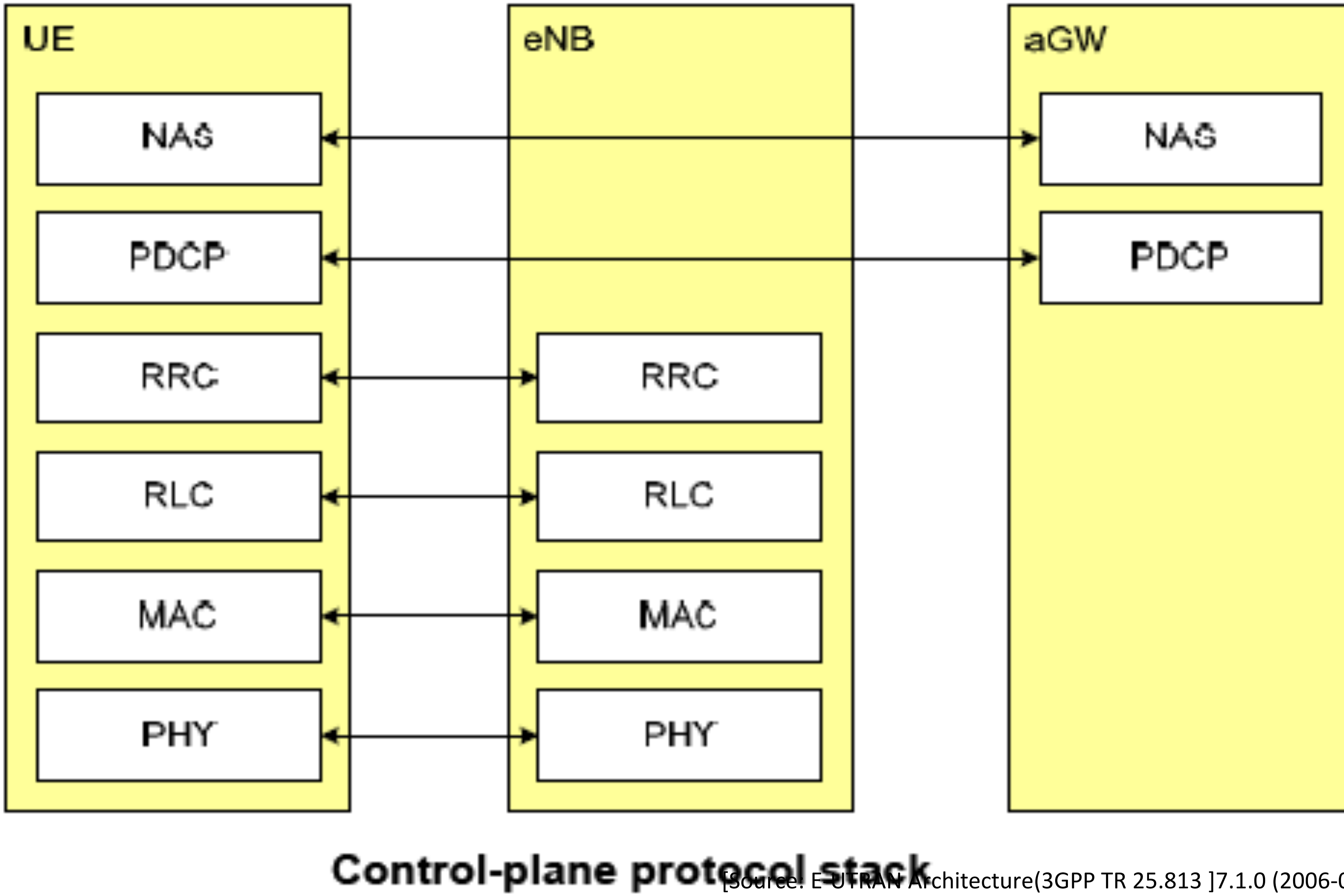
User-plane Protocol Stack



User-plane protocol stack

[Source: E-UTRAN Architecture(3GPP TR 25.813]7.1.0 (2006-09))]

Control-plane protocol Stack



[Source: E-UTRAN Architecture(3GPP TR 25.813]7.1.0 (2006-09))]

Physical layer

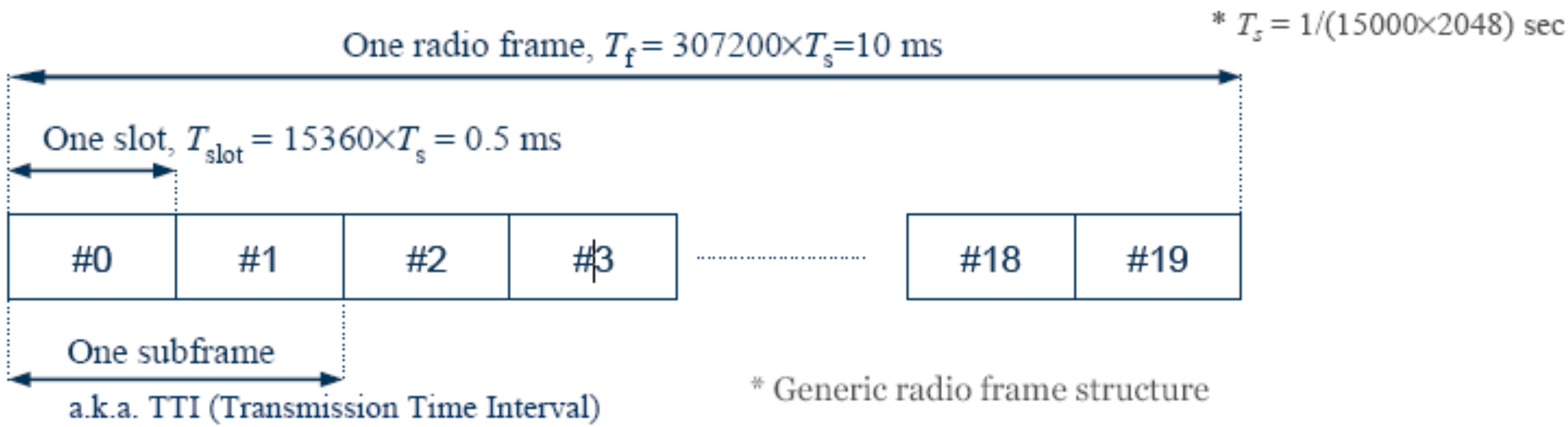
- The physical layer is defined taking bandwidth into consideration, allowing the physical layer to adapt to various spectrum allocations.

- The modulation schemes supported in the downlink are QPSK, 16QAM and 64QAM, and in the uplink QPSK, 16QAM.The Broadcast channel uses only QPSK.

- The channel coding scheme for transport blocks in LTE is Turbo Coding with a coding rate of R=1/3, two 8-state constituent encoders and a contention-free quadratic permutation polynomial (QPP) turbo code internal interleaver.

- Trellis termination is used for the turbo coding. Before the turbo coding, transport blocks are segmented into byte aligned segments with a maximum information block size of 6144 bits. Error detection is supported by the use of 24 bit CRC.

LTE Frame Structure

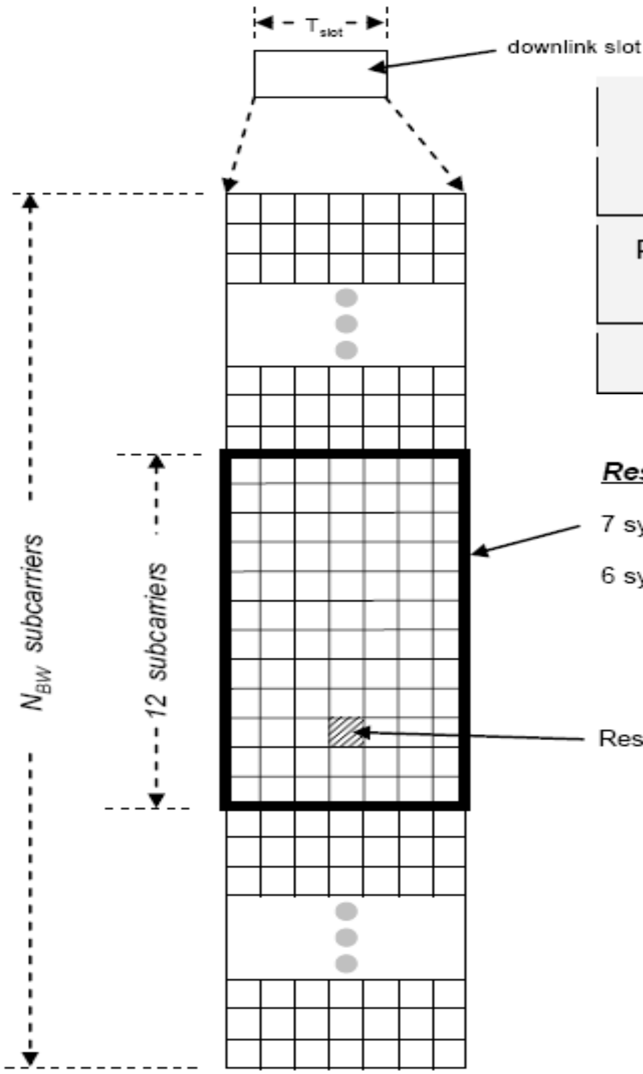


- One element that is shared by the LTE Downlink and Uplink is the generic frame structure. The LTE specifications define both FDD and TDD modes of operation. This generic frame structure is used with FDD. Alternative frame structures are defined for use with TDD.

- LTE frames are 10 msec in duration. They are divided into 10 subframes, each subframe
- being 1.0 msec long. Each subframe is further divided into two slots, each of 0.5 msec duration. Slots consist of either 6 or 7 ODFM symbols, depending on whether the normal or extended cyclic prefix is employed

[source: 3GPP TR 25.814]

Generic Frame structure



Available Downlink Bandwidth is Divided into Physical Resource Blocks

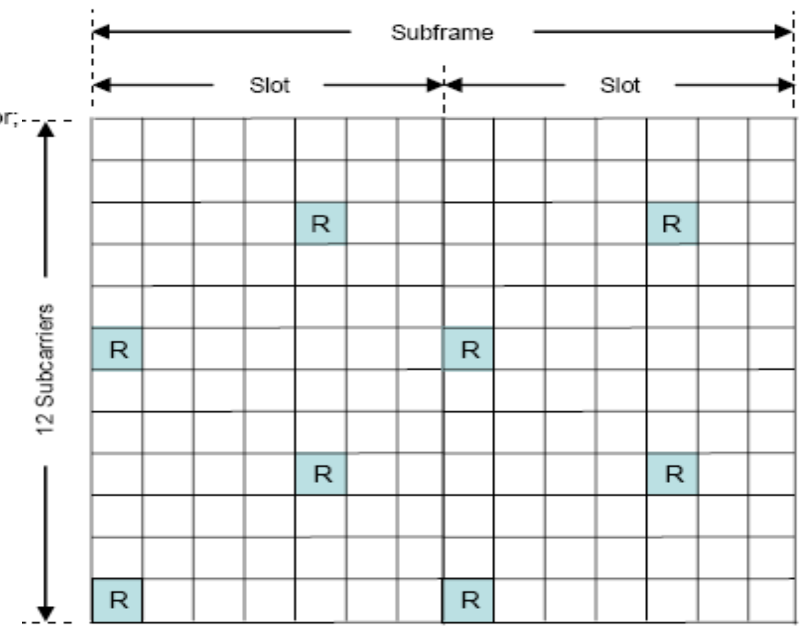
Bandwidth (MHz)	1.25	2.5	5.0	10.0	15.0	20.0
Subcarrier bandwidth (kHz)	15					
Physical resource block (PRB) bandwidth (kHz)	180					
Number of available PRBs	6	12	25	50	75	100

Resource Block:

7 symbols X 12 subcarriers (short CP), or;

6 symbols X 12 subcarriers (long CP)

Resource Element



LTE Reference Signals are Interspersed Among Resource Elements

[source: 3GPP TR 25.814]

OFDM

- LTE uses OFDM for the downlink – that is, from the base station to the terminal. OFDM meets the LTE requirement for spectrum flexibility and enables cost-efficient solutions for very wide carriers with high peak rates. OFDM uses a large number of narrow sub-carriers for multi-carrier transmission.

- The basic LTE downlink physical resource can be seen as a time-frequency grid. In the frequency domain, the spacing between the subcarriers, Δf, is 15kHz. In addition, the OFDM symbol duration time is $1/\Delta f$ + cyclic prefix. The cyclic prefix is used to maintain orthogonality between the sub-carriers even for a time-dispersive radio channel.

- One resource element carries QPSK, 16QAM or 64QAM. With 64QAM, each resource element carries six bits.

- The OFDM symbols are grouped into resource blocks. The resource blocks have a total size of 180kHz in the frequency domain and 0.5ms in the time domain. Each 1ms Transmission Time Interval (TTI) consists of two slots (Tslot).

- In E-UTRA, downlink modulation schemes QPSK, 16QAM, and 64QAM are available.

Downlink Physical Layer Procedures

- Downlink Physical Layer Procedures

- For E-UTRA, the following downlink physical layer procedures are especially important:

- Cell search and synchronization:
- Scheduling:
- Link Adaptation:
- Hybrid ARQ (Automatic Repeat Request)

SC-FDMA

- The LTE uplink transmission scheme for FDD and TDD mode is based on SC-FDMA (Single Carrier Frequency Division Multiple Access).

- This is to compensate for a drawback with normal OFDM, which has a very high Peak to Average Power Ratio (PAPR). High PAPR requires expensive and inefficient power amplifiers with high requirements on linearity, which increases the cost of the terminal and also drains the battery faster.

- SC-FDMA solves this problem by grouping together the resource blocks in such a way that reduces the need for linearity, and so power consumption, in the power amplifier. A low PAPR also improves coverage and the cell-edge performance.

- Still, SC-FDMA signal processing has some similarities with OFDMA signal processing, so parameterization of downlink and uplink can be harmonized.

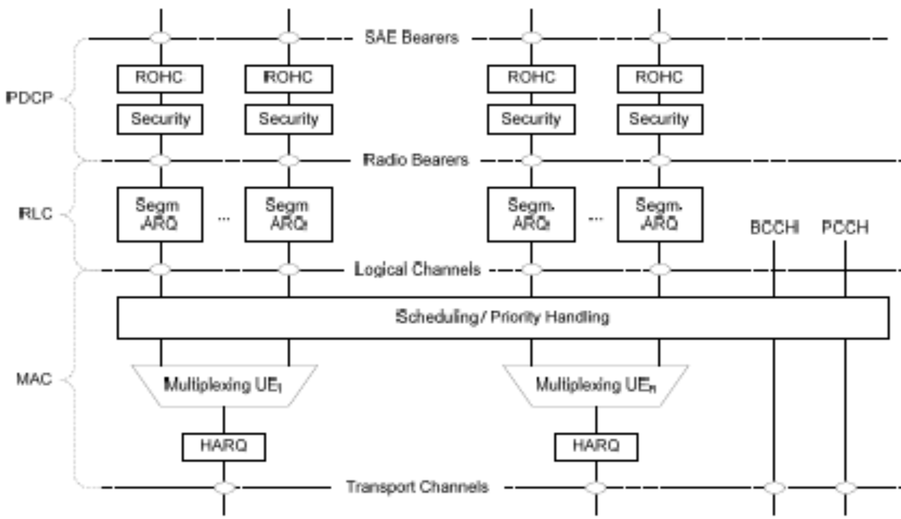
Uplink Physical Layer Procedures

- Uplink Physical Layer Procedures

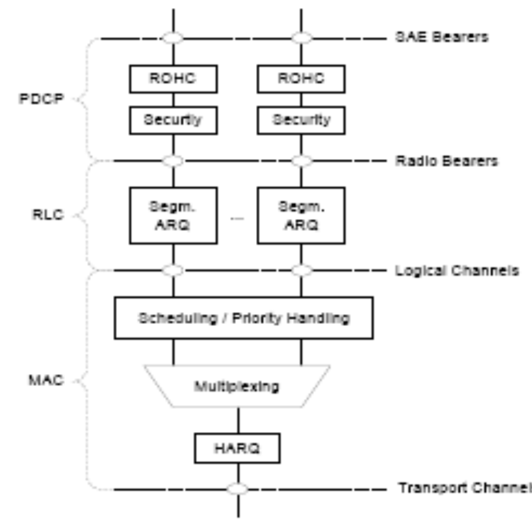
- For E-UTRA, the following uplink physical layer procedures are especially important:

- Random access
- Uplink scheduling
- Uplink link adaptation
- Uplink timing control
- Hybrid ARQ

Layer 2



DL



UL

The three sublayers are
Medium access Control(MAC)
Radio Link Control(RLC)
Packet Data Convergence Protocol(PDCP)

[Source: E-UTRAN Architecture(3GPP TR 25.012]

Layer 2

- MAC (media access control) protocol
- handles uplink and downlink scheduling and HARQ signaling.
- Performs mapping between logical and transport channels.

- RLC (radio link control) protocol
- focuses on lossless transmission of data.
- In-sequence delivery of data.
- Provides 3 different reliability modes for data transport. They are
- Acknowledged Mode (AM)-appropriate for non-RT (NRT) services such as file downloads.
- Unacknowledged Mode (UM)-suitable for transport of Real Time (RT) services because such services are delay sensitive and cannot wait for retransmissions
- Transparent Mode (TM)-used when the PDU sizes are known a priori such as for broadcasting system information.

Layer 2

- PDCP (packet data convergence protocol)
- handles the header compression and security functions of the radio interface

- RRC (radio resource control) protocol
- handles radio bearer setup
- active mode mobility management
- Broadcasts of system information, while the NAS protocols deal with idle mode mobility management and service setup

Channels

- Transport channels
- In order to reduce complexity of the LTE protocol architecture, the number of transport channels has been reduced. This is mainly due to the focus on shared channel operation, i.e. no dedicated channels are used any more.

- Downlink transport channels are
- Broadcast Channel (BCH)
- Downlink Shared Channel (DL-SCH)
- Paging Channel (PCH)
- Multicast Channel (MCH)

- Uplink transport channels are:
- Uplink Shared Channel (UL-SCH)
- Random Access Channel (RACH)

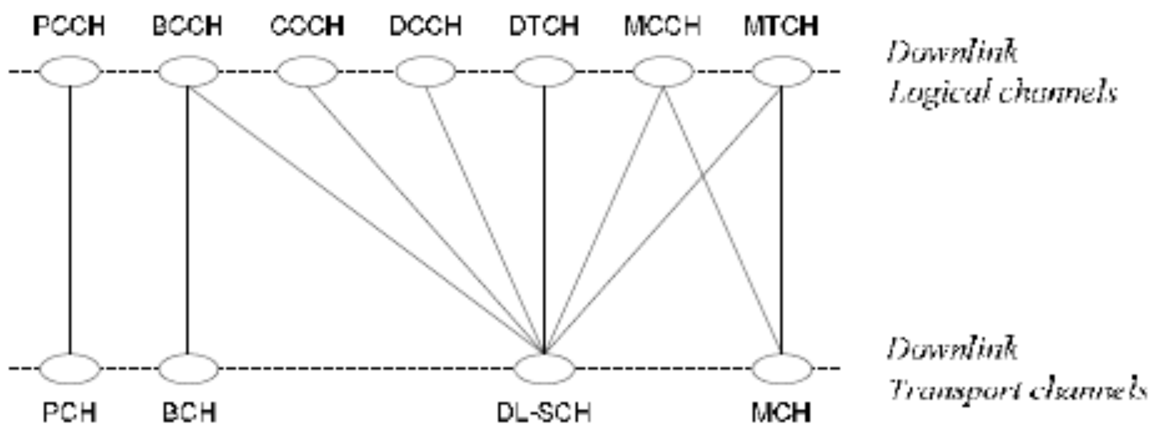
Channels

- Logical channels
- Logical channels can be classified in control and traffic channels.

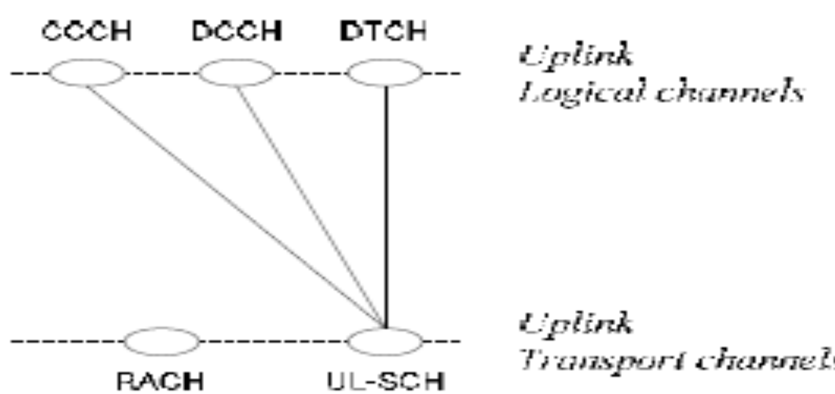
- Control channels are:
- Broadcast Control Channel (BCCH)
- Paging Control Channel (PCCH)
- Common Control Channel (CCCH)
- Multicast Control Channel (MCCH)
- Dedicated Control Channel (DCCH)

- Traffic channels are:
- Dedicated Traffic Channel (DTCH)
- Multicast Traffic Channel (MTCH)

Mapping between downlink logical and transport channels



Mapping between uplink logical and transport channels



LTE MBMS Concept

- MBMS (Multimedia Broadcast Multicast Services) is an essential requirement for LTE. The so-called E-MBMS will therefore be an integral part of LTE.

- In LTE, MBMS transmissions may be performed as single-cell transmission or as multi-cell transmission. In case of multi-cell transmission the cells and content are synchronized to enable for the terminal to soft-combine the energy from multiple transmissions.

- The superimposed signal looks like multipath to the terminal. This concept is also known as Single Frequency Network (SFN).

- The E-UTRAN can configure which cells are part of an SFN for transmission of an MBMS service. The MBMS traffic can share the same carrier with the unicast traffic or be sent on a separate carrier.

- For MBMS traffic, an extended cyclic prefix is provided. In case of subframes carrying MBMS SFN data, specific reference signals are used. MBMS data is carried on the MBMS traffic channel (MTCH) as logical channel.

Multiple Antenna Techniques

- MIMO employs multiple transmit and receive antennas to substantially enhance the air interface.

- It uses spacetime coding of the same data stream mapped onto multiple transmit antennas, which is an improvement over traditional reception diversity schemes where only a single transmit antenna is deployed to extend the coverage of the cell.

- MIMO processing also exploits spatial multiplexing, allowing different data streams to be transmitted simultaneously from the different transmit antennas, to increase the end-user data rate and cell capacity.

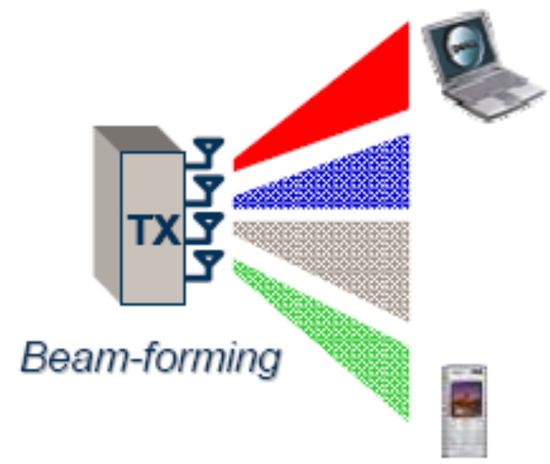
- In addition, when knowledge of the radio channel is available at the transmitter (e.g. via feedback information from the receiver), MIMO can also implement beam-forming to further increase available data rates and spectrum efficiency

Advanced Antenna Techniques

- Single data stream / user
- Beam-forming
- Coverage, longer battery life

- Spatial Division Multiple Access (SDM
- Multiple users in same radio resource

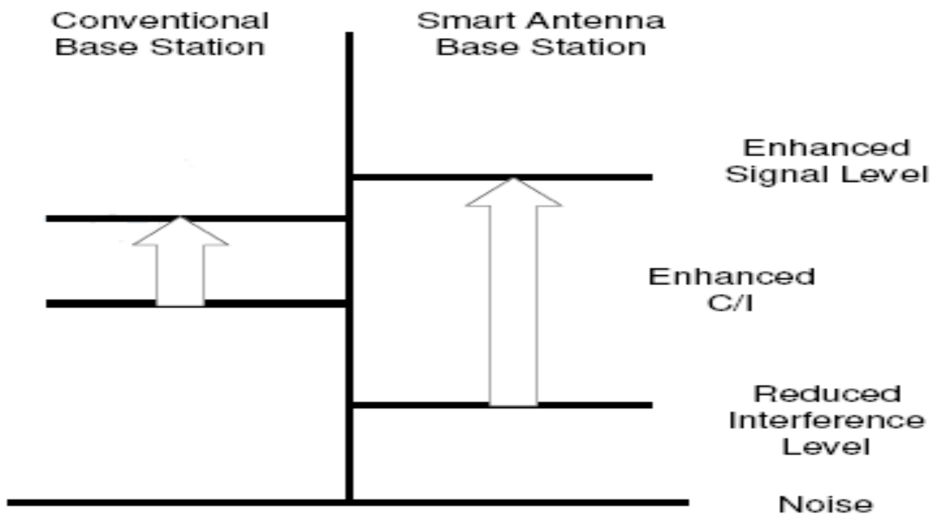
- Multiple data stream / user Diversity
- Link robustness
-
- Spatial multiplexing
- Spectral efficiency, high data rate suppo



Multi-layer transmission
("MIMO")

Beamforming & SDMA

- Enhances signal reception through directional array gain, while individual antenna has omni-directional gain
- • Extends cell coverage
- • Suppresses interference in space domain
- • Enhances system capacity
- • Prolongs battery life
- • Provides angular information for user tracking



Source: Key Features and Technologies in 3G Evolution, http://www.eusea2006.org/workshops/workshopsession.2006-01-1 1.3206361376/sessionspeaker.2006-04-10.9519467221/file/atdownload

Services

Service category	Current environment	LTE environment
Rich voice	Real-time audio	VoIP, high quality video conferencing
P2F messaging	SMS, MMS, low priority e-mails	Photo messages, IM, mobile e-mail, video messaging
Browsing	Access to online information services, for which users pay standard network rates. Currently limited to WAP browsing over GPRS and 3G networks	Super-fast browsing, uploading content to social networking sites
Paid information	Contentforwhich users pay over and above standard network charges. Mainly text-based information.	E-newspapers, high quality audio streaming
Personalisation	Predominantly ringtones, also includes screensavers and ringbacks	Realtones (original artist recordings), personalised mobile web sites
Games	Downloadable and online games	A consistent online gaming experience across both fixed and mobile networks
TV/ video on demand	Streamed and downloadable video content	Broadcast television services, true on-demand television, high quality video streaming
Music	Full track downloads and analogue radio services	High quality music downloading and storage
Content messaging and cross media	Peer-to-peer messaging using third party content as well as interaction with other media	Wide scale distribution of video clips, karaoke services, video-based mobile advertising
M-commerce	Commission on transactions (including gambling) and payment facilities undertaken over mobile networks	Mobile handsets as payment devices, with payment details carried over high speed networks to enable rapid completion of transactions
Mobile data networking	Access to corporate intranets and databases, as well as the use of applications such as CRM	P2P file transfer, business applications, application sharing, M2M communication, mobile intranet/ extranet

Source: Analysys Research/UMTS Forum 2007]

Conclusions

- LTE is a highly optimized, spectrally efficient, mobile OFDMA solution built from the ground up for mobility, and it allows operators to offer advanced services and higher performance for new and wider bandwidths.

- LTE is based on a flattened IP-based network architecture that improves network latency, and is designed to interoperate on and ensure service continuity with existing 3GPP networks. LTE leverages the benefits of existing 3G technologies and enhances them further with additional antenna techniques such as higher-order MIMO.

LTE vs WiMAX

- First, both are 4G technologies designed to move data rather than voice and both are IP networks based on OFDM technology.

- WiMax is based on a IEEE standard (802.16), and like that other popular IEEE effort, Wi-Fi, it's an open standard that was debated by a large community of engineers before getting ratified. In fact, we're still waiting on the 802.16m standard for faster mobile WiMax to be ratified. The level of openness means WiMax equipment is standard and therefore cheaper to buy — sometimes half the cost and sometimes even less. Depending on the spectrum alloted for WiMax deployments and how the network is configured, this can mean a WiMax network is cheaper to build.

- As for speeds, LTE will be faster than the current generation of WiMax, but 802.16m that should be ratified in 2009 is fairly similar in speeds.

- However, LTE will take time to roll out, with deployments reaching mass adoption by 2012 . WiMax is out now, and more networks should be available later this year.

- The crucial difference is that, unlike WiMAX, which requires a new network to be built, LTE runs on an evolution of the existing UMTS infrastructure already used by over 80 per cent of mobile subscribers globally. This means that even though development and deployment of the LTE standard may lag Mobile WiMAX, it has a crucial incumbent advantage.

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