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3GPP LTE 표준화 동향

표준 동향 및 주요 기술 소개

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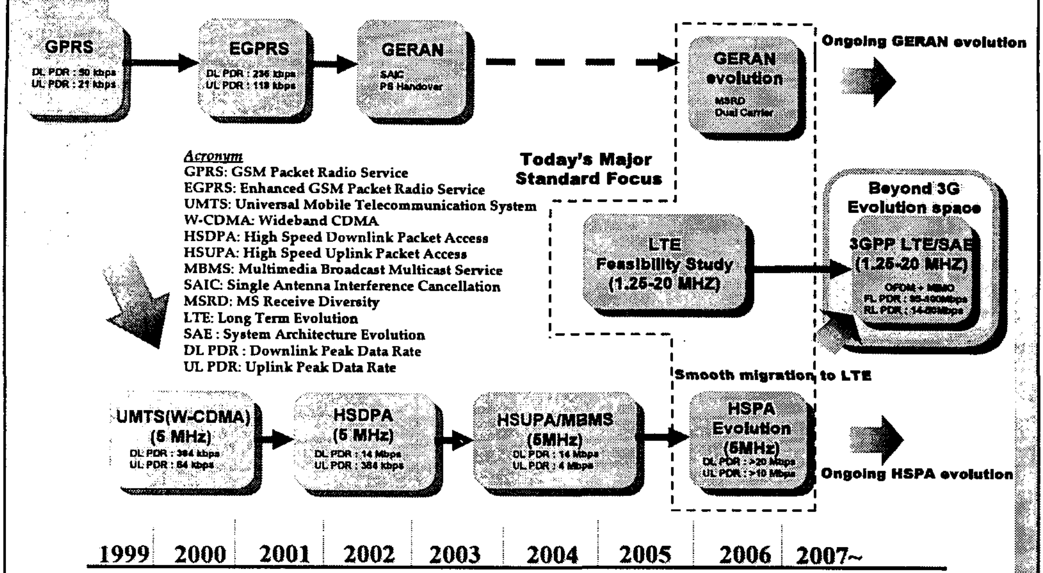
Contents

- 3GPP standardization - overview
- Introduction of 3GPP LTE
- Requirements for 3GPP LTE
- Radio access technologies
  - Downlink radio access
  - Uplink radio access
- Scheduling/link adaptation/HARQ scheme
- Pilot channel/control channel design
- Inter-cell interference mitigation
- MIMO Scheme
- Evolved UTRAN architecture
- LTE protocol architecture

3GPP standardization - overview

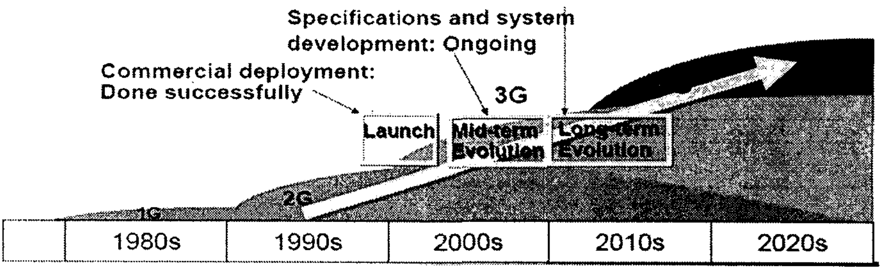


GSM/UMTS Evolution

Introduction of 3GPP LTE [1/2]

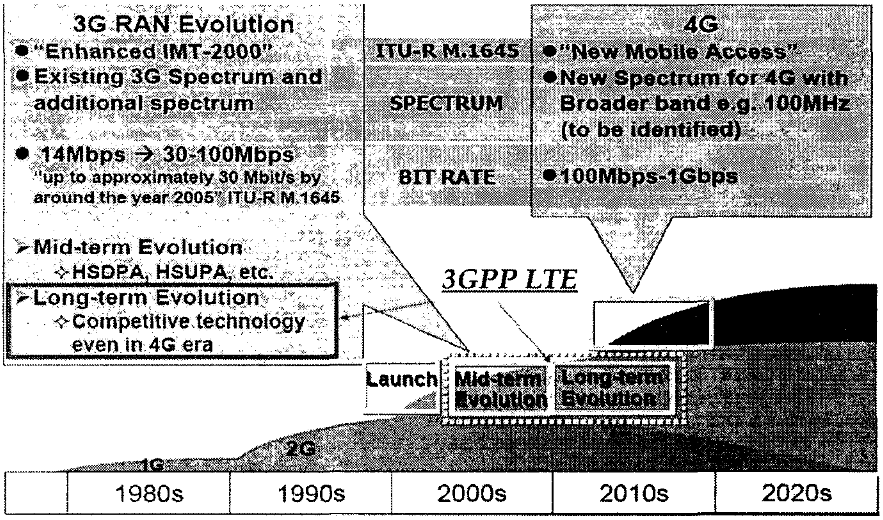
- What is 3GPP RAN LTE?
  - Long Term Evolution for 3GPP RAN to keep the continuous growth of mobile communication industry
  - Initiated mainly by NTT-DoCoMo in November, 2004
  - Currently still in the study item phase
    - ✓ Work item started officially in June, 2006
  - Competitive technology even in 4G era

Technical study for LTE



Introduction of 3GPP LTE [2/2]

❑ **Position of 3GPP LTE vs. 4G Radio**



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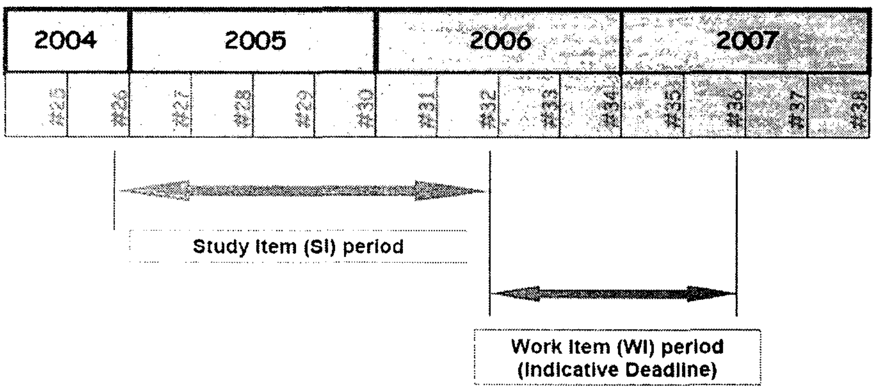
Time schedule for 3GPP LTE

❑ **Overall schedule for LTE standardization**



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Requirements for 3GPP LTE [1/2]

- **Major requirements (from 25.913)**
  - Significantly increased peak data rate e.g. 100 Mbps (downlink) and 50 Mbps (uplink)
  - Increase "cell edge bitrate" whilst maintaining same site locations as deployed today
  - Significantly improved spectrum efficiency e.g. 5bit/s/Hz (downlink), 2.5bit/s/Hz (uplink)
  - Significantly reduced U/C-plane latency
  - Scaleable bandwidth e.g. 1.25, 2.5, 5, 10, 15, and 20MHz
  - Support for inter-working with existing 3G systems and non-3GPP specified systems
  - Further enhanced MBMS
  - Reduced CAPEX and OPEX including backhaul
  - Cost effective migration from Release 6 UTRA radio interface and architecture

Requirements for 3GPP LTE [2/2]

- **Major requirements for evolved system**
  - Reasonable system and terminal complexity, cost, and power consumption
  - Support of further enhanced IMS and core network
  - Backwards compatibility is highly desirable, but the trade off versus performance and/or capability enhancements should be carefully considered
  - Efficient support of the various types of services, especially from the PS domain (e.g. Voice over IP, Presence)
  - System should be optimized for low mobile speed but also support high mobile speed (~15, ~120, ~350km/h)
  - Operation in paired and unpaired spectrum should not be precluded
  - Possibility for simplified co-existence between operators in adjacent bands as well as cross-border co-existence

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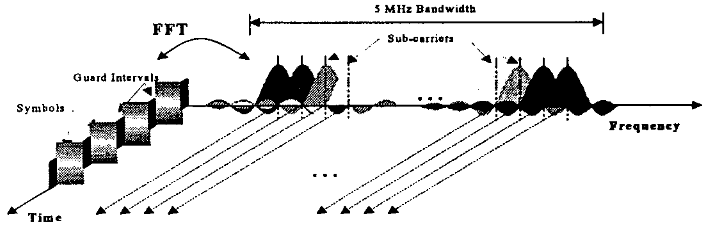
Radio access technology

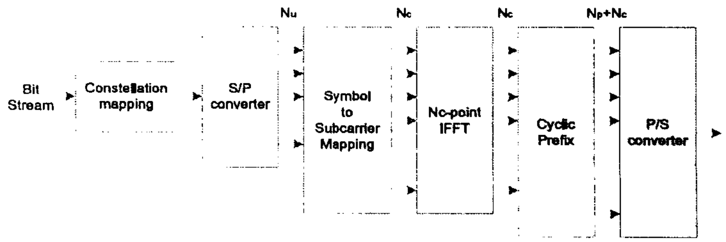
- OFDM (Orthogonal Frequency Division Multiplexing)
  - OFDM uses many subcarriers/tones to carry signal
  - Data from a user encoded on multiple tones
  - The subcarriers overlap but are orthogonal to each other, with no mutual interference



- Advantages compared with CDMA
  - Higher spectral efficiency in time-dispersive channel
  - More robust to multipath interference
  - More suitable to MIMO technologies
  - Simpler receiver to cope with dispersive channels

Downlink radio access scheme

- DL radio access scheme for LTE
  - OFDM based multiplexing (beneficial for channels subject to severe time dispersion)
    - ✓ Higher data rate and capacity (sector throughput) than Nx HSDPA with 5 MHz bandwidth
    - ✓ Combined more easily with MIMO tech. → influence of delayed paths is mitigated
  - Fast scheduling in the unit of 0.5 ms sub-frame
    - ✓ Channel dependent scheduling and link adaptation can be applied on the sub-frame level



Downlink frame structure

❑ Downlink frame structure with scalable bandwidth

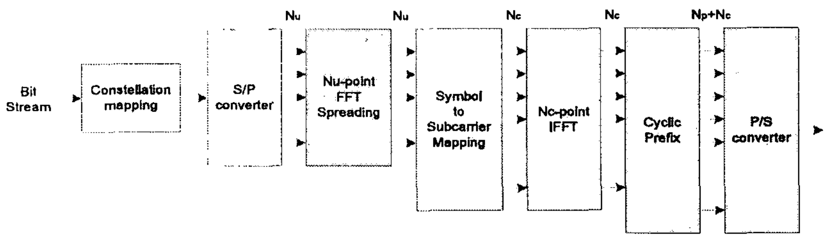
Transmission BW		1.25 MHz	2.5 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Sub-frame duration		0.5 ms					
Sub-carrier spacing		15 kHz					
Sampling frequency		1.92 MHz (1/2 × 3.84)	3.84 MHz	7.68 MHz (2 × 3.84)	15.36 MHz (4 × 3.84)	23.04 MHz (6 × 3.84)	30.72 MHz (8 × 3.84)
FFT size		128	256	512	1024	1536	2048
Number of occupied sub-carriers		76	151	301	601	901	1201
Number of OFDM symbols per sub frame (Short/Long CP)		7/6					
CP length (μs/samples)	Short	(4.69/9) × 6, (5.21/10) × 1	(4.69/18) × 6, (5.21/20) × 1	(4.69/36) × 6, (5.21/40) × 1	(4.69/72) × 6, (5.21/80) × 1	(4.69/108) × 6, (5.21/120) × 1	(4.69/144) × 6, (5.21/160) ×1
	Long	(16.67/32)	(16.67/64)	(16.67/128)	(16.67/256)	(16.67/384)	(16.67/512)

• Parameters for Downlink Transmission Scheme. Numerology are for evaluation purpose only

Uplink radio access scheme

❑ UL radio access scheme for LTE

- DFT-S-OFDMA based multiple access
  - ✓ Can be considered as variation of OFDMA with DFT spreading so that lower PAPR (Peak to Average Power Ratio) can be achieved
  - ✓ Preserves orthogonality among simultaneous users
    - Larger capacity than CDMA if intercell interference can be mitigated
  - ✓ Also known as SC-FDMA (Single Carrier FDMA)
- Fast scheduling in the unit of 0.5 ms sub-frame
  - ✓ Channel dependent scheduling and link adaptation can be applied on the sub-frame level



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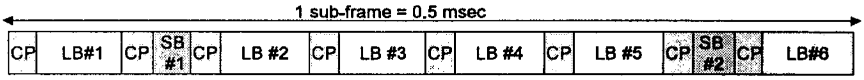
Uplink frame structure

❑ Uplink frame structure with scalable bandwidth

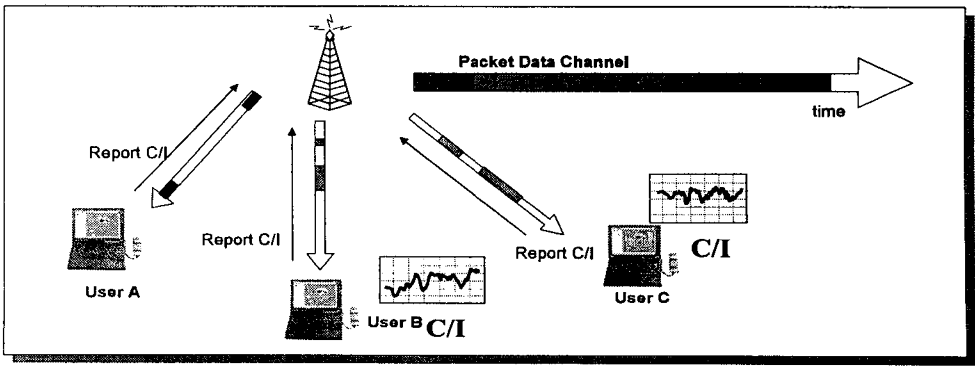


Spectrum Allocation (MHz)	Sub-frame duration (ms)	Long block size (μs/#of occupied subcarriers /samples)	Short block size (μs/#of occupied subcarriers /samples)	CP duration (μs/samples *1)
20	0.5	66.67/1200/2048	33.33/600/1024	(4.13/127) × 7, (4.39/135) × 1
15	0.5	66.67/900/1536	33.33/450/768	(4.12/95) × 7, (4.47/103) × 1
10	0.5	66.67/600/1024	33.33/300/512	(4.1/63) × 7, (4.62/71) × 1
5	0.5	66.67/300/512	33.33/150/256	(4.04/31) × 7, (5.08/39) × 1
2.5	0.5	66.67/150/256	33.33/75/128	(3.91/15) × 7, (5.99/23) × 1
1.25	0.5	66.67/75/128	33.33/38/64	(3.65/7) × 7, (7.81/15) × 1

Downlink scheduling mechanism

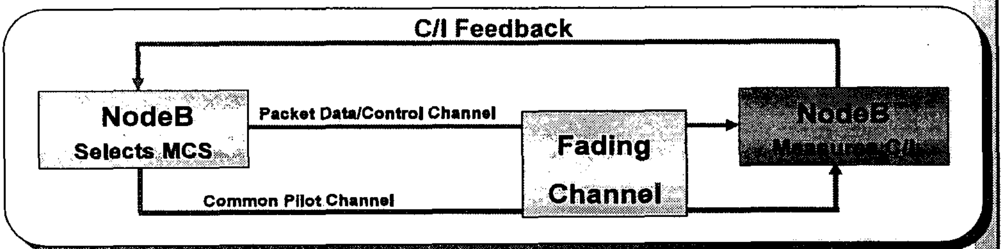
❑ Multi-user diversity

- The UE to be served is selected by scheduler, based on C/I feedback values from UE
- By transmitting the packet on better channel condition, the average sector throughput can be increased



Downlink link adaptation mechanism

- **Operation of AMC**
  - Based on instantaneous channel conditions and system restrictions
    - ✓ C/I feedback from UEs
    - ✓ Available power & time-frequency resource at the NodeB
  - Selection of modulation and coding
    - ✓ Maximization of system throughput by efficient exploitation of radio spectrum capacity
    - ✓ Users near/far from the sector → higher/lower order modulation with higher/lower code rates



Uplink scheduling mechanism

- **Basic decision to be made**
  - Scheduling in which domain?
    - ✓ Time domain scheduling with pre-assigned tx bandwidth
    - ✓ Time and frequency domain scheduling
  - Scheduling in terms of time
    - ✓ Fast scheduling
      - 1 Sub-frame (fast scheduling)
      - Large overhead
      - Efficient usage of resource
      - Delay-sensitive application
    - ✓ Multi sub-frame (slow scheduling)
      - Of how many sub-frames does a time unit for scheduling consist?
      - Small overhead
      - waste of resource in case of small size of buffered data
      - May not be appropriate to real-time service (e.g. VoIP)

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Uplink link adapation mechanism

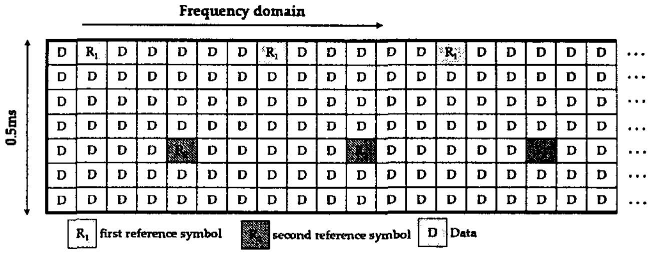
- Link Adaptation Mechanism for Uplink
  - Fast AMC + Slow Power Control (or Full Power)
    - ✓ Link adaptation for residual path loss and fast fading variation
    - ✓ SINR measure pilot is required for UE (semi-fixed pilot power level)
    - ✓ High sector/user throughput ?
    - ✓ What does Slow PC mean? : Distance-based power level determination
      - proper power transmission at cell edge (in case of high frequency reuse factor): minimize inter-NodeB interference :
      - High power transmission at cell edge : maximize worst user's throughput (This scheme needs inter-cell interference coordication?)
  - Slow AMC + Fast Power Control
    - ✓ Do not necessarily require SINR measure pilot
    - ✓ R-CQICH, or power head room report can be used for slow AMC

HARQ for downlink and uplink

- Possible Consideration on HARQ Mechanism
  - Synchronous/Non-adaptive
    - ✓ Lower overhead
    - ✓ Less flexibility
    - ✓ Maybe less throughput
  - Asynchronous/Adaptive
    - ✓ Larger overhead
    - ✓ More flexible
    - ✓ Higher throughput
- Further Consideration
  - Control Signal Design for HARQ Mechanism
    - ✓ Possible extension of control channel message using a kind of flag in case of large overhead

Pilot design for downlink/uplink

- **Pilot structure for downlink**
  - Common pilot channel



- **Pilot structure for uplink**
  - Pilot for channel estimation
    - ✓ Distributed pilot or localized pilot : related to resource allocation mechanism for uplink
  - Pilot for fast scheduling/link adaptation
    - ✓ Definition of link adaptation pilot or reuse of power controlled pilot with power headroom report

Control channel design for downlink

- **Location of control channel in a subframe**
  - Should be close to pilot channel for better channel estimation
  - Should be located in the first and second symbol of subframe
- **What kind of information?**
  - For downlink shared channel
    - ✓ Information on resource block allocation for scheduled UE
    - ✓ Target UE ID
    - ✓ MCS Information
    - ✓ HARQ related information
  - For uplink
    - ✓ Information on resource block allocation for scheduled UE
    - ✓ Power control bit
    - ✓ MCS Information
    - ✓ HARQ related information
- **Coding scheme for control channel**
  - Joint coding for multiple UE?
  - Control channel transmission in case of multiple antenna in Node B
  - Control channel design in case of variable control signal length
  - Any method for overhead reduction?
    - ✓ Compression, Power ranking, AMC

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Control channel design for uplink

- **Required control signal in uplink**
  - Data assoicated control signaling (e.g. TFCI)
  - Data non-associated control signaling
    - ✓ CQICH, ACKCH, or request channel
- **Multiplexing scheme for L1/L2 control signal**
  - TDM vs. FDM
  - Distributed vs. localized
- **CQI Report**
  - Procedure and method for transmitting channel quality information (CQI) through UL control channel to support efficient DL scheduling
  - Considered Method:
    - ✓ Physical control channel/MAC signaling
    - ✓ Full band CQI reporting/N-best band CQI reporting/etc
    - ✓ Contiguous/Non-contiguous CQI band reporting
    - ✓ Node B initiative/MS initiative
    - ✓ Scheduling dependent/independent
    - ✓ Periodic/aperiodic/event-triggered
    - ✓ Fast feedback or slow feedback

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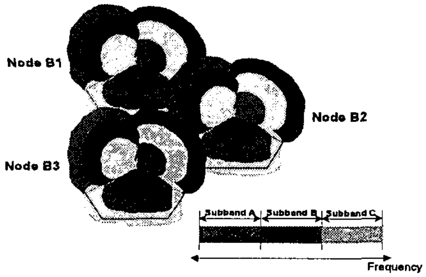
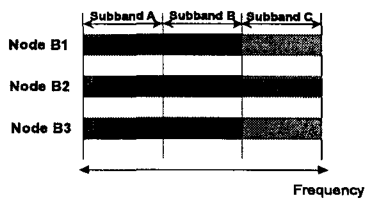
Intercell interference mitigation

- **Inter-cell interference randomization**
  - Cell specific scrambling/ freuqency hopping
- **Inter-cell interference cancellation**
  - Implentation specific scheme/IDMA
- **Inter-cell interference coordination**
  - Semi-static coordination of frequency resource allocations between neighbor cells to minimize the overlapping of DL transmission in the same frequency band





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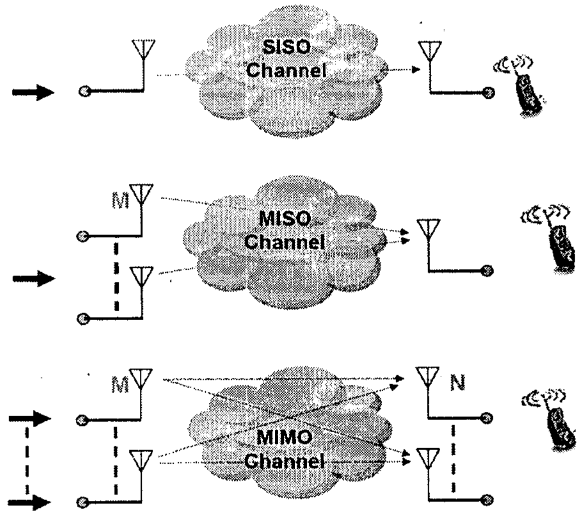
MIMO scheme [1/3]

❑ **MIMO (Multiple Input Multiple Output) Concept**



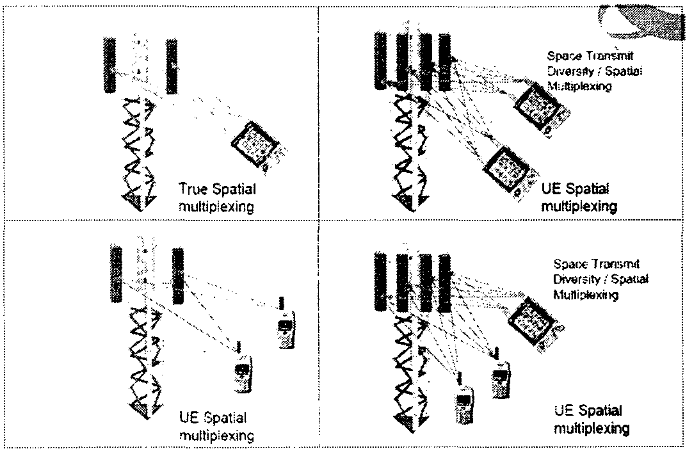
MIMO scheme [2/3]

❑ **Why MIMO?**

- MIMO increases the capacity
  - ✓ Independent streams can be transmitted from each Tx antenna
  - ✓ Same resources can be used for each stream → no waste in resource
- MIMO boosts the peak rate and increases downlink spectral efficiency
- Generalization of Tx diversity with multiple Rx antennas
  - ✓ Multiple stream transmission offers new perspectives compared to Tx diversity + Rx diversity
- Provides performance improvements for
  - ✓ High scattering environment
  - ✓ High SNR
  - ✓ Low to medium mobility

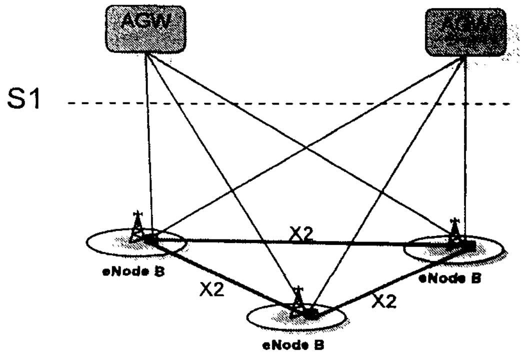
MIMO scheme [3/3]

- Virtual MIMO
  - Uplink MIMO configuration Scenario



Evolved UTRAN Architecture [1/3]

- LTE Architecture with new interface
  - Simplified two-node network architecture
    - ✓ Only enhanced Node B (eNB) and Access Gateway (AGW)
      c.f.) 4 nodes in UMTS: NB-RNC-SGSN-GGSN



E-UTRAN Architecture

Evolved UTRAN Architecture [2/3]

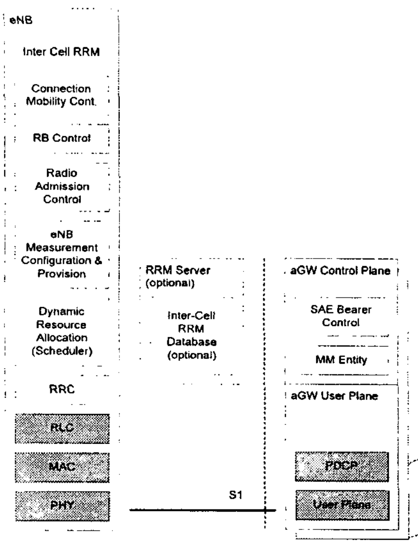
- **LTE Architecture with new interface**
  - AGW (Access Gateway)
    - ✓ U-plane: UPE
    - ✓ C-plane: MME
  - eNB (enhanced Node B)
    - ✓ U-plane: PHY/MAC
    - ✓ C-plane: RRC
  - X2 Interface
    - ✓ Interconnection between eNBs
    - ✓ Meshed connection
  - S1 Interface
    - ✓ Interconnection between eNB and AGW
    - ✓ Many:Many connection between eNB and AGW

Evolved UTRAN Architecture [3/3]

- **Network architecture for Macro Diversity**
  - No inter-Node B macro diversity for Downlink
  - No inter-Node B macro diversity for Uplink
  - Fast cell switching or fast handover should be investigated further
  - Single frequency network (SFN) for broadcast traffic is being considered positively (However, synchronized network is not basic assumption for EUTRAN)

LTE Protocol Architecture [1/3]

❑ Overall protocol architecture

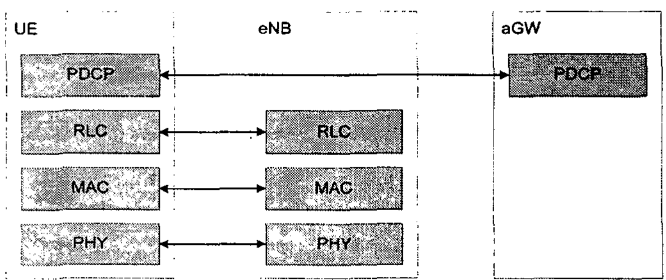


- **Locating most of radio functions at eNB**
  - Faster control of radio transmissions
    - ✓ **RRC/RLC@eNB in LTE vs. RRC/RLC@RNC in UTRAN**
- **AGW(MME/UPE) have similar role of the SGSN/GGSN in UMTS**
  - Paging origination
  - LTE_IDLE state management
  - Ciphering of the user plane
  - PDCP
  - SAE Bearer Control

LTE Protocol Architecture [2/3]

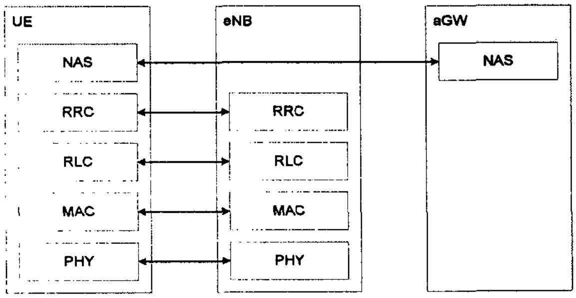
❑ User plane protocol stack

- RLC/MAC (terminated in eNB on the network side)
  - ✓ Scheduling/ARQ/HARQ
- Security (terminated in aGW on the network side)
  - ✓ Ciphering/Integrity protection (FFS)
- PDCP (terminated in aGW on the network side)
  - ✓ Header Compression.



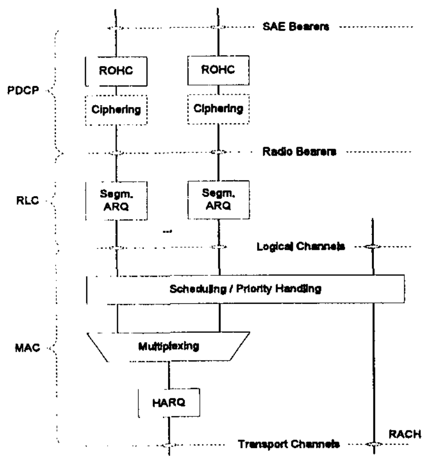
LTE Protocol Architecture [3/3]

- Control plane protocol stack
  - RLC/MAC (terminated in eNB on the network side)
  - RRC (terminated in eNB on the network side)
    - ✓ Broadcast/Paging/RRC conn manage/RB control
    - ✓ /Mobility functions/UE measurement reporting&control.
  - NAS (terminated in aGW on the network side)
    - ✓ SAE bearer management/Authentication/Idle mode mobility handling/Paging origination/Security control



LTE layer2 protocol [1/2]

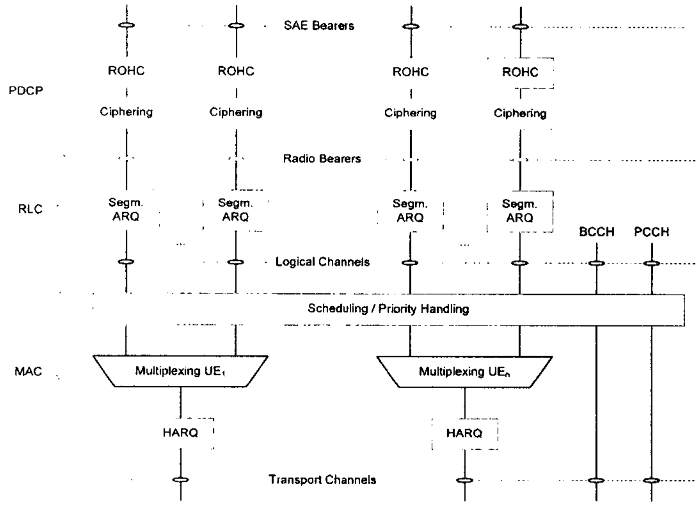
- UE Side L2 Structure
  - Similar to UTRA Layer 2 at this moment
  - PDCP (Packet Data Conference Protocol)
    - ✓ ROHC (Robust Header Compression)
  - RLC (Radio Link Control)
    - ✓ ARQ function
    - ✓ Segmentation etc.
  - MAC (Medium Access Control)
    - ✓ Channel Multiplexing
    - ✓ HARQ
    - ✓ Scheduling



Layer 2 Structure for UL in UE

LTE layer2 protocol [2/2]

❑ Network Side L2 Structure



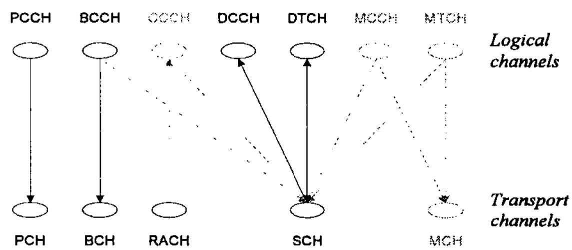
Layer 2 Structure for DL in eNB and aGW

LTE radio channels

❑ Characteristic

- Tempting to reduce number of channel types
  - ✓ Most of signaling & traffic are carried on SCH (Shared Channel)
- However, BCH/PCH/RACH still remain
  - ✓ BCH (Broadcast Channel) for System Information
  - ✓ PCH (Paging Channel) for Paging
  - ✓ RACH (Random Access) e.g. for Initial Cell Access

❑ Channel Mapping



Mapping between Logical Channels and Transport Channels @ MAC layer