3GPP RAN Evolution: Proposal

Motorola

3GPP RAN Evolution Workshop
(Toronto, 2-3 November 2004)

Contents

- Supported channel bandwidths for Enhanced UMTS (E-UMTS)
- Main features for E-UMTS
- Key technical components of air-interface technology for E-UMTS
- Key technical components network architecture and deployment scenarios for E-UMTS
- 3GPP E-UMTS work prioritization and working group structure

Support for Wideband Operation

- **Channel Widths**
  - **Possible supported channel bandwidth modes**

FDD Allocations (MHz)	2x2.5[1]	2x5	2x10	2x20
TDD Allocations (MHz)		5	10	20

Channel Bandwidth (MHz)

1. Defined to assist 2G spectrum technology migration.

- **Bandwidths at or below 10MHz most likely practicable – 15-20MHz operation must also be considered from perspective of long-term evolutionary growth**
- **Deployment Spectrum**
  - **Legacy UMTS Spectrum (1.7GHz-2.1GHz)**
  - **Emerging bands (2.5GHz-2.7+GHz, 450-800 MHz (VHF/UHF) etc.)**
  - **Unlicensed option could be created**
- **Deployment Strategy**
  - **Optimal Cell Radius : 1000m**
  - **Typical RMS delay Spread (1-2μs)**
  - **Performance optimized for operating range between nomadic and 30km/h with graceful degradation for velocities up to 120km/h on wide area basis.**
  - **Higher velocities (200-300 km/h) supported for special topology**
  - **Converge FDD and TDD baseband functions**

Opportunities for RAN Enhancement

System Feature	Enhancement Goal	Comments or Possible Solutions
Latency Reduction	• Improved session setup and reduced latency	• Affects air interface, RAN, CN • Impact physical channel design & RRC
VoIP	• Efficient VoIP support. Conv. class support in PS mode.	• Must offer convincing performance gains over traditional CS approaches
Wideband (Flexi-band) Operation	• Increased peak user data rates & spectral efficiency	• Extend to wideband modes • Flexible bandwidth – allow <5MHz channels
Broadcast Services	• Efficient broadcast modes	• Improved macro-diversity operation
Spectrum and Duplexing	• Enable efficient spectrum management • Re-merge FDD/TDD solutions	• Re-converge FDD & TDD baseband design • Prep. for re-mining 2G global spectrum
UL Link Enhancements	• Improved UL data rates • Inference – reduced latency	• UL orthogonalisation & PAR enhancement • Relaying
MIMO & Multi-Antenna Subsystems (MAS)	• Enhanced coverage • Improved data rates	• Effective CL & OL MIMO solutions • Deeply embedded support for MAS • Enhance UTRA fixed / nomadic use
Seamless Operation	• Improved L1/L2 support for seamlessness	• Improved other-RAT measurements • Very low latency inter-RAT HO

•Above enhancements should lead into lower cost/bit and better user experience

Key Goals and Air-Interface Technologies for E-UMTS

- **Maintain support for 1-cell re-use**
- **Support flexible bandwidths: 2.5MHz to 20MHz**
- **Goal is to provide DSL/Cable-like service for mobile and nomadic applications**
- **Key components required to meet the above goals**
  - **Both Orthogonal Downlink and Uplink (no intra-cell interference)**
    - E-UMTS Air-Interface based on Alternate Waveform Designs
  - **Excellent performance in frequency selective fading channels**
  - **Fully integrated Multi Antenna Subsystem (MAS) and MIMO technology**
  - **AMC, HARQ, Smart Scheduling and Resource allocation**
  - **System synchronization to enable efficient broadcasting**
  - **Tower Mounted LNAs at Base Stations**
    - Potentially tower mounted power amplifiers
  - **Low air-interface latency (e.g. <= 20 ms)**

DL Link Budget for EUMTS Deployment Topology (Prelim)

	Rel-6	EUMTS	EUMTS	
Propagation Loss Model	In-Veh	In-Veh	In-Bldg	Units
Test Service	**Data**	**Data**	**Data**	
Information Rate	**625**	**9600**	**5300**	**Kbps**
(a0) Average Transmitter Power per Traffic Channel	41.5	46.0	46.0	dBm
(a1) Maximum Total Transmitter Power	43.0	46.0	46.0	dBm
(b) Cable, Connector, and Combiner Losses	3.0	0.5	0.5	dB
(c) Transmitter Antenna Gain	17.0	17.0	17.0	dBi
(d2) Total EIRP = (a1 - b + c - c2)	57.0	62.5	62.5	dBm
(d1) EIRP per Traffic Channel = (a0 - b + c - c2)	**55.5**	**62.5**	**62.5**	**dBm**
(e) Receiver Antenna Gain	0.0	0.0	0.0	dBi
(f) Cable and Connector Losses	0.0	0.0	0.0	dB
(g) Receiver Noise Figure	9.0	9.0	9.0	dB
(h) Thermal Noise Density	-174.0	-174.0	-174.0	dBm/Hz
Rise Over Thermal, (Io + No)/No				dB
(i) Receiver Interference Density	-158.2	-155.3	-170.2	dBm/Hz
(j) Total Effective Noise Plus Interference Density	-157.4	-154.8	-163.9	dBm/Hz
(k) Information Rate	58.0	69.8	67.2	dB-Hz
(l) Required Eb/(No + Ioc)	3.4	6.1	2.8	dB
(l) Required Eb/(No + Io)				dB
(m) Receiver Sensitivity = (j + k + l)	**-96.0**	**-77.3**	**-92.3**	**dBm**
(n) Handoff or Fast Cell Selection	0.0	0.0	0.0	dB
(n') Inter-sector Antenna Rolloff w Combining Gain (e.g. SFN, antenna)	-1.0	-1.0	-1.0	dB
(o) Smart Antenna Gain (e.g. beamforming)	0.0	9.0	9.0	dB
(p) Other Diversity Gain (e.g. rx antenna diversity, MIMO)	0.0	3.0	3.0	dB
(q) Other Gain (Vehicle or Building Penetration Loss + Body Loss)	-10.0	-10.0	-25.0	dB
(r) Log-Normal Fade Margin	12.1	12.1	12.1	dB
(s) Total Gains/Margins = (n + n' + o + p + q - r)	**-23.1**	**-11.1**	**-26.1**	**dB**
(q) Maximum Path Loss = (d1 - m + e - f + s)	**128.4**	**128.7**	**128.7**	**dB**
Maximum Range (PL model: 128.1+37.6log10(.R))	**1.02**	**1.04**	**1.04**	**km**

~10 Mbps Coverage for 1km radius cell

- **In vehicle**
  - 98% ACR

Technology features

=

High Data Rate Coverage

5 Mbps Coverage for 1km radius cell

- **In building**
  - 95% ACR
  - Same technology features

UL Link Budget for EUMTS Deployment Topology (Prelim)

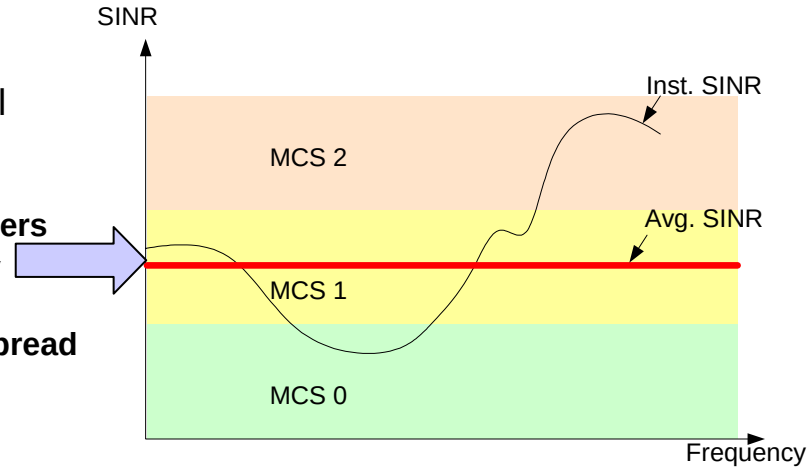
	Rel-99	EUMTS	EUMTS	
Propagation Loss Model	In-veh	In-veh	In-bldg	Units
Test Service	**Data**	**Data**	**Data**	
Information Rate	**64**	**4000**	**500**	**Kbps**
(a0) Average Transmitter Power per Traffic Channel	24.0	24.0	24.0	dBm
(a1) Maximum Total Transmitter Power	24.0	24.0	24.0	dBm
(b) Cable, Connector, and Combiner Losses	0.0	0.0	0.0	dB
(c) Transmitter Antenna Gain	0.0	0.0	0.0	dBi
(d2) Total EIRP = (a1 - b + c - c2)	24.0	24.0	24.0	dBm
(d1) EIRP per Traffic Channel = (a0 - b + c - c2)	**24.0**	**24.0**	**24.0**	**dBm**
(e) Receiver Antenna Gain	17.0	17.0	17.0	dBi
(f) Cable and Connector Losses	3.0	0.5	0.5	dB
(g) Receiver Noise Figure	5.0	3.4	3.4	dB
(h) Thermal Noise Density	-174.0	-174.0	-174.0	dBm/Hz
Rise Over Thermal, (Io + No)/No	6.0	3.0	3.0	dB
(i) Receiver Interference Density				dBm/Hz
(j) Total Effective Noise Plus Interference Density	-163.0	-167.6	-167.6	dBm/Hz
(k) Information Rate	48.1	66.0	57.0	dB-Hz
(l) Required Eb/(No + Ioc)				dB
(l) Required Eb/(No + Io)	4.7	3.4	1.5	dB
(m) Receiver Sensitivity = (j + k + l)	**-110.3**	**-98.2**	**-109.1**	**dBm**
(n) Handoff or Fast Cell Selection	3.5	0.0	0.0	dB
(n') Inter-sector Antenna Rolloff w Combining Gain (e.g. SFN, antenna)	0.0	0.0	0.0	dB
(o) Smart Antenna Gain (e.g. beamforming)	0.0	9.0	9.0	dB
(p) Other Diversity Gain (e.g. rx antenna diversity, MIMO)	0.0	3.0	3.0	dB
(q) Other Gain (Vehicle or Building Penetration Loss + Body Loss)	-10.0	-10.0	-25.0	dB
(r) Log-Normal Fade Margin	12.1	12.1	8.5	dB
(s) Total Gains/Margins = (n + n' + o + p + q - r)	**-18.6**	**-10.1**	**-21.5**	**dB**
(q) Maximum Path Loss = (d1 - m + e - f + s)	**129.7**	**128.6**	**128.1**	**dB**
Maximum Range (PL model: 128.1+37.6log10(.R))	**1.10**	**1.03**	**1.00**	**km**

- **4Mbps Coverage for 1km radius cell**
  - **In vehicle**
    - 98% ACR
    - TTA (2.5+1.6dB)
    - Orthogonal UL
    - Higher BW – higher rates with same ER
    - HARQ
    - Inter-sector antenna combining
    - Smart Antenna
    - UL MAS
- **0.5Mbps Coverage for 1km radius cell**
  - **In building**
    - 90% ACR

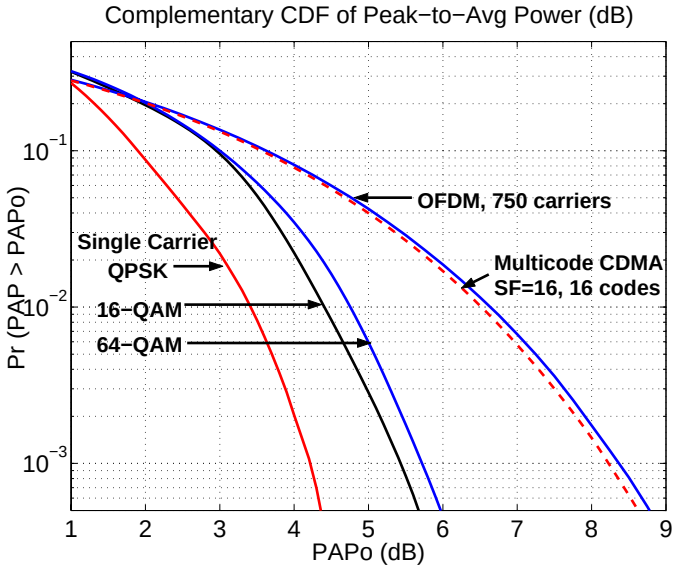
Key Air-Interface Technology for E-UMTS (Downlink)

E-UMTS Downlink Options

- **OFDM**
  - Exploits frequency selectivity of the multi-path channel
    - **By coding the information across sub-carriers for diversity**
    - **User can be assigned a favorable subset of sub-carriers**
    - **Modulation/coding rate can be varied over frequency based on the channel response**
    - **Maintains orthogonality between symbols in delay-spread channels**



- **Spread-OFDM (S-OFDM)**
  - Similar to OFDM but data symbols are spread across multiple carriers by an orthogonal spreading code
- **Single Carrier with Cyclic Prefix and Frequency Domain Equalization**
  - Cyclic prefix is added to the data block before transmission
  - Frequency domain MMSE equalizer is implemented at the receiver
  - Low peak-to-average power ratio (PAR)
  - Obtains frequency diversity regardless of coding rate
    - **Leads to a performance benefit for QPSK with R > 2/3 coding**



Key Air-Interface Technology for E-UMTS (Downlink)

Parameter	Units	Carrier Bandwidth			
		20MHz	10MHz	5MHz	2.5MHz
TTI Duration	ms	2	**2**	**2**	2
FFT Size	samples	2048	**1024**	**512**	256
Guard Period	us	5	**5**	**5**	5
OFDM Symbol Duration	us	83	**83**	**83**	83
OFDM Symbols Per TTI	symbols/TTI	24	**24**	**24**	24

Example

- **Support 2.5 MHz-20 MHz channel bandwidth**
  - **E.g. Use 2048 FFT size @ 20 MHz for OFDM/S-OFDM**
  - **E.g. Use 2048 Block size @ 20 MHz for Single Carrier CP**
- **Radio Frame Structure (example)**
  - **2ms transmission unit**
  - **Similar structure used for FDD and TDD**
- **Support of AMC, HARQ, BPSK, QPSK, 16-QAM, 64-QAM modulation**
- **Turbo-codes with robust and simplified Turbo Interleaver**
- **Support Node-E based frequency-domain scheduling and sub-channelisation**
- **Support of MIMO(up to 8x4) and up to *n*-element (e.g. n=8) Multi-antenna subsystem (MAS)**
  - **Both open-loop and closed-loop MIMO**
- **Robust Control Channel Structure with low overhead (e.g. <= 20%)**
- **Multiple users per time transmission unit**
- **Broadcast support**
  - **Synchronised cells**
  - **Larger Guard period (e.g. 10-20 μs)**

Key Air-Interface Technology for E-UMTS: Uplink

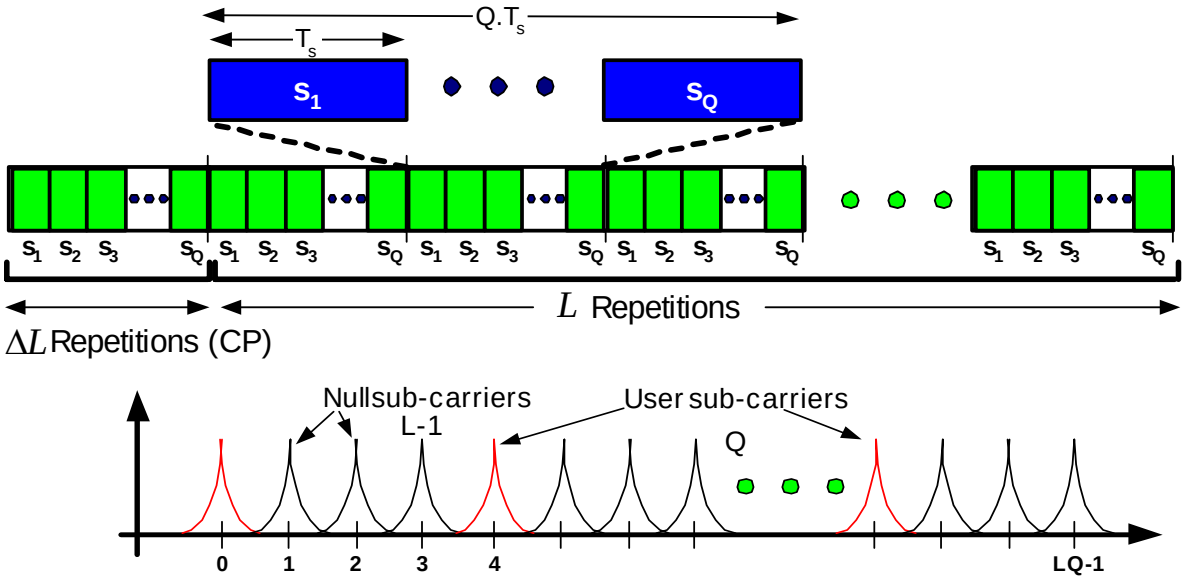
- **HSUPA will be standardized by Rel-6 and commercial operation is expected to start by 2007**
  - **HSUPA is a significant enhancement – has many advanced uplink features such as AMC, HARQ, Node-B based scheduling etc.**
  - **Further improvement possible via**
    - Reduction in intra-cell interference
    - Additional improvements in uplink waveform CM
- **E-UMTS Uplink**
  - **Goal is to eliminate intra-cell interference**
  - **Keep CM/PAR low**
    - TDM multiple services (per UE) with different rates/QoS in the same frame
  - **Key options**
    - OFDM (similar to downlink)
    - Enhanced CP Single Carrier
      - Interleaved Frequency Division Multiple Access (IFDMA)

Key Air-Interface Technology for E-UMTS: Uplink

- **OFDM**
  - **OFDM uplink waveforms maintain orthogonality between users and minimizes intra-cell interference in multi-path channels**
    - Provided a) uplink waveforms time-aligned within cyclic prefix window
    - b) uplink frequency error maintained within acceptable limits
  - **Conceptually simple waveform design**
    - Achieves frequency-diversity in frequency-selective channels
    - Readily applicable to frequency-specific scheduling
    - FFT offers computationally efficient base-band implementation
  - **Disadvantages of OFDM**
    - Classical OFDM uplink waveform has poor peak-average ratio (PAR)
    - Can be alleviated by reduced post-PA losses for TDD architectures
    - PAR/CM at the UE significantly higher than UMTS Release-6 HSUPA
- **Interleaved Frequency Division Multiple Access (IFDMA)**
  - **Special Type of CP Single Carrier that provides orthogonal tone sets for multiple access**
    - Combines the desirable characteristics of multi-carrier and single-carrier modulation
  - **Reduced PAR/CM (Cubic Metric)**

Key Air-Interface Technology for E-UMTS: Uplink

- **Interleaved Frequency Division Multiple Access (cont'd)**
  - **Each user assigned set of sub-carriers orthogonal to other users**
    - Establishes intra-cell user orthogonality
    - Achieves frequency-diversity in frequency-selective channels
  - **Can support:**
    - Multi-rate operation by variable repetition factor
    - Orthogonal multiple-access
  - **Reduced PAR/CM**
  - **Node-E equalizer can be implemented efficiently in the frequency domain**



Key Air-Interface Technology for E-UMTS: Uplink

- Radio Frame Structure (example)
  - 2ms Transmission unit
  - Similar structure used for FDD and TDD
  - PAR and CM no worse than Release-6 EUL
- Support of AMC, HARQ, BPSK, QPSK, 8-PSK/16-QAM modulation
- Turbo-codes with robust and simplified Turbo-Interleaver
- Support Node-E based scheduling and so that users are orthogonal (no intra-cell interference)
- Multiple users per time transmission unit
- Possibility to use MIMO/Beamforming gain
- Robust control channel structure with low overhead
- RACH Enhancements
- Support of relays for range extension

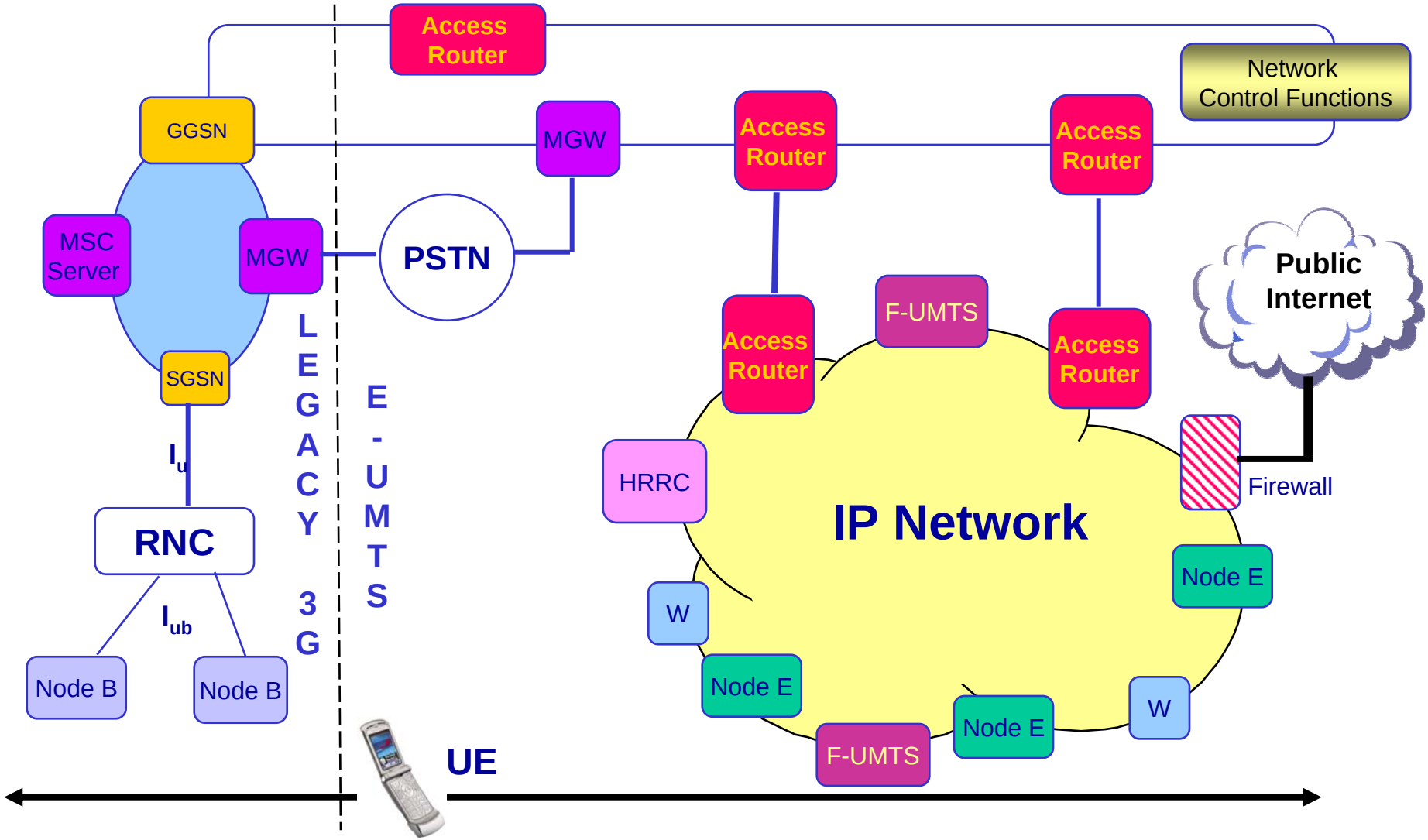
Adaptive Antenna Arrays

- **Antenna Arrays enable both the PHY layer and the MAC layer to exploit the space-dimension of the channel**
  - **Goal = increase capacity, range and reliability**
  - **Antenna arrays extend coding and equalization into the space domain**
    - *Receive array processing* = "joint space-time-frequency equalization, interference suppression, and decoding"
    - *Transmit array processing* = "space-time-frequency encoding and pre-equalization"
  - **Antenna arrays provide a spatial dimension to the MAC scheduler.**
- **Array design for E-UMTS requires**
  - **Tight integration with PHY and MAC design to take full advantage of antenna array processing gains**
  - **Broadband channel presents a different set of challenges**
- **Many different Antenna Array techniques**
  - **Spatial Multiplexing, Space-Time Coding, Beam-forming, MIMO etc.**
- **Gains depend on environment and deployment scenario**

Other Air-Interface Technology Elements for E-UMTS

- **Enhancements is also required in the following areas**
  - **Handover and Multicasting**
    - Soft-Handoff and Fast Cell Selection
  - **Latency and Delay Components**
    - Efficient signaling: low overhead session setup
    - State Management: modified RRC state machine to permit rapid state transitions
    - Efficient support for low-power modes
    - Minimal protocol layer between TCP/RTP and HARQ at Physical layer
  - **Advanced Receiver Design for UL and DL**

Network Architecture – An Example



Network Architecture – An Example (continued)

Notations

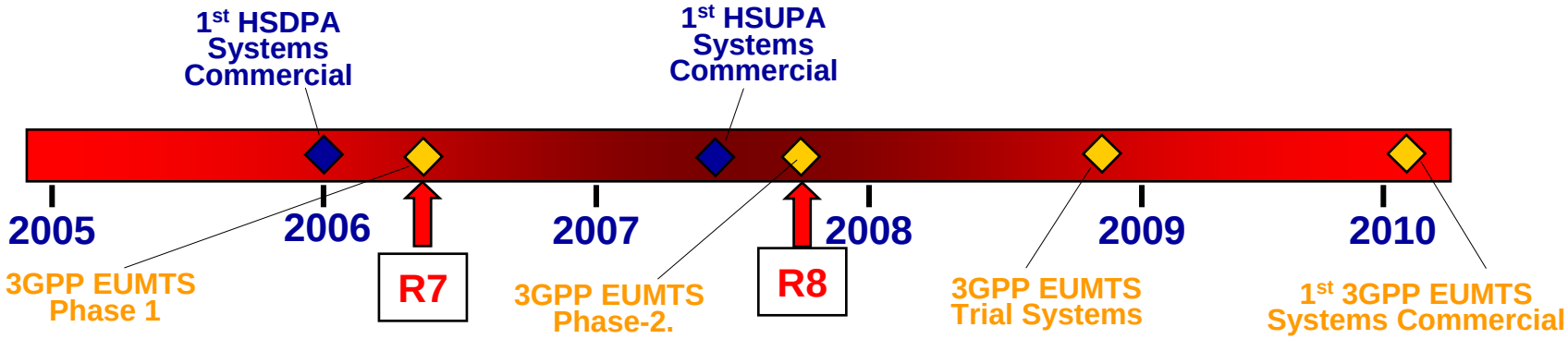
- **W** **WLAN Access Point (802.11 a/b/g/n etc) – non-optimized IP transport**
- **Node B** **3G BTS**
- **Node E** **Enhanced UMTS BTS (optimized for IP transport)**
- **F-UMTS** **A future UMTS BTS (optimized for IP transport)**
- **HRRC** **Heterogeneous Radio Resource Controller** (optional element used for coordinate use of multiple access technologies)
- **UE** **User Equipment** (typically equipped with one or more access modes to be used in a judicious manner)
- **Network Control Functions** Responsible for mobility management, QoS management, Security, Charging, Media Conversion & Distribution, Session control and management etc.

The heart of the network and services standardization for E-UMTS

3GPP RAN Evolution – Exemplary Timeline

- **3GPP Air Interface Evolution – Multi-Year Process**
  - Initial concept overview: Future Evolution Workshop – Toronto, Nov. 2004
  - Outline specification development timeline:

3GPP Next-Gen Timeline



- **Timeline Summary**
  - Phase-1: Study Item(s) complete: Q2-2006
  - Phase-2: Core specifications complete: Q3-2007
  - Initial trial systems: Q4-2008
  - Initial commercial systems: Q1-2010

3GPP EUMTS Work Prioritization & Working Groups

- **Key 3GPP Work Group Tasks – 2004-2005**
  - **Key#1: Drive implementation improvements in Releases 99/4/5/6**
  - **Key#2: Create core technology evolution (EUMTS)**
  - **Both elements essential – EUMTS should not distract from Key#1**

- **Motorola View on Options for EUMTS Working Groups**
  - **Execute EUMTS work within existing WG's**
    - Create EUMTS sub-working group within each RAN working group
      - *Advantage*: same experts available, ensure alignment with Releases 99/4/5/6
    - Allocate 1 day sessions at collocated RAN1/2/3/4 WG meetings
      - *Advantage: ensure alignment with co-located groups*
      - *Advantage: improve working practise and avoid multiple LS between groups*
    - Organize additional EUMTS ad-hoc meetings in 2005 –2007 timeframe
      - *Advantages*: appropriate to large scope of task