



# Long Term Evolution (LTE): Overview of LTE Air-Interface Technical White Paper



Abstract —With the emergence of packet-based wireless broadband systems such as WiMAX 802.16e, it is evident that a comprehensive evolution of the Universal Mobile Telecommunications System (UMTS) specifications is required to remain competitive. As a result, work has begun on Long Term Evolution (LTE) of the UMTS Terrestrial Radio Access and Radio Access Network aimed for commercial deployment in 2010. Goals for the evolved system include support for improved system capacity and coverage, high peak data rates, low latency, reduced operating costs, multi-antenna support, flexible bandwidth operations and seamless integration with existing systems. To reach these goals, a new design for the air interface is envisioned. This paper provides a preliminary look at the air interface for LTE Evolved UTRA (E-UTRA) and associated key technologies required to reach its design objectives. Initial LTE E-UTRA system performance results show a 2 to 3x improvement over a reference Rel-6 UMTS/HSxPA system configuration [1, 2] for both uplink and downlink.

## I. INTRODUCTION

In the current Universal Mobile Telecommunications System (UMTS/HSxPA) specifications, systems are capable of supporting high speed packet access for both downlink (up to 14 Mbps) and uplink (up to 5.76 Mbps). Although HSxPA systems offer substantial improvement for packet data transmission over earlier UMTS systems, their designs were limited by compatibility requirements with previous generations of UMTS specifications. With the emergence of packet-based mobile broadband systems such as WiMAX 802.16e, it is evident that a comprehensive long term evolution (LTE) of UMTS is required to remain competitive in the long term. As a result, work has begun on LTE Evolved UMTS Terrestrial Radio Access (E-UTRA) aimed at commercial deployment around 2010 timeframe. Long term goals for the system include support for high peak data rates (100 Mbps downlink and 50 Mbps uplink), low latency (10ms round-trip delay), improved system capacity and coverage, reduced operating costs, multi-antenna support, efficient support for packet data transmission, flexible bandwidth operations (up to 20 MHz) and seamless integration with existing systems. To reach these goals, a new design for the air interface is envisioned. This paper provides a preliminary look at the air interface for LTE E-UTRA and initial system results in comparison to the current UMTS/HSxPA systems.

The UMTS standards timeline is shown in Figure 1. The first phase of the physical layer specification was completed in May 2006 with the conclusion that LTE E-UTRA physical layer performance requirements are achievable. Complete specifications are then expected to be ready by the end of 2008. By 2009, trial LTE E-UTRA systems are expected with commercial deployment by 2010.

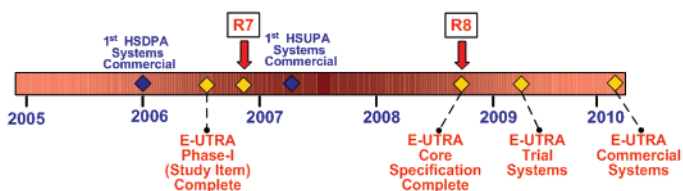


Figure 1 – LTE E-UTRA Standards Timeline

The paper is organized as follows. In Section II, an overview of LTE E-UTRA performance requirements is provided. This is followed, in Section III, by a discussion on new physical layer techniques being introduced. In Section IV, design for supporting channels is provided. Section V presents system simulation results for LTE E-UTRA.

## II. LTE E-UTRA PERFORMANCE REQUIREMENTS

The LTE E-UTRA performance requirements are provided in [1] with the main objective of developing an optimized packet-based access system with high data rate and low latency. Examples of intended services include HDTV broadcast, movies on demand, and voice-over-IP (VoIP). The physical layer performance requirements are summarized in Table 1.

Table 1 - Physical layer requirements for LTE E-UTRA

Requirement	Current Release (Rel-6 HSxPA)	LTE E-UTRA
Peak data rate	14 Mbps DL / 5.76 Mbps UL	100 Mbps DL / 50 Mbps UL
Spectral Efficiency	0.6 – 0.8 DL / 0.35 UL (bps/Hz/sector)	3-4x DL / 2-3x UL improvement
5% packet call throughput	64 Kbps DL / 5 Kbps UL	3-4x DL / 2-3x UL improvement
Averaged user throughput	900 Kbps DL / 150 Kbps UL	3-4x DL / 2-3x UL improvement
U-Plane Latency	50 ms	5 ms
Call setup time	2 sec	50 ms
Broadcast data rate	384 Kbps	6-8x improvement
Mobility	Up to 250 km/h	Up to 350 km/h
Multi-antenna support	No	Yes
Bandwidth	5 MHz	Scalable (up to 20 MHz)

Other E-UTRA objectives include common base-band support for TDD and FDD modes, reduced capital expenditure and operating costs, and reasonable system / terminal complexity. When compared to existing wireless broadband access technologies such as 802.16, E-UTRA will employ similar frequency domain based air interface and support advanced multi-antenna features. However, E-UTRA will be designed to have fewer options than 802.16, an improved uplink with low power amplifier de-rating, better support for VoIP, lower latency, and seamless inter-working with legacy systems such as UMTS. In addition, E-UTRA is expected to support mobility up to 350 km/h, conserve mobile station's power consumption through micro-sleep, and provide seamless integration of unicast and enhanced broadcast transmission.

### III. KEY AIR-INTERFACE TECHNOLOGY

#### A. OFDM Downlink Transmission

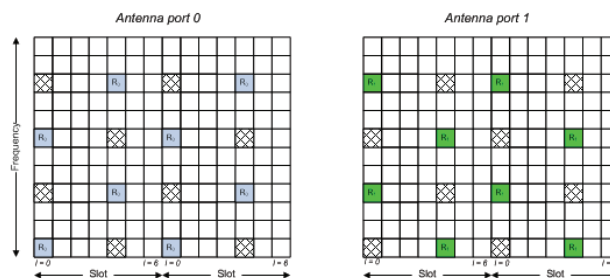
In the downlink, OFDM is selected to efficiently meet E-UTRA performance requirements. With OFDM, it is straightforward to exploit frequency selectivity of the multi-path channel with low-complexity receivers. This allows frequency selective in addition to frequency diverse scheduling and one cell reuse of available bandwidth. Furthermore, due to its frequency domain nature, OFDM enables flexible bandwidth operation with low complexity. Smart antenna technologies are also easier to support with OFDM, since each sub-carrier becomes flat faded and the antenna weights can be optimized on a per sub-carrier (or block of sub-carriers) basis. In addition, OFDM enables broadcast services on a synchronized single frequency network (SFN) with appropriate cyclic prefix design. This allows broadcast signals from different cells to combine over the air, thus significantly increasing the received signal power and supportable data rates for broadcast services.

**Table 2 – E-UTRA Numerology [2]**

Transmission BW (MHz)	1.4	3	5	10	15	20
Sub-frame duration	1.0 ms					
Sub-carrier spacing	15 kHz					
Sampling frequency (MHz)	1.92	3.84	7.68	15.36	23.04	30.72
FFT size	128	256	512	1024	1536	2048
Number of occupied sub-carriers	72	180	300	600	900	1200
CP length (μs)	Normal	4.69 × 6, 5.21 × 1				
	Extended	16.6				

To provide great operational flexibility, E-UTRA physical layer specifications are bandwidth agnostic and designed to accommodate up to 20 MHz system bandwidth. Table 2 provides the downlink sub-frame numerology for different spectrum allocations. Sub-frames with one of two cyclic prefix (CP) durations may be time-domain multiplexed, with the shorter designed for unicast transmission and the longer designed for larger cells or broadcast SFN transmission. The useful symbol duration is constant across all bandwidths. The 15 kHz sub-carrier spacing is large enough to avoid degradation from phase noise and Doppler (250km/h at 2.6 GHz) with 64QAM modulation. [3]

The downlink reference signal structure for channel estimation, CQI measurement, and cell search/acquisition is shown in Figure 2. Reference symbols (RS) are located in the 1st OFDM symbol (1st RS) and 3rd to last OFDM symbol (2nd RS) of every sub-frame, with micro-sleep enabled by having control decodable without using the 2nd RS. For FDD, it may be possible to reduce overhead by not transmitting the 2nd RS for at least low to medium speeds, since adjacent sub-frames can often be used to improve channel estimation performance. This dual TDM (or TDM) structure has similar performance to a scattered structure in 0.5ms sub-frames, and an advantage in that low complexity channel estimation (interpolation) is supported as well as other excellent performance, low-complexity techniques such as MMSE-FIR and IFFT-based channel estimators. To provide orthogonal signals for multi-antenna implementation, FDM is used for different TX antennas of the same cell, and CDM is used for different cells.

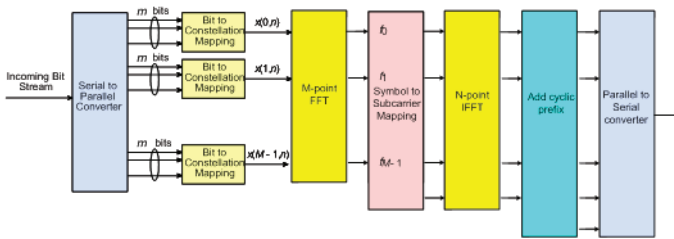


**Figure 2 - Downlink reference signal structure – normal cyclic prefix, two transmit antennas**

#### B. SC-FDMA Uplink Transmission

In the uplink, Single-Carrier Frequency Division Multiple Access (SC-FDMA) is selected to efficiently meet E-UTRA performance requirements. SC-FDMA has many similarities to OFDM, chief among them for the uplink that frequency domain orthogonality is maintained among intra-cell users to manage the amount of interference generated at the base. SC-FDMA also has a low power amplifier de-rating (Cubic Metric / PAPR) requirement, thereby conserving battery life or extending range.

The baseline SC-FDMA signal is DFT-Spread OFDM (DFT-SOFDM) [2] as shown in Figure 3. The only difference from OFDM is the addition of the M-point FFT (DFT) in the figure which “spreads” M symbols onto the M sub-carriers selected by the symbol to sub-carrier mapping. The selected sub-carriers must also be either adjacent to or evenly spaced to maintain the low PA power de-rating. The signal is considered single carrier as the first M-point FFT and the larger N-point IFFT cancel each other resulting in a single carrier signal in the time domain. The receiver can use simple frequency domain equalization.



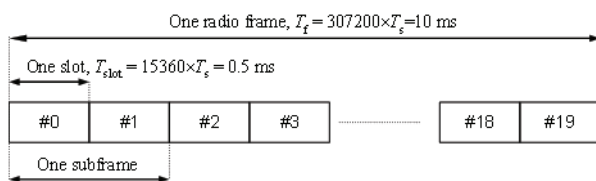
**Figure 3 - Block diagram for DFT-SOFDM**

An advantage for DFT-SOFDM as a SC-FDMA technique is that the numerology can match the OFDM downlink, with excellent spectral occupancy due to the IFFT providing pulse shaping of the signal. The OFDM numerology provides for an additional vacant DC sub-carrier to simplify some receiver architectures; a vacant sub-carrier cannot be used with DFT-SOFDM without affecting the low PA de-rating property of DFT-SOFDM. Table 2 also provides the uplink sub-frame numerology for different spectrum allocations.

Two types of reference signals (RS) are supported on the uplink - demodulation reference signal, associated with transmission of uplink data and/or control signaling and sounding reference signal, not associated with uplink data transmission used mainly for channel quality determination if channel dependent scheduling is used. Orthogonality of reference signals is obtained via frequency domain multiplexing onto a distinct set of sub-carriers. The RS sequence length is equal to the number of sub-carriers in the resource blocks. For allocation sizes of 3 resource blocks or more, the demodulation RS sequence is generated by truncation of ZC (Zadoff-Chu) sequences. For smaller allocations, computer generated sequences will be used.

### C. Frame Structure

The E-UTRA frame structure is shown in Figure 4 where one 10ms radio frame is comprised of ten 1ms sub-frames. For FDD, uplink and downlink transmissions are separated in the frequency domain. For TDD, a sub-frame is either allocated to downlink or uplink transmission. Note that for TDD, sub-frame 0 and sub-frame 5 are always allocated for downlink transmission. An alternative frame structure exists in E-UTRA to provide compatibility with LCR-TDD. However, only the frame structure shown in Figure 4 will be discussed in this paper. Note that the basic time unit is given by  $T_s = 1/(15000 \times 2048)$  seconds.



**Figure 4. E-UTRA frame structure**

Transmitted signal in each slot is described by a resource grid of sub-carriers and available OFDM symbols. Each element in the resource grid is called a resource element and each resource element corresponds to one complex-valued modulation symbol. The number of OFDM symbols per sub-frame is 7 for normal cyclic prefix and 6 for extended cyclic prefix.

In both downlink and uplink, a basic scheduling unit is denoted a resource block. A resource block is defined as 7 or 6 consecutive OFDM symbols in the time domain depending on the cyclic prefix length and 12 consecutive sub-carriers (180 kHz) in the frequency domain.

### D. Extensions of Existing Rel-6 UMTS Techniques

Several advanced packet transmission techniques have been standardized in the current UMTS standards, namely fast link adaptation (adaptive modulation and coding with hybrid ARQ) on short frame durations. Table 3 details existing Rel-6 techniques and their possible extension for E-UTRA.

In the downlink and uplink of E-UTRA, frequency domain (or selective) scheduling (FDS) can significantly (e.g., 20-30% [4][5]) improve system capacity over time domain scheduling (TDS). In E-UTRA, both frequency selective and frequency diverse scheduling will be supported. The frequency diverse mode may be used at higher speeds, for edge-of-cell operation, low-overhead services, and for some control channels.

Feature	Rel-6 HSxPA	LTE E-UTRA
TTI Size	2 msec	1.0 msec
Modulation	QPSK, 16-QAM DL, QPSK, 2-QPSK UL	QPSK, 16-QAM, 64-QAM DL, QPSK, 16-QAM UL
HARQ + N-channel Stop-and-Wait	N=6 DL, N=8 UL Async DL, Sync UL IR is default	Synchronous UL / Asynchronous DL IR is default
Coding	Conv & Turbo Code	Advanced coding with lower base rate
Fast Scheduling	TDS	TDS and FDS

**Table 3 - Physical layer techniques for E-UTRA (FDD)**

### F. Multi-Antenna Subsystem (MAS) and MIMO

To reach the E-UTRA peak data rate requirement, spatial division multiplexing of multiple data streams to a single mobile station must be supported. At least 2, and up to 4 transmit antennas are considered (FDD). In addition to single-user MIMO, multi-user MIMO may be supported by transmitting different data streams to different users within the same resource region via spatial division multiple access (SDMA). For the control channels, open-loop transmit diversity schemes such as cyclic shift diversity or space-time block codes will be considered. To support closed-loop MIMO operation for the shared data channel, feedback of channel information or precoding information is needed.

### G. Interference Mitigation

To maximize the spectral efficiency, frequency reuse factor of one is proposed for both downlink and uplink. Inter-sector/cell interference can be especially severe for mobile stations at the edge of cell or at bad coverage locations. Slow power control on the uplink will mitigate interference, as may interference coordination/avoidance or averaging. Beam-forming antenna solutions at the base station can also be seen as a means for uplink inter-cell interference mitigation.

## IV. CONTROL CHANNELS

### A. Downlink Control Channel

Within each downlink sub-frame, downlink control signaling is located in the first  $n$  OFDM symbols ( $n \leq 3$ ). There is no mixing of control signaling and shared data in an OFDM symbol. Downlink control signaling consists of: format indicator to indicate the number of OFDM symbols used for control in this sub-frame; scheduling control information (downlink assignment and uplink scheduling grant); and downlink ACK/NACK associated with uplink data transmission. An example of how downlink control signaling is mapped in a sub-frame is shown in Figure 5.

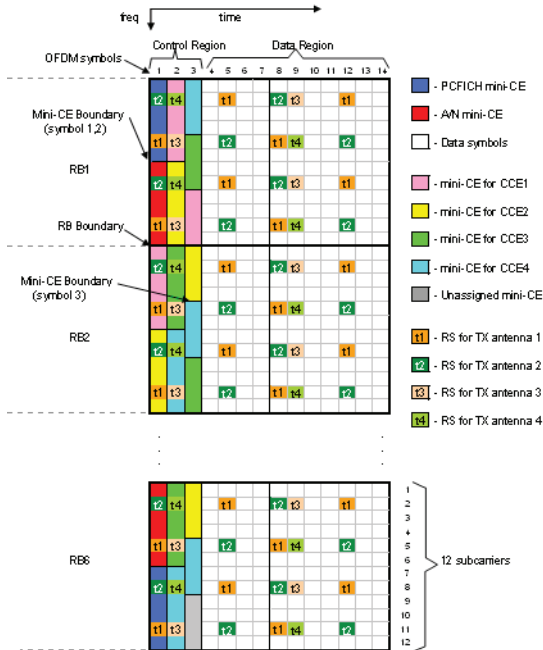


Figure 5. Example of downlink control signaling mapping

Information fields in the scheduling grants can be divided into distinct categories as follows: control fields containing information related to resource indication such as resource block and duration of assignment; control fields containing information related to the transport format such as multi-antenna information, modulation scheme, and payload size; and control fields containing information related to H-ARQ support such as process number, redundancy version, and new data indicator. For the DL/UL assignment, per-user control channel is used with multiple control channels within each sub-frame. Each control channel carries downlink or uplink scheduling information for one MAC ID, the ID is implicitly encoded in CRC.

For good control channel performance different coding schemes are necessary. As a result, each scheduling grant is defined based on fixed size control channel elements (CCE) which are combined in a predetermined manner to achieve different coding rates. Only QPSK modulation is used so that only a small number of coding formats have to be defined. Because multiple control channel elements can be combined to effectively reduce effective coding rate, a user control channel assignment would then be based on channel quality information reported. A user then monitors a set of candidate control channels which may be configured by higher layer signaling. To minimize the number of blind decoding attempts, 1, 2, 4, 8 CCEs may be aggregated, resulting in code rates of approx 2/3, 1/3, 1/6, 1/12.

The downlink acknowledgment comprises of one-bit control information sent in association with uplink data transmission. The resources used for the acknowledgment channel is configured on a semi-static basis and defined independently of the grant channel. Because only one information bit is to be transmitted, CDM multiplexing among acknowledgments is proposed. CDM allows for power control between acknowledgments for different users and provides good interference averaging. However, orthogonality is not maintained in frequency selective channels for wideband transmission. As a result, a hybrid CDM/FDM scheme (i.e. localized CDM with repetition in different frequency regions) was adopted.

Table 4 provides the required quality targets for downlink control signaling.

Event	Target quality
DL scheduling information miss detection	(1e-2)
UL scheduling grant miss detection	(1e-2)
NACK to ACK error	(1e-4)
ACK to NACK error	(1e-4)

Table 4. Downlink control signaling target quality

### B. Uplink Control Channel

In E-UTRA, uplink control signaling includes ACK/NACK, CQI, scheduling request indicator, and MIMO codeword feedback. When users have simultaneous uplink data and control transmission, control signaling is multiplexed with data prior to the DFT to preserve the single-carrier property in uplink transmission. In the absence of uplink data transmission, this control signaling is transmitted in a reserved frequency region on the band edge as shown in Figure 6. Note that additional control regions may be defined as needed.

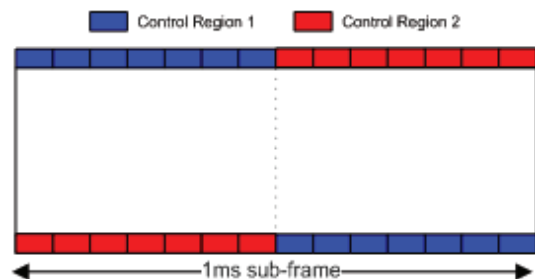


Figure 6. Control regions for uplink

Allocation of control channels with their small occupied bandwidth to carrier band edge resource blocks reduces out of carrier band emissions caused by data resource allocations on inner band resource blocks and maximizes the frequency diversity benefit for frequency diverse control channel allocations while preserving the single carrier property of the uplink waveform. This FDM allocation of control resources to outer carrier band edge allows an increase in the maximum power level as well as maximizes the assignable uplink data rate since inserting control regions with consecutive sub-carriers in the central portion of a carrier band requires that the time and frequency resources on either side of the control region to be assigned to different UEs.

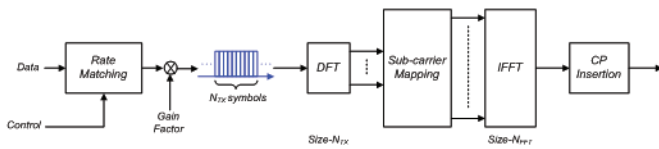


Table 5 provides the required quality targets for uplink control signaling.

Event	Target quality
ACK miss detection	(1e-2)
DTX to ACK error	(1e-2)
NACK to ACK error	(1e-4)
CQI block error rate	FFS (1e-2 – 1e-1)

**Table 5. Uplink control signaling target quality**

To preserve the single-carrier property of uplink transmission, L1/L2 control signaling must be multiplexed with data prior to the DFT when both data and control are to be transmitted in the same sub-frame. This may be performed as shown in Figure 7 where uplink data is rate-matched to provide room for control signaling. The rate matching is performed in one stage – the circular buffer RM takes presence of control signaling into account. Since the Node B has prior knowledge of uplink control signaling transmission, it can easily de-multiplex control and data packets. In addition, a power boosting factor may be applied when data is punctured to ensure similar data packet performance to when control is absent. This is especially important in the case of re-transmission since the data MCS cannot be changed due to synchronous H-ARQ operation in the uplink. This appropriate power boosting factor (in the order of 0.5-1.5dB) can be calculated based on the coding rate reduction resulting from puncturing.



**Figure 7. Multiplexing of control signaling with data**

Each control field is individually coded and separately multiplexed with data. This allows individual adjustments of transmission energy using different coding rate hence performance of each control field can be controlled. Note that the coding rate to use for the control signaling is linked to the data MCS and the relation is expressed in a table.

## V. SIMULATION RESULTS

To evaluate E-UTRA performance requirements, link and system simulation parameters have been defined in [2]. Table 6 summarizes main system simulation parameters.

**Table 6. System simulation parameters**

Parameter	Assumption	
Cellular Layout	Hexagonal grid, 19 cell sites, 3 sectors per site	
Inter-site distance (ISD)	500m, 1732m	
Distance-dependent path loss	$L = l + 37.6 \log_{10}(.R)$ , R in kilometers $l = 128.1 - 2\text{GHz}$	
Lognormal Shadowing	Similar to UMTS 30.03, B 1.41.4	
Shadowing standard deviation	8 dB	
Correlation distance of Shadowing	50 m	
Shadowing correlation	Between cells	0.5
	Between sectors	1.0
Penetration Loss	10, 20dB	
Carrier Frequency	2.0GHz	
Channel model	Typical Urban (TU)	
UE speeds of interest	3 & 30 km/h	
Total BS TX power	43dBm	
UE power class	24dBm	
Inter-cell Interference modeling	UL: Explicit modeling (all cells occupied by UEs),	
Min distance between UE and cell	$\geq 35$ meters	

Table 7 summarizes the system simulation reference cases with full-buffer traffic. The results presented are normalized to bits/second/Hz as 5MHz bandwidth is used for Rel-6 UMTS, while 10MHz bandwidth is used for E-UTRA.

**Table 7. System simulation cases**

Simulation	ISD	PLoss	Speed	Traffic Type
Cases	(m)	(dB)	(km/h)	Used
1	500	20	3	Full-buffer
2	500	10	30	Full-buffer
3	1732	20	3	Full-buffer

### A. Downlink Performance

Downlink performance for E-UTRA is evaluated in comparison to High Speed Downlink Packet Access (HSDPA). For the downlink results shown, non-ideal channel estimation is assumed with realistic CQI feedback and frequency selective scheduling with 10 mobiles per sector. For MIMO, explicit frequency/spatial multi-cell interference are modeled. Control channel is also explicitly model ( $n=3$ ). The resource block is 12 sub-carriers (180 kHz) by 7 OFDM symbols. In Tables 8 and Table 9, gains from E-UTRA over HSDPA for SIMO are shown. The E-UTRA spectral efficiency and average user throughput performance gain over HSDPA Type I receiver is ~ 2.1x and for 5%-ile user throughput ~ 1.7x.

**Table 8. Sector throughput – spectral efficiency (SIMO)**

Simulation Case	HSDPA (bps/Hz)	E-UTRA			
		1x2 IRC using RR	gain	1x2 IRC using PF	gain
1	0.658	1.31	2.0 x	1.38	2.1 x
3	0.683	1.12	1.6 x	1.32	1.9 x

**Table 9. 5%-ile cell-edge user throughput (SIMO)**

Simulation Case	HSDPA (bps/Hz)	E-UTRA			
		1x2 IRC using RR	gain	1x2 IRC using PF	gain
1	0.024	0.052	2.1 x	0.042	1.7 x
3	0.023	0.030	1.3x	0.035	1.5 x

In Tables 10 and Table 11, gains from E-UTRA over HSDPA for MIMO are shown. The performance gap in reaching the desired target range of 3-4x spectral efficiency and average user throughput can be met using MIMO techniques.

**Table 10. Sector throughput – spectral efficiency (MIMO)**

Simulation Case	HSDPA (bps/Hz)	E-UTRA			
		2x2	gain	4x2	gain
1	0.658	1.81	2.7 x	2.09	3.2 x
3	0.683	1.70	2.5 x	1.96	2.9 x

**Table 11. 5%-ile cell-edge user throughput (MIMO)**

Simulation Case	HSDPA (bps/Hz)	E-UTRA			
		2x2	gain	4x2	gain
1	0.024	0.045	1.9 x	0.045	1.9 x
3	0.023	0.036	1.6 x	0.036	1.6 x

### B. Uplink Performance

Uplink performance for E-UTRA is evaluated in comparison to High Speed Uplink Packet Access (HSUPA). For the uplink results shown, non-ideal channel estimation is assumed and explicitly modeled. Localized FDM is used and no uplink sounding is assumed. Therefore, only long term average channel quality and received interference levels are known at the base station. Although resource blocks are multiplexed in the frequency domain, frequency selective scheduling is not used in the simulation. Only the static interference coordination scheme given in [7] is used.

**Table 12. Uplink comparison (SIMO)**

Simulation Case	HSUPA		E-UTRA			
	Sector (bps/Hz)	5%-ile (bps/Hz)	Sector		5%-ile	
			bps/Hz	gain	bps/Hz	gain
1	0.312	0.0087	0.624	2.0x	0.0276	3.2x
2	0.307	0.0087	0.655	2.1x	0.0285	3.3x
3	0.261	0.0008	0.634	2.4x	0.0021	2.6x

In Table 12, gains from E-UTRA over HSUPA for SIMO are shown. The table shows a 2-3x E-UTRA performance improvement for 5%-tile and average user throughput, and spectral efficiency over HSUPA using the baseline technologies and without the use of channel aware scheduling. Table 13 shows performance gain with 1x4 SDMA. In this case, a sector throughput greater than 3x and edge user throughput of greater than 5x over HSUPA is achieved

**Table 13. Uplink comparison (1x4 SDMA)**

Simulation Case	HSUPA		E-UTRA			
	Sector (bps/Hz)	5%-ile (bps/Hz)	Sector		5%-ile	
			bps/Hz	gain	bps/Hz	gain
1	0.312	0.0087	0.996	3.2x	0.0460	5.3x
2	0.307	0.0087	1.027	3.3x	0.0480	5.5x
3	0.261	0.0008	0.888	3.4x	0.0047	5.9x

### C. VoIP Performance

VoIP performance is evaluated for full rate AMR (12.2 kbps), 50% VAF with 2 state Markov model. For the downlink, results are shown for two different control channel overhead scenarios where the n=2 scenario assumes two symbols in each DL sub-frame are reserved for L1/L2 control signaling and the n=3 scenario assumes three symbols are reserved. Note that even higher capacities are expected by increasing the number of NB TX antennas beyond 2 and also through the use of MU-MIMO

**Table 14. Downlink VoIP capacity**

Deployment Scenario	DL VoIP Capacity (n=2)	DL VoIP Capacity (n=3)
Case1	320	285
Case3	260	220

For the uplink, two VoIP scheduling approaches group scheduling (GRP) and semi persistent scheduling (SMP) were considered. VoIP capacity results are shown in Table 15. As expected, LTE VoIP performance for these scenarios is uplink limited. Note that higher capacities are expected with 4 NB RX antennas and also by employing MU-MIMO

**Table 15. Uplink VoIP capacity**

Deployment Scenario	UL VoIP Capacity (GRP, 10% blocking)	UL VoIP Capacity (GRP, 20% blocking)	UL VoIP Capacity (SMP, 10% blocking)
Case1	223	-	181
Case3	111	174	-

## VI. CONCLUSIONS

In this paper, an overview of the air interface for LTE E-UTRA with system performance results is provided. It was shown that LTE E-UTRA system performance can achieve 3-4x improvement over HSDPA and HSUPA with receiver diversity. LTE E-UTRA uplink performance improvement relative to HSUPA was achieved without using any MIMO, interference suppression, or larger TTI and was mainly due to orthogonality and ability to use narrow band transmissions for coverage limited situations. In the downlink, the performance gap in reaching the desired target range of 3-4x spectral efficiency and average user throughput can be met using MIMO techniques.

Motorola is leveraging its extensive expertise in mobile broadband innovation, including OFDM technologies (wi4 WiMAX), high speed backhaul solutions (Orthogon), IMS ecosystem, collapsed IP architecture, standards development and implementation, and comprehensive services to deliver industry leading LTE solutions.

For more information on LTE, please talk to your Motorola representative.

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Note – 3GPP documents may be downloaded from <ftp://ftp.3gpp.org>



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