3GPP
Release 5 and Beyond

The Evolution of UMTS

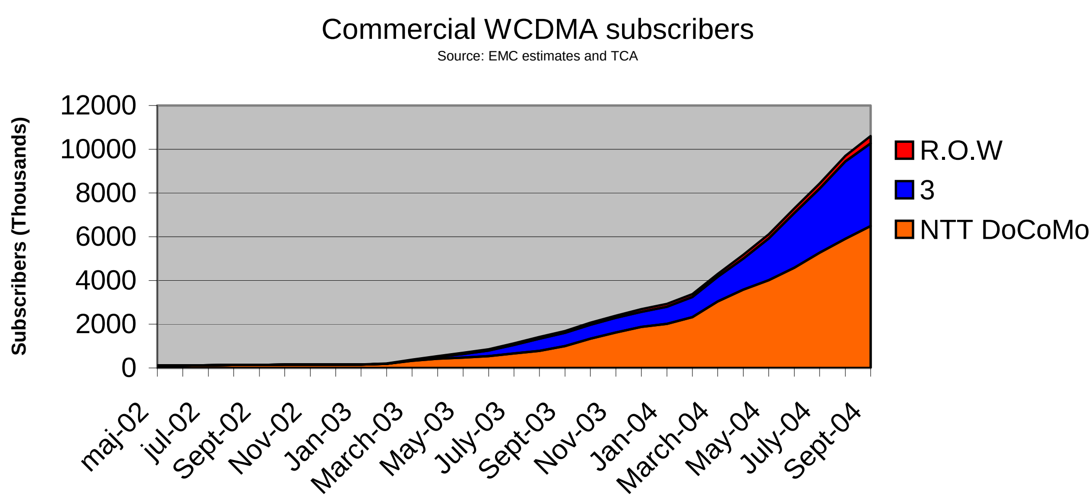
June 2004
(November 2004 Update)

The Evolution of UMTS - 3GPP Release 5 and Beyond

Preface

3G Americas presents this report on the fast growing commercialization of the Universal Mobile Telecommunications System (UMTS) and the significant progress being made in the industry towards the evolution of UMTS to Release 5 (Rel'5) of the 3rd Generation Partnership Program (3GPP). Our organization is committed to the GSM evolution of GSM/GPRS/EDGE and UMTS and its seamless deployment throughout the Americas.

3G Americas prepared a white paper in March 2003 titled *"UMTS to Mobilize the Data World"* to report on the progress of UMTS – from its inception in 1995; standardization by ETSI[1] in January 1998; to the commercialized launch in Japan by NTT DoCoMo and phase one trial launches in nine other countries by the first quarter of 2003. The paper provided documentation on the installation, testing and preparation of UMTS networks on several continents and the prediction that UMTS and EDGE would serve as complementary technologies for GSM operators throughout the world.



Since that time, UMTS has grown to be used by more than 10.7 million[2] customers worldwide as of September 2004 and is growing faster than GSM at the same point in its development timeline history. The rapid growth of UMTS, sometimes referred to as Wideband Code Division Multiple Access (WCDMA), led to a focus on the next significant evolution phase of UMTS, namely Rel'5. Rel'5 of the 3GPP standards has many important enhancements worth examining that are easy upgrades to the currently deployed Release 1999 (R'99) UMTS networks and that are a lot closer to deployment than many analysts originally forecasted. UMTS Rel'5 will provide wireless operators and consumers the improvements they need for offering higher speed wireless data services with vastly improved spectral efficiencies through the High Speed Downlink Packet Access (HSDPA) feature. In addition to HSDPA, UMTS Rel'5 introduces the IP Multimedia System (IMS) architecture that promises to greatly enhance the end-user experience for integrated multimedia applications and offer the mobile operator an efficient means for offering such services. UMTS Rel'5 also introduces the IP UTRAN concept to realize network efficiencies and reduce network costs.

UMTS 3G deployments will reach widespread implementation around the world throughout 2004 and 2005. Over the same time period, pre-commercial testing and trials of Rel'5 features are expected with

[1] ETSI: European Telecommunications Standards Institute
[2] This figure (and others given later in this paper) includes NTT DoCoMo's FOMA subscribers. FOMA is an early deployment of 3GPP Rel'99 equivalent UMTS radio. Proprietary aspects due to the early deployment are planned to be removed in 2004.

commercial roll-outs likely in the mid-late 2005 and early 2006 timeframe. In fact, NTT DoCoMo of Japan is already planning to launch HSDPA as early as 2005 to enhance its FOMA network and Cingular Wireless (USA) has announced a UMTS trial in Atlanta which includes a testing of HSDPA with the expectation that they will launch UMTS/HSDPA in 2H 2005. 3G Americas offered a new white paper, *"The Evolution of UMTS – 3GPP Release 5 and Beyond",* to build upon its 2003 UMTS progress report and provide an overview and status update of the key 3GPP Rel'5 specifications and features including HSDPA, IMS and IP UTRAN. *"The Evolution of UMTS – 3GPP Release 5 and Beyond"* was a collaborative effort by 3G Americas' Board member companies.

Due to the significant speed of change in the wireless industry, *"The Evolution of UMTS – 3GPP Release 5 and Beyond"* white paper has been updated as of November 23, 2004 to provide more timely data points.

Introduction

In early 2003, 3G Americas reported on the progress of the Third Generation (3G) UMTS technology, noting that the industry was preparing for widespread commercialization of UMTS. Now, in less than two years, there are 53 3G UMTS networks in commercial service in 27 countries[3] and many other UMTS networks in pre-commercial or trial phase with still other networks in planning/deployment stages. NTT DoCoMo (Japan) has more than seven million Freedom of Mobile Multimedia Access (FOMA®) customers as of the end of October 2004. In first quarter 2004, NTT DoCoMo grew its customer base by one million, adding more than 0.5 million subscribers in April 2004 alone. The company added another 1.5 million FOMA customers in 2Q and 1.91 million in 3Q 2004. By early 2007, NTT DoCoMo expects to have 25 million customers on its 3G mobile phone network. Additionally, there are more than 3.5 million UMTS customers throughout Europe and more than a quarter of a million with Vodafone KK (Japan) as of September 2004. 3G UMTS networks offer services in Australia, Austria, Bahrain, Belgium, Denmark, Finland, France, Germany, Greece, Guernsey, Hong Kong, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland, UAE, U.K., and the U.S. as of November 23, 2004. According to EMC, there are an additional 87 operators in 37 countries committed to launching UMTS service[4]. TIM Italy launched their complementary EDGE and UMTS networks nationwide in November 2004. Announcements of similar EDGE/UMTS business plans have been publicly discussed by other operators throughout the world including: AT&T Wireless (former) and Cingular Wireless (USA); MTC Vodafone (Bahrain); VIPNet (Croatia); Investom/Scancom (Cyprus); Eurotel Praha and T-Mobile (Czech Republic); TeliaSonera, DNA, and Elisa (Finland); Bouygues Telecom (France); STET Hellas (TIM) in Greece; CSL and Sunday (Hong Kong); Cellcom (Israel); TIM (Italy); GPTC (Libya); DiGi (Malaysia); Telfort (Netherlands); Telenor Mobile and Netcom (Norway); Polkomtel/Plus GSM (Poland); Eurotel Bratislava (Slovak Republic); MTN (South Africa); Swisscom Mobile (Switzerland); and Mobifone (Vietnam).

A further indication of the substantial growth of UMTS over the past year is provided in Figure 1 where it is shown that the number of different brands and models of 3GPP UMTS terminals commercially available has nearly quadrupled over the last year. A representation of the various UMTS terminal devices commercially available in the marketplace today is shown in Appendix B of this paper.

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[3] EMC World Cellular Database, November 23, 2004, see Appendix A

[4] Appendix A: *Global UMTS Operator Network Status*, EMC, November 23, 2004

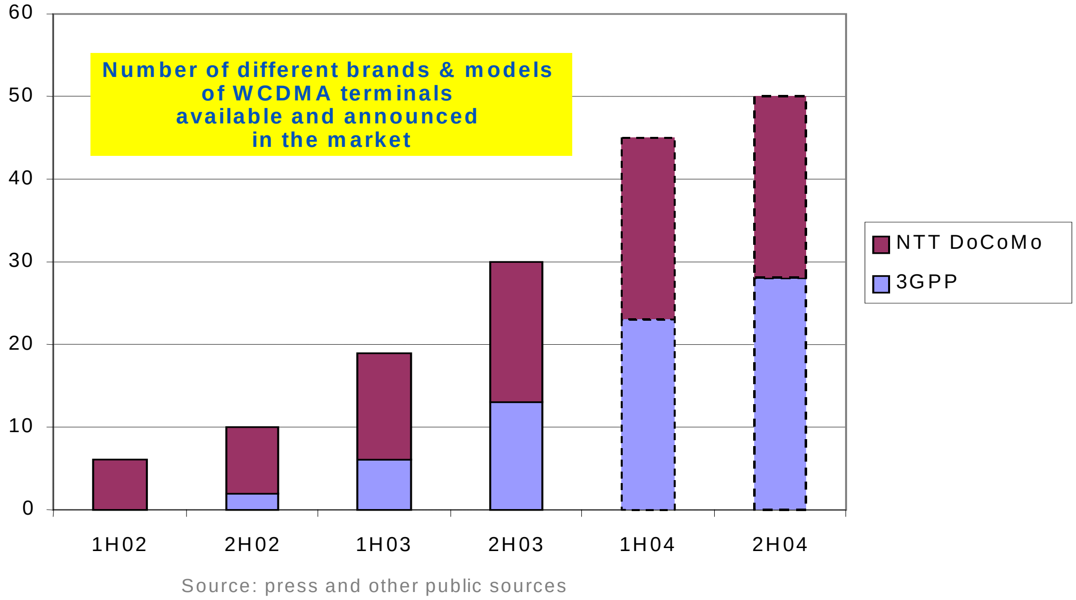

Figure 1. Growth in UMTS Terminal Availability

The initial standards for UMTS were completed by 3GPP in April of 1999 and termed Release 1999 (R'99). These standards are the basis for a majority of the current commercially deployed UMTS systems previously discussed. In April of 2001, a follow up release to R'99 was standardized in 3GPP, termed Release 4 (Rel'4), which provided minor improvements of the UMTS transport, radio interface and architecture. In March 2002, Rel'5 of UMTS was completed which defined features such as the High Speed Data Packet Access (HSDPA) channel, the IP Multimedia Subsystem (IMS) and IP UTRAN that provide significant spectral/network efficiency, performance and functionality advantages over the R'99 and Rel'4 standards. The support of UMTS in different frequency bands is release independent. UMTS was initially defined in the IMT-2000 defined frequency band (1885-2025 MHz and 2110-2200 MHz) with support for UMTS in the US PCS 1800/1900 MHz band following shortly after. Most recently, support of UMTS in the 850 MHz (December 2003) and 1700/2100 MHz (March 2004) bands has been completed.

The Rel'5 UMTS standards were developed such that the Rel'5 enhancements can co-exist on the same RF carrier as currently deployed R'99 UMTS. Thus, a current R'99 UMTS carrier can be upgraded to support legacy R'99 as well as new Rel'5 terminals in the same 5 MHz band (e.g. HSDPA and R'99 traffic can be supported on the same 5 MHz carrier). HSDPA is one of the key Rel'5 features that offers significantly higher data capacity and data user speeds on the downlink (theoretically up to 14 Mbps peak) compared to R'99 UMTS through the use of very dynamic adaptive modulation, coding and scheduling with Hybrid Automatic Retransmission Request (H-ARQ) processing. Through HSDPA, operators will benefit from a technology that will provide improved end-user experience for web access, file download and streaming services. Wireless Broadband access to the Internet, intranet and corporate LAN will benefit greatly from HSDPA. In addition to HSDPA, UMTS Rel'5 introduces the IP Multimedia System (IMS) architecture that promises to greatly enhance the end-user experience for integrated multimedia applications and offer the mobile operator an efficient means for offering such services. The IMS enables new and more advanced multimedia applications for operators (including VoIP), the ability for these services to interact and the ability to fully integrate real-time, near real-time as well as non-real-time services. UMTS Rel'5 also introduces the IP UTRAN concept to realize network efficiencies and reduce network costs. IP UTRAN uses IP as a transport protocol to realize network efficiencies that reduce the cost of delivering traffic and can provide wireless traffic routing flexibility.

The performance and spectral/network efficiency advantages offered through Rel'5, coupled with new service creation opportunities made possible through the IMS architecture, are key factors accelerating the interest and momentum towards realization of Rel'5 of UMTS. This white paper, *"The Evolution of UMTS – 3GPP Release 5 and Beyond",* published in June 2004 and updated as of November 23, 2004, reports on the significant progress made towards commercialization of R'99 UMTS since our last report[5], which has now led the industry to focus on the evolution to Rel'5. An overview of the key Rel'5 features will be provided along with the expected timeframe for the development, trial introduction and commercial deployment of the Rel'5 feature set. Lastly, this paper looks at the evolution beyond Rel'5 and likely future enhancements through Rel'6 and Rel'7 of 3GPP.

The Growing Demands for Wireless Data

The appetite for wireless data has only just begun. End users are eager to adopt new bandwidth-hungry voice and data services that push current network spectrums to their limits. Wireless data is forecast to be the new revenue bread-winner for wireless operators as the trend for mobile internet applications and wireless data mobile services for both the enterprise market and consumers begins to grow exponentially and become as common as making a wireless phone call.

Recent predictions by leading analysts and organizations on the opportunities for wireless data include:

> "Mobile services will be worth 126 billion dollars worldwide by 2008, and will account for almost 20% of total mobile operator revenues," according to a strategic report, *Mobile Content and Applications 2003* published by the ARC Group. "While voice revenues are forecast to grow at a slower pace the total mobile market will continue to expand as usage of services such as messaging, games and music start to penetrate the mass market." [6] The ARC Group added, "This represents a solid growth trend for the mobile services market over the next five years, with revenues more than doubling from their current level."
>
> In-Stat/MDR reported that in the U.S., "54% of mobile consumers were using one or more data services over their phones, led by SMS but with strong showings by Internet access services, ringtones and mobile games." In-Stat also noted that, "Wireless data customers use 42% more voice minutes than non-data users, in addition to spending an average of 19% more on their total wireless bill each month and 64 percent more on their current handset." [7]
>
> Strategy Analytics estimates that U.S. operators made a gross profit of roughly $50 for every Mb of Over the Air (OTA) download content sold in 2003: a healthy return when compared to the revenues generated by voice traffic ($1.63/Mb).[8]
>
> Roughly two-thirds of all businesses and organizations will deploy a mobile data solution by 2007 according to research from the Meta Group. Mobile email will top the application list and will only be the start for most businesses, with half of the organizations launching a wireless email solution within three years and 75% in four years.[9]

These predictions clearly point towards growing demands for wireless data capacity and performance. There have been several other reports recently that further support the trend towards significant growth in wireless data services. For instance, CTIA reports currently 150 million Americans sending 2.5 billion monthly mobile text messages and that it won't be long before customers demand the capability to send MMS messages that require bandwidth and capacity. Cellular camera phones are outselling digital cameras. In fact, worldwide camera phone sales are expected to double this year, accounting for more than 24 percent of all handset sales, up from 70 million in 2003 to 150 million in 2004, according to a report from InfoTrends Research Group.[10]

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[5] 3G Americas, "*UMTS to Mobilize the Data World*", February 2003: www.3gamericas.org/pdfs/umtspaper_march2003.pdf
[6] Telecomtv.com, "*SMS helps drive wireless data in the US*"; Tim Marshall, April 20, 2004
[7] In-Stat/MDR, *"Psychographics and Demographics of Wireless Data Subscribers"*, April 2004
[8] Convergence Catalysts, *"US Carriers Make Gross Profit of $121 Million on 2003 Content Download Sales Totaling 2.5 Million Mb*", Issue: 2004-15, April 26, 2004
[9] VNU Network, *"Two-thirds of firms will be wireless by 2007"*; Robert Jaques, October 20, 2004; based on Meta Group research study, October 19, 2004
[10] InfoTrends Research Group, "*2004 Worldwide Camera Phone and Photo Messaging Forecast*", March 2004

Another study from Dresdner Kleinwort Wasserstein (DrKW) Equity Research predicts more than a ten-fold increase in cellular traffic, in European cities for example, by 2010. Predictions of cellular traffic growth by application type from this study are shown in Figure 2 below. In addition to a more than five-fold increase in cellular voice traffic by 2010 relative to 2002, this report predicts that cellular video traffic will increase from negligible levels in 2002 up to 7.7 Mbit/user/day by 2010. Similarly, cellular packet data (e.g. internet, email, etc.) is predicted to increase from negligible levels in 2002 up to 6.8 Mbit/user/day in 2010. Combined cellular video and packet data traffic is expected to outpace voice traffic by 2010, illustrating the need for spectrally efficient cellular data technologies to support this growth.

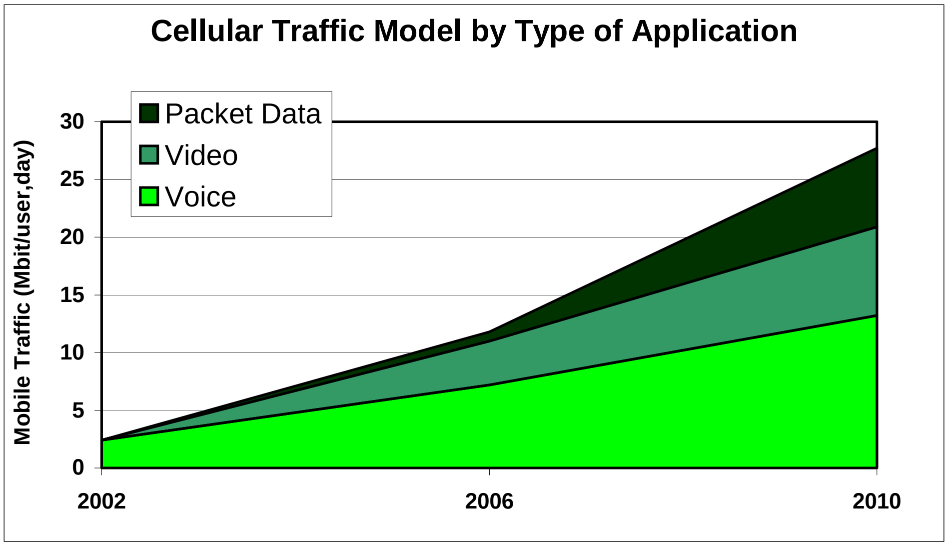

Figure 2. Cellular Traffic Model by Type of Application

Coupled with the market trends toward significant growth and demand for mobile data services are the growing expectations for the end user experience. Figure 3 illustrates typical speeds required for different wireless application types, showing user speeds in excess of 200 Kbps will be required. Although today's UMTS R'99 can provide data rates of approximately 200-300 Kbps for wide area coverage, which is sufficient for most existing packet-data applications, only a limited number of users can be supported simultaneously at such speeds. As the use of packet-data services increases and new services are introduced, greater capacity for high speed data applications will be required. Deployment of UMTS Rel'5 features will be critical to meeting these high expectations and quickly growing data capacity requirements.

Mapping of Services to Preferred Speeds

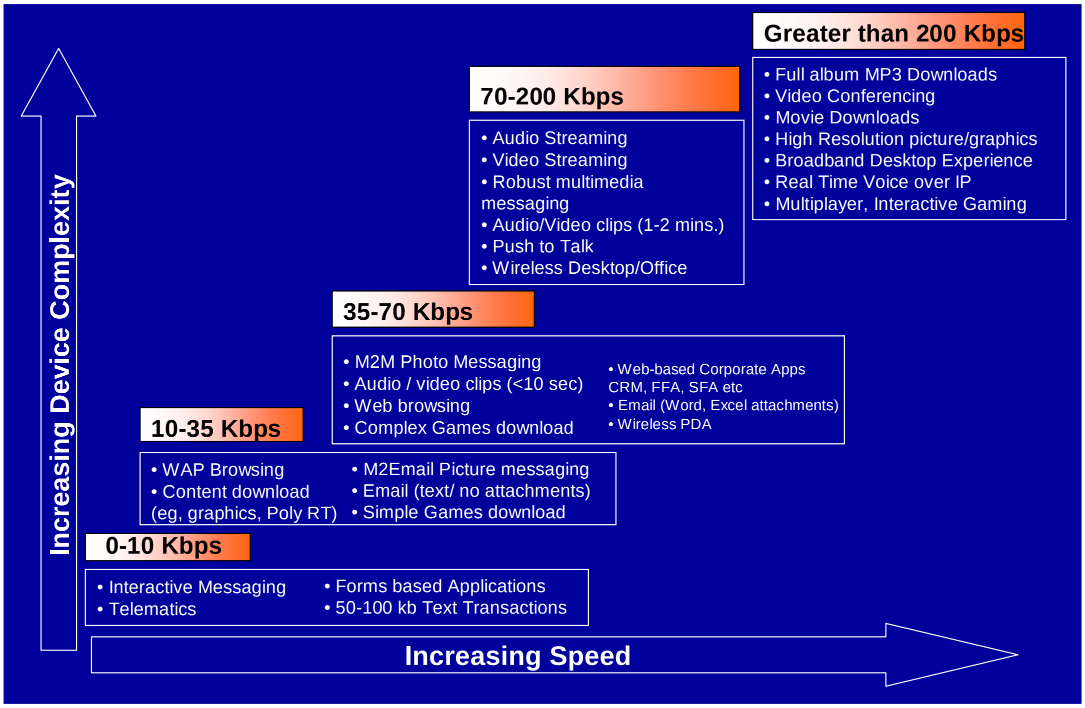

Figure 3. Mapping of Wireless Data Services to Preferred Speeds

For GSM operators, UMTS is 'open for business'. As basic mobile data services provide higher percentages of revenues for GSM operators, UMTS delivers increased bandwidth and capacity for both voice and data (particularly through Rel'5), opens up more revenue generating services, improves overall end-user experience and ultimately drives higher revenues. Leading industry analysts' predictions on the growth of UMTS subscribers vary in numbers but remain optimistic for benefits to operators and their customers.

> UMTS Forum forecasts there will be "12-15 million 3G/UMTS customers by end of 2004…" [11]
>
> The Shosteck Group reported that, "UMTS subscribers worldwide will increase to 125 million to 150 million subscribers by year-end 2007." This number, the firm references, would be 20-25 million greater than was previously estimated in September 2003. In September 2004, the firm extended its forecast of UMTS handsets sales to 140 million sold during 2007 and 190 million in 2008.[12]
>
> "In 2004, UMTS technology is poised to grow more than 200 percent from 2003." according to a report by ABI Research.[13]
>
> Analysys Research forecasts that there will be 5.3 million 3G subscribers in Western Europe by end of 2004, up from 600,000 at the end of 2003; however the firm expects subscriber growth to stall until 2005, while network operators and handset manufacturers work through problems associated with new mass market launches. From 2005 to 2009, it expects subscribers to grow to a whopping 70 percent to 240 million Western European subscribers.[14]

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[11] UMTS Forum presentation, *"3G/UMTS: The Natural Choice*", Jean-Pierre Bienaimé, EuroIndia 2004 - March 24-26, 2004, New Delhi

[12] Shosteck Group white paper, "*UMTS - When and Why It Will Happen: Timetables and Forecasts"*, September 2003, page 35; *Shosteck E-STATS, September 2004*

[13]ABI Research, *Wireless Infrastructure Quarterly Service*/press release: *Cellular Pessimism Takes a Holiday Says ABI Research*, April 29, 2004

[14] Analysys Research, "*Western European Mobile Forecasts and Analysis 2004-2009"*/press release, April 27, 2004

> The number of WCDMA users worldwide will rise from 2.1 million at the end of 2003, to 361 million by the end of 2008. By then, 43% of all mobile users in Western Europe will use 3G, with Japan and China accounting for nearly a quarter of the world's WCDMA users.[15]

Recent industry progress of UMTS, which is discussed in the next section, clearly supports these analyst predictions.

Progress of R'99 UMTS

R'99 UMTS is a very mature specification, having been initially standardized in the early-mid 1999 timeframe. The R'99 UMTS specifications provided an evolution path for the GSM, GPRS and EDGE technologies that enables more spectrally efficient and better performing voice and data services through the introduction of a 5 MHz UMTS carrier. Commercial deployments of R'99 UMTS networks began well over a year ago and the number of commercially deployed UMTS systems has grown rapidly since then, as indicated in the introduction to this paper and as evidenced by Appendix A of this paper. To further illustrate the rapid progress and growth of UMTS, recent accomplishments from each of the 3G Americas participating vendors on R'99 UMTS are given in this section.

Ericsson has published commercial agreements with 47 operators to supply 3G UMTS network infrastructure equipment and is the primary supplier to 28 of 46 launched commercial networks as of October 2004. In the U.S., AT&T Wireless commercially launched UMTS services in Dallas and San Diego using equipment provided by Ericsson, following a successful UMTS network trial in Dallas that began in December 2002 and was also provided by Ericsson. Ericsson's extensive experience in the areas of network design, end-to-end system performance and 3G Radio Access Network tuning and optimization have been very valuable for Ericsson and its customers. Ericsson-powered networks have In-Service-Performance figures in line with GSM. At 3GSM World Congress 2004, Ericsson demonstrated continued market progress for 3G services with interoperable and commercial 3G handsets from eight leading handset vendors. Visitors experienced live video telephony and different kinds of streaming services as proof of the great steps taken in true UMTS interoperability between commercial handsets and systems. The demonstration of video telephony and live streaming show the potential of new exciting services that fully leverage the capabilities of 3G and the Internet.

Gemplus has already delivered millions of USIM to support UMTS operators, including NTT DoCoMo, the H3G networks, mobilkom Austria, KT Freetel, and SK Telecom.

Lucent Technologies and Cingular Wireless are currently conducting a 3G UMTS and HSDPA trial in the Atlanta market. The network has been deployed in Cingular Wireless' 1900 MHz spectrum and is supporting voice, high-speed data and multimedia services. Lucent Technologies and T-Mobil recently completed a R'99 UMTS pilot project with participating companies including Rödl & Partner, SanData IT group, DATEV, the IT systems company BRZ Deutschland Bauinformationstechnologie, and the consultancy and systems house Dr. Städtler. The participating companies were provided high-speed access to their corporate networks using their laptops so that while working in the field they were able to access their customary applications with the corresponding speed and security as if they had been using their wireline office network. Lucent has also been working with AT&T Wireless (now merged with Cingular Wireless) on a UMTS trial in the greater Miami area to evaluate mobile voice and high-speed data services. Lucent also participated in field testing of 3G mobile networking technologies (including UMTS) sponsored by China's Ministry of Information Industries (MII), and teamed up with China Netcom for a UMTS trial in Shanghai. Lucent also has various other UMTS pilot network deployments underway in Europe.

Lucent also has seen tremendous uptake from customers for Merlin U530™ and U520 3G UMTS wireless PC card modems (jointly developed with Novatel Wireless) which support high-speed data connections on laptops, PDAs and other mobile devices. These cards are now being used in commercial 3G UMTS launches by more than a dozen operators in more than 17 countries, including: 3 (Australia, Denmark, Hong Kong, Italy, Sweden and U.K.), e-plus (Germany), Orange (U.K. and France), Telecom Italia Mobile

[15] Research and Markets Ltd., "Launching 3G: Progress and Bright Prospects for WCDMA"; September 2004

(Italy), Telefonica Moviles Espana (Spain), TMN (Portugal), O2 (Germany and U.K.), T-Mobile (Austria, Germany, UK), KPN Mobile (Netherlands and Germany), PTC (Poland), Partner Communications (Israel), AT&T Wireless (U.S.) and more.

Nokia currently has 44 UMTS R'99 reference customers, of which 31 are currently rolling out their networks and many others will be starting their rollout in the coming months. There are 53 fully commercially open UMTS networks at this time, and Nokia is supplying close to half of these networks. Nokia estimates that there will be 60 commercial UMTS R'99 networks open by the end of 2004. On the terminal side, Nokia has introduced four UMTS/GSM phones to date. The most recent addition was the Nokia 6630, the first quad-band phone for GSM 900/1800/1900, EDGE and WCDMA 2100 networks, which began shipping in November.

Nortel Networks is supplying infrastructure to the major global UMTS operators and a number of these operators have already made their commercial launch. The first Nortel Networks' customer to launch UMTS commercially was Mobilkom Austria who launched its UMTS service commercially nationwide in April 2003. The offer was based on UMTS mobile terminals delivered to Mobilkom by Siemens. In February 2004, a number of group operators within Vodafone announced the launch of UMTS commercial service for the corporate segment using a data-card supporting 384 Kbps. Among these operators were Nortel Networks' customers, Vodafone UK, Vodafone Spain, Vodafone Italy, and Vodafone Portugal. Each of these operators is deploying the UTRAN solution from Nortel Networks, while the core network solution is deployed in Spain, the UK, and Portugal. On March 18 2004, another Nortel Networks UMTS customer (T-Mobile International) announced its launch of UMTS service based on a Multimedia Net Card. Other Nortel Networks customers for UMTS are AT&T Wireless Systems at 1900 MHz in the U.S., Partner in Israel, O2 in the U.K., Germany, and Ireland, and Orange. Each of these operators has made extensive national deployments of UMTS and is expected to make a full commercial launch by the end of the year.

Siemens and NEC have commercial agreements to supply 30 customers with UMTS network infrastructure. At the end of September 2004, more than 40,000 base stations have been deployed in these networks and eighteen of these customers have launched commercial service and are delivering service to more than three million 3G subscribers. At the 3GSM World Congress 2004 in Cannes, Siemens showcased video telephony over a local commercial UMTS radio access network using the Siemens U15 terminal both to other U15s as well as a set-top residential video telephony solution connected to a fixed broadband IP connection.

Overview of 3GPP Rel'5

Through R'99, the 5 MHz UMTS carrier was defined to provide capacity and user performance advantages over predecessor technologies such as GSM, GPRS and EDGE. While Rel'4 of UMTS provided nominal enhancements to the transport, radio interface and features defined in R'99 UMTS Rel'5 extends the R'99 and Rel'4 specifications, offering an enhancement now called High Speed Downlink Packet Access, or HSDPA, a first step of evolving UMTS to deliver even more outstanding throughput and capacity performance. HSDPA will provide peak theoretical speeds up to 14 Mbps. Rel'5 of the 3GPP standards defines several new features that provide significant capacity, performance and efficiency advantages relative to R'99 UMTS and greatly enhances the ability to offer person-to-person services using a wide range of both real-time and non-real time media, voice, text, picture, video, etc. in an integrated fashion. Three of the key features that are part of Rel'5 are HSDPA, IMS and IP UTRAN, each of which is discussed below.

High Speed Downlink Packet Access (HSDPA)

HSDPA is based on a new distributed architecture enabling low delay link adaptation, channel quality feedback and H-ARQ processing. This is accomplished by incorporating many of the key scheduling and control processes at the base station, as opposed to the Radio Network Controller (RNC), and thus closer to the air-interface (see Figure 4). Specifically, the Medium Access Control (MAC) functionality, which fully resided in the RNC in R'99, is split between the RNC and NodeB (i.e. the base station) in Rel'5. In

Rel'5, most of the key MAC functions critical to delay and performance are defined by the MAC-HS, which is located in the NodeB.

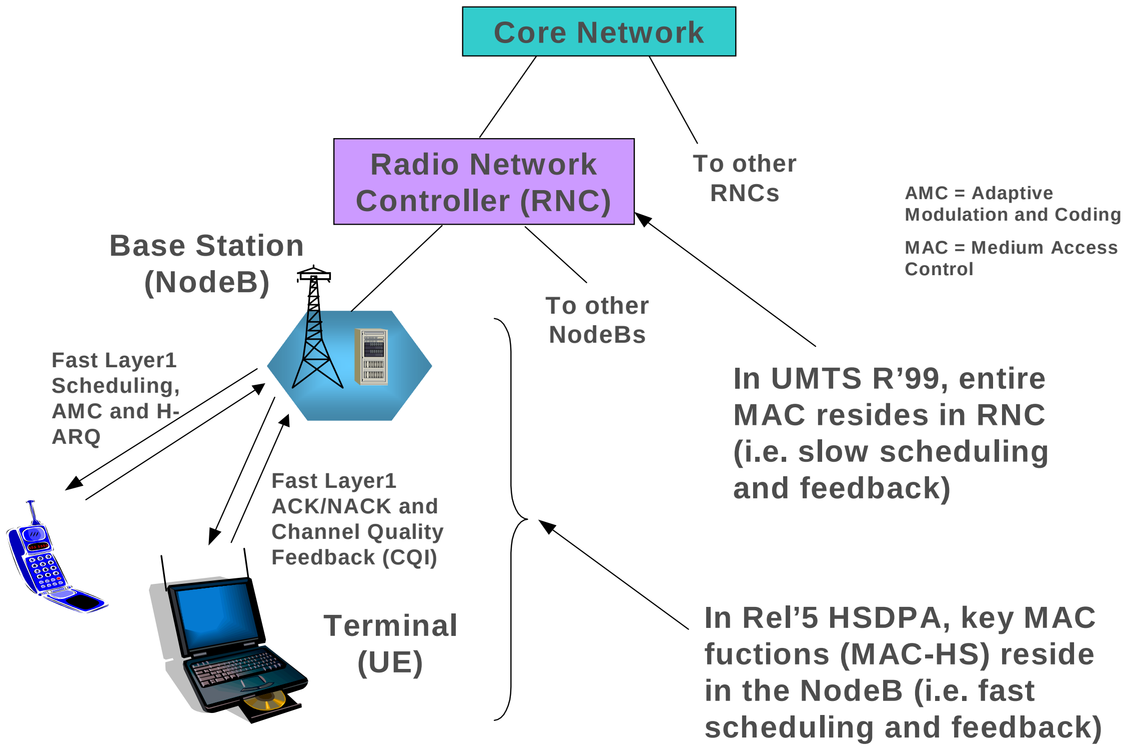


Figure 4. HSDPA System Architecture

HSDPA introduces a new paradigm for packet data where the fast power control and variable spreading factor principles inherent to R'99 are replaced with dynamic adaptive modulation and coding, multi-code operation, fast scheduling and physical layer retransmissions. The following paragraphs describe some of the details of the key HSDPA technology enhancements.

High-Speed Downlink Shared CHannel (HS-DSCH)

HSDPA defines a new transport channel type, known as the High-Speed Downlink Shared CHannel (HS-DSCH), which allows several users to share the air interface channel dynamically with peak channel rates up to 14 Mbps. The HS-DSCH uses 2-ms Transmission Time Intervals (TTIs) and a fixed spreading factor of 16 that allows for a maximum of 15 parallel codes for user traffic and signaling. The HS-DSCH supports QPSK and 16-QAM modulations, link adaptation, and the combining of retransmissions at the physical layer with HARQ. HSDPA downlink control needs are accommodated by a High-Speed Shared Control CHannel (HS-SCCH) that informs all the terminals how to decode the HS-DSCH (e.g. modulation, codes, retransmission information, etc.).

Fast scheduling

While R'99 uses scheduling of packet data at the radio network controller (RNC) level, HSDPA moves these decisions to the base station, and thus closer to the air interface. HSDPA uses terminal feedback information about channel quality, terminal capabilities, quality of service (QoS) needs, and air interface resource availability to achieve more efficient scheduling of data packet transmissions. Base station scheduling allows the system to take full advantage of short-term variations, and thus to speed and simplify the critical transmission scheduling process. HSDPA can, for example, manage scheduling to track fast fading fluctuations of the users and allocate resources to a single user (or a few number of users) for very short periods of time when their channel conditions are favorable. The scheduler will attempt to maximize the overall aggregate throughput of the HSDPA carrier while maintaining a certain level of fairness (i.e. making sure all users get some downlink resources periodically). The Proportional

Fair scheduler is one example of a scheduler that prioritizes users in the best channel conditions, while also prioritizing users that are not receiving a specified minimum data rate regardless of their channel conditions.

Fast Retransmissions and H-ARQ

When channel decoding of a data packet fails, due to interference or other causes, a mobile terminal immediately requests the retransmission of the data packets. While R'99 based networks handle those retransmission requests by the RNC, in HSDPA those retransmission requests are managed in the base station. If decoding of the initial transmission fails, a retransmission is sent which is self-decodable or can be combined with the initial transmission, still kept in the buffer, before channel decoding. The combining of different transmissions provides improved decoding efficiencies and diversity gains while minimizing the need for additional repeat requests. This Layer 1 operation is known as hybrid automatic repeat request (H-ARQ). By residing in the base station, H-ARQ avoids lub delays, measurably reducing the resulting retransmission delay.

Channel Quality Feedback

To accommodate fast Channel Quality Indications (CQI) and ACK/NACK signaling for H-ARQ from the terminal, an uplink High-Speed Dedicated Physical Control CHannel (HS-DPCCH) is defined. The base station gathers and utilizes the CQI of each active user to determine when each user is scheduled on the HS-DSCH.

Adaptive modulation and coding

The fast scheduling capability of HSDPA can be taken advantage of through adaptive modulation and coding to provide all users the highest possible data rate. The modulation and coding schemes are adapted dynamically based on the quality of the radio link while maintaining the power level constant. In addition to QPSK, HSDPA defines 16-QAM modulation that can be used when interference conditions are favorable. HSDPA supports the use of up to 15 parallel codes that can be dynamically shared amongst different users. Rate 1/3 turbo coding is used in HSDPA. However, by varying the transport block size, modulation and number of multi-codes the effective code rate can be anywhere from ¼ to ¾. Through H-ARQ with early terminations the code rate can approach 1.

Performance

Based on the attributes of HSDPA just discussed, HSDPA offers significant advantages over R'99 UMTS in peak throughput, latency and data capacity. The addition of 16-QAM modulation and the early termination capabilities of H-ARQ are the main enhancements enabling up to 14 Mbps peak throughputs for HSDPA (compared to 2 Mbps peaks for R'99 UMTS). The reduction of the TTI to 2 ms for HSDPA (compared to 10 ms minimum for R'99) and the distributed architecture of HSDPA discussed above lead to significantly lower latencies for HSDPA compared to R'99 UMTS.

In addition to higher peak data rates and reduced latency, HSDPA offers significant data capacity advantages over R'99 UMTS. Figure 5 demonstrates this capacity benefit of HSDPA compared to R'99 UMTS in both macro-cell and micro-cell environments. The average capacity in this figure represents the average aggregate throughput of all users serviced by a 5 MHz HSDPA carrier that is part of a multi-cell system. Results for HSDPA are shown with both a Round Robin (RR) scheduler and a proportional fair (PF) scheduler. The PF scheduler improves the aggregate throughput by prioritizing users in good channel conditions while still maintaining a minimum throughput performance level for users in poor channel conditions. Results for HSDPA with advanced receivers in the terminal including 2-way receive diversity and equalization are also shown. Figure 5 illustrates that HSDPA offers more than a three times increase in data capacity (without advanced receivers in the terminals) for densely populated environments (i.e. micro cell) where capacity demands are typically the greatest. With advances to include two antennas with equalization in the terminal, HSDPA can offer nearly five times the data capacity of R'99 UMTS.

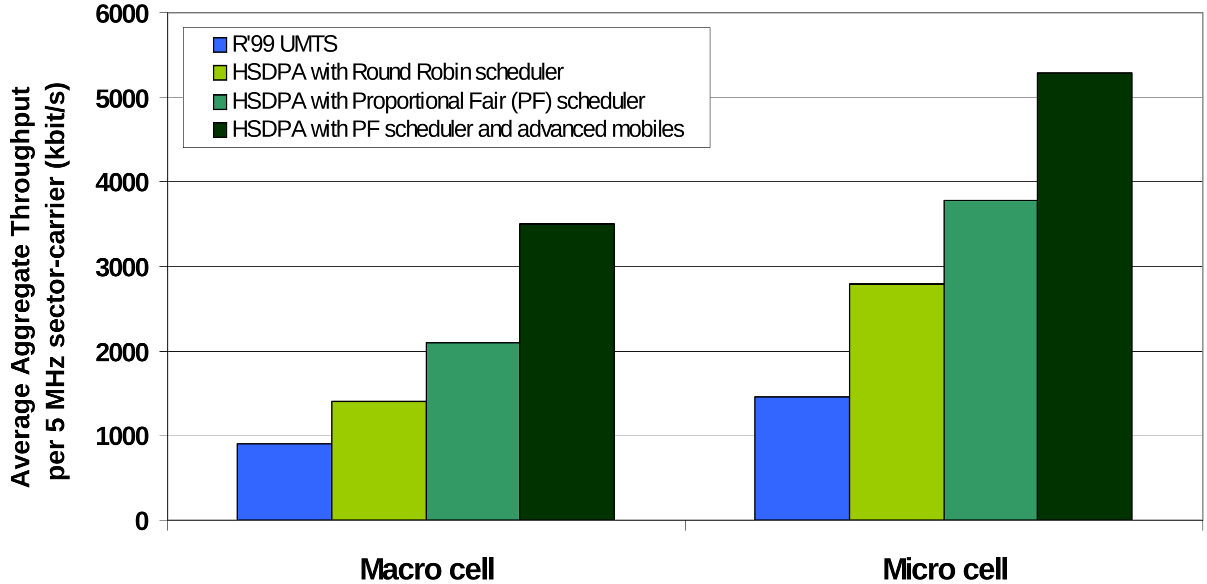


Figure 5. Capacity Improvement of HSDPA

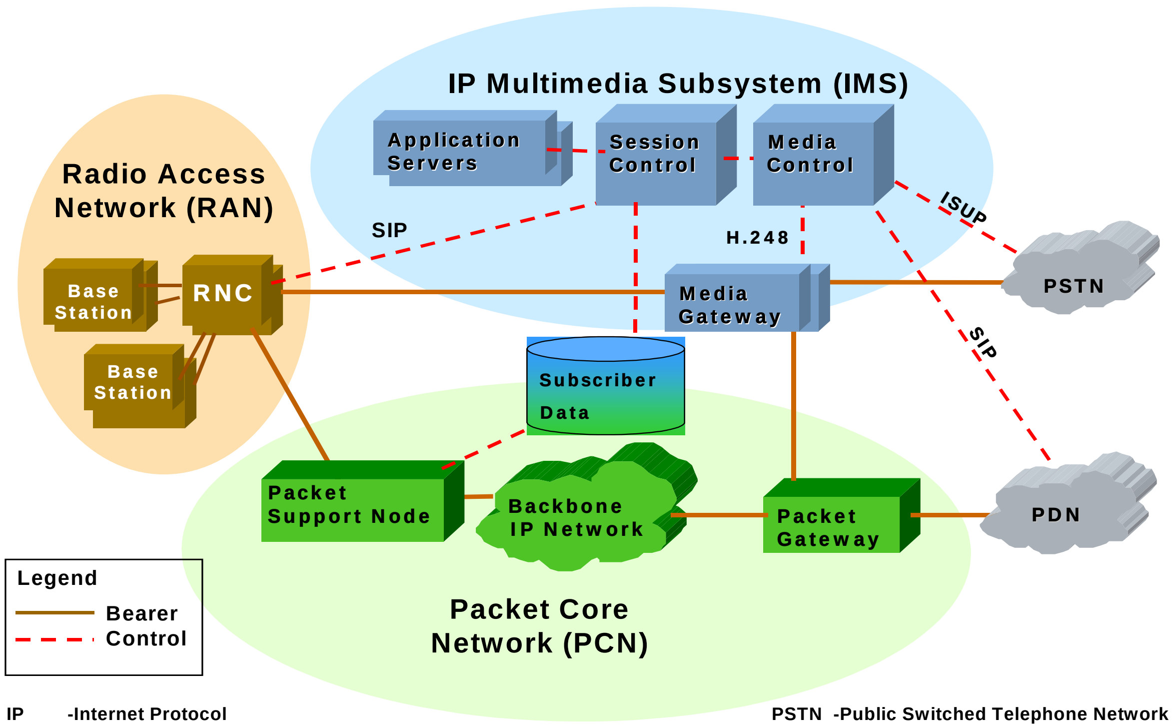
HSDPA Upgrade

The upgrade from R'99 UMTS to HSDPA is smooth since, from an air-interface perspective, HSDPA can co-exist on the same RF carrier with R'99 UMTS. The dynamic code sharing capabilities of HSDPA makes it possible to dynamically share code resources between R'99 UMTS and HSDPA. In the areas where HSDPA coverage is rolled out, the introduction of HSDPA mainly affects the radio base station (or NodeB) through the introduction of a new Medium Access Control sub-layer (MAC-hs) while for the most part maintaining the Radio Network Controller (RNC) functionality of R'99. To enable the use of HSPDA, the base station must be capable of supporting the new baseband and MAC-hs processing. This could be done through remote software downloads to the NodeB or could require new hardware (e.g. new baseband channel cards) depending on the legacy NodeB capabilities. It is expected that the RNC will only require a software upgrade to support HSDPA. No substantial impact to the core network is expected. New terminal devices are required to support the HAR-Q, multi-code and control processing for HSDPA. There are twelve different categories of mobiles defined for HSDPA that specify the modulations and number of codes the terminals must support to be compliant with each category, allowing for various complexities of terminals to be implemented.

IP Multimedia Subsystem (IMS)

The IP Multimedia Subsystem (IMS) provides a flexible architecture for the rapid deployment of innovative and sophisticated features. The IMS focuses on introducing both a technical and commercial framework for a mobile operator to offer person-to-person services using a wide range of integrated media, voice, text, picture, video etc. The standards have recommended the adoption of the Session Initiation Protocol (SIP) as the service control protocol, and this will allow operators to offer multiple applications simultaneously over multiple access technologies such as GPRS or UMTS or ultimately other wireless or even fixed network technologies. The IMS standard will speed the adoption of IP based multimedia on handsets, allowing users to communicate via voice, video, or text via a single client on the handset.

The vision for the IMS core network is maximum flexibility and independence from the access technologies. This flexibility is accomplished, in part, via a separation of access, transport, and control. The control is further separated into media control, session control, and application control. Figure 6 illustrates this with a simplified view of the IMS. The Radio Access Network (shown in brown) provides the over-the-air connection from the user equipment to the core network. It also provides low level mobility management. The Packet Core Network (shown in green) provides transport for the signaling and bearer, and high level mobility management. The IMS provides the control of applications, control of sessions, and media conversion. Within the IMS, media control, session control, and application control are separated in distinct entities.



IP	**-Internet Protocol**	**PSTN**	**-Public Switched Telephone Network**
ISUP	**-Integrated Services digital network User Part**	**RNC**	**-Radio Network Controller**
PDN	**-Packet Data Network**	**SIP**	**-Session Initiation Protocol**

Figure 6. IP Multimedia Subsystem and Connected Networks

Some of the first applications expected to be launched using the standard will be Push-to-Talk over Cellular (PoC), Presence and Instant Messaging and many other interactive applications eventually evolving to full fledged Voice and Video over IP. These applications can use a variety of basic network services offered by IMS like:

- session control services including subscription, registration, routing and roaming
- combination of several different media bearer per session
- central service based charging
- secure authentication and confidentiality based on the ISIM/USIM
- quality of service support

A central component of the IMS is the serving Call State Control Function (CSCF) which proxies all SIP signaling traffic in order to provide the above stated network services. Persistent subscriber data (including the current subscriber location in terms of network connection) is held in the Home Subscriber Server (HSS) which is the evolution of the HLR in the standardization. Application servers connect via standardized interfaces to the CSCF for being part of a session with one or several subscribers and the HSS for accessing and storing highly-available subscriber data. The proxy CSCF dynamically authorizes QoS e.g. on the GPRS and UMTS access via the Go interface. This will reduce the integration effort for introducing additional multimedia applications which leverage the mobile operator assets.

Beside these basic services, the IMS supports the interworking with PSTN and CS domain for voice, and with corporate intranets, ISP networks and the Internet. Further, IMS is access agnostic and works together with any packet-based access network. This allows operators to leverage the IMS core infrastructure by using it not only for UMTS radio access, but also for GPRS, EDGE, TD-SCDMA, license-free hot spot radio technologies (e.g. Wi-Fi) and wire line networks.

IP UTRAN

The introduction of IP transport in the UTRAN is part of the Rel'5 recommendations and offers operators the potential to evolve the UTRAN architecture from a dependence on point to point links using TDM or ATM to one using broadband IP connectivity. This will become of particular importance to operators as wireless broadband services reach higher rates of adoption in the market and the transmission requirements of high capacity base station sites become excessive. With the support of IP in the UTRAN, transmission technologies such as IP over Ethernet will provide operators with a more scalable and cost effective solution when compared with the solutions implemented today. While not replacing existing transmission solutions in all sites, IP UTRAN will allow operators to ensure that they have the most cost-effective transmission solution for each base station site.

Progress of 3GPP Rel'5

With the commercialization of R'99 well under way, operators are starting to focus on the evolution of UMTS to Rel'5 to realize larger capacities, better user experiences and network efficiencies, and to better enable new, integrated multimedia solutions. The Rel'5 3GPP standards were completed in March 2002 and thus prototypes, demos and trials of Rel'5 functionality are being planned and in some cases have already been demonstrated. To illustrate the current industry focus and momentum towards the development and deployment of UMTS Rel'5, recent accomplishments from each of the 3G Americas participating vendors on the key Rel'5 UMTS features are given in this section.

HSDPA

Ericsson was first to demonstrate live mobile broadband with HSDPA over a live system at the China PT Expo Comm in Beijing October 26-30 2004. Ericsson demonstrated mobile broadband Internet access with video streaming and large downloads with HSDPA over a live WCDMA system, running traffic over the air. Performance information with data throughput up to 4.9 Mb/s was shown on a graphical user interface. Ericsson HSDPA systems are up and running since the second quarter 2004, validating end-to-end performance. Ericsson is committed to numerous customer trials throughout 2004 and 2005, and expects commercial release of HSDPA during the second half of 2005. Ericsson delivered WCDMA products since year 2000 are easily up-gradable to HSDPA. Within Ericsson, the infrastructure side and Ericsson Mobile Platforms (EMP) work in close cooperation to provide Rel'5 functionality for future terminals. Ericsson established Ericsson Mobile Platforms as a wholly owned company in September 2001 to help drive the development of the mobile industry. It is one of the first companies in the world to license open-standard 2.5G and 3G technology platforms to manufacturers of mobile phones and other wireless information devices.

Lucent Technologies and Cingular Wireless have deployed a 3G UMTS trial network in the Atlanta market that includes field-testing of HSDPA, a technology that will ultimately support data speeds of up to 14.4 Mbps. Lucent Technologies demonstrated HSDPA capability initially in March of 2003 at the CTIA Wireless 2003 trade show in New Orleans. The demonstration was performed on Lucent's commercial OneBTS system and utilized a prototype terminal emulator showing peak downlink data rates up to 4.6 Mbps. The demonstration consisted of transmitting simultaneously to two mobile devices running 700 Kbps high quality video streams and browser applications. The demonstration implemented the full protocol stack. At the March 2004 CTIA show in Atlanta, Lucent enhanced the demo to simulate a rapidly moving environment and used equalization techniques to minimize channel interference, while maximizing signal quality – illustrating the robustness and suitability of the technology to support high-speed mobile data applications. Lucent's HSDPA solution is available for trials, and will be available for commercial deployments in the 2H 2005 timeframe. Lucent's HSDPA solution requires software-only upgrades, which can be downloaded remotely to its R'99/R4 UMTS RNC and NodeB. Lucent also demonstrated the ability to support BLAST (Bell Labs Layered Space and Time) at these CTIA shows, which utilizes Multiple Input Multiple Output (MIMO) antennas, illustrating the feasibility, utility and relatively high capacity of MIMO technology when applied to UMTS/HSDPA. Lucent also is working jointly with various device partners to ensure a supply of end-user terminals to support HSDPA in the 2H 2005 timeframe.

Nokia Research Center Dallas completed its first HSDPA demonstration in January 2003. The system was demonstrated publicly in Cannes at the 3GSM World Congress in February 2003 and 2004 as well as in New Orleans at CTIA in March 2003. The demonstration highlighted the main features of HSDPA by showing the following:

- A DVD-quality streaming video application running over a complete HSDPA radio system. In this demonstration, the layer 1 supported data rates up to 10 Mbps
- Simultaneous multiple high bandwidth applications -- concurrent video conferencing, downloading of a large video clip and web browsing
- The link adaptation feature by showing how the signal constellation changes from 16-QAM (Quadrature Amplitude Modulation) to QPSK (Quadrature Phase Shift Keying) by introducing interference in the wireless link

Nokia's current commercial UMTS system can be software upgraded to commercial HSDPA, which will be available in 2H 2005 timeframe. While implementing high speed downlink packet access, uplink should also be further enhanced. Nokia is looking at implementing HSUPA (high speed uplink packet access) once the standardization is completed.

Nortel Networks has been shipping its HSDPA-ready NodeBs since 2002, and all Nortel Networks' NodeBs currently deployed across the globe will support HSDPA. Based on three earlier generations of IS-95 CDMA base stations, and leveraging Nortel Networks' extensive experience in developing and deploying 1xEV-DO, the fourth generation CDMA (UMTS) BTS hardware is ready to support both QPSK and 16 QAM HSDPA modulation. The wireless HSDPA demo performed in October 2004 enabled the download of a high quality DVD video and a composite video of height 384 kbps encoded videos at 3.6 Mbps of throughput using a Nortel Networks UMTS Mono BTS and a Ubinetics TM500.

Nortel Networks continues to deliver solid milestones to a full HSDPA commercial delivery in 2005. This commercial delivery is on track and also gaining from Nortel Networks 1xEV-DO commercial experience. Indeed, the closest analogy to HSDPA is 1xEV-DO and 1xEV-DV as both technologies are using the same set of mechanisms like Adaptive Modulation and Coding, 16 QAM, and HARQ. Nortel Networks is the only supplier supporting commercial 1xEV-DO and UMTS networks – which gives operators a full commitment of a stable and complete HSDPA solution Day ONE.

HSDPA readiness of Nortel Networks' UMTS equipment was demonstrated in the spring of 2004 with a peak data rate of 3.6 Mbps. In 3Q 2004 Nortel Networks demonstrated how HSDPA will empower UMTS networks with key applications like video streaming, mobile gaming and other high bandwidth services.

Siemens and NEC are shipping their second generation NodeB. For support of HSDPA, the U.S. PCS 1900 MHz band capable NodeB requires software-only upgrades which can be downloaded remotely when they become available in 2005. The first commercial HSDPA-capable terminal is planned to be a PCMCIA form-factor data card, which will support the market trials and commercial deployments expected to take place in 2005.

IMS

Ericsson is today commercially offering IMS for wireless and wireline operators including a range of applications targeting both consumers and enterprises. Ericsson has signed 25 IMS system contracts for commercial launch or trial, all based on the IMS (IP Multimedia Subsystem) standard. They are distributed over Americas, Europe, Asia and Africa and include GSM/GPRS, WCDMA, CDMA2000 and Wireline implementations. The various contracts include a mix of applications such as push to talk, combinational services (voice and media), Voice over IP and IP Centrex. Ericsson's IMS system and professional services are complemented with Ericsson Mobile Platforms for core handset technology and Sony Ericsson for handsets to ensure true end-to-end capabilities. Ericsson's professional services offering encompasses advisory services in advance of a commercial launch as well as integration and managed services to handle the introduction of IMS and subsequent applications into a live network environment. A service creation environment, coupled with the existing Ericsson Mobility World as a link into the developer's community, enables additional, independent application development of IMS services.

Hewlett-Packard will introduce a range of IMS service delivery products in 2H of 2004. The HP OpenCall IMS product suite provides the service platforms and extended subscriber profile components that will be required in order to develop and deliver the innovative, real-time IP media applications that can take full advantage of the Rel'5 IMS infrastructure. When combined with best-of-breed components for the IMS session control layer (e.g. CSCF), the HP OpenCall IMS product suite provides a rich environment for hosting third party value-add applications. Through its existing ISV partner program, HP can deliver a range of innovative IP media applications such as Push-to-Talk over Cellular (PoC), voice conferencing and interactive streaming content applications. These applications have already been deployed in pre-IMS IP environments, and are now available for trials within an IMS environment. To further facilitate the rapid deployment of new applications, HP's high performance, scalable, Universal HLR can act as a centralized data store for subscriber information. HP will bundle IMS service enablers such as presence servers and group list management servers with its enhanced HLR/HSS to provide centralized management of extended user profile data.

Lucent Technologies has introduced a commercially available standards-based IMS service delivery architecture that enables 3G mobile operators to simply and cost-effectively introduce multimedia services including Voice over IP (VoIP); Lucent's IMS solutions is involved in a variety of customer trials and commercial deployments worldwide. Lucent's IMS is based on IP core networking standards that have been developed by the 3GPP and 3GPP2, industry bodies that are responsible for the establishment of standards for 3G networks. At the heart of Lucent's IMS solution is the softswitch (next-generation switching platform that utilizes SIP and bearer independent call control to manage voice and multimedia communications on IP networks), media gateways, Lucent's Super Distributed Home Location Register (S-DHLR) enabling a single profile per subscriber (i.e. the Home Subscriber Server), and mobile service solutions including an OSA Gateway and series of application servers based upon a robust set of platforms and software -- designed to support enhanced voice and data services. Lucent's IMS solution features a variety of unique software innovations, developed by Bell Labs, that are designed to enhance the end-user experience, reliability and QOS capabilities of Lucent's IMS solution. Lucent's IMS also incorporates infrastructure and software from IBM, Broadsoft and other industry leaders.

Nokia has been running IP Multimedia Subsystem trials for several years, and in June 2004 announced the end-to-end availability of its end-to-end 3GPP compliant IP Multimedia Subsystem, including network elements, terminals supporting downloadable SIP clients, and Software Development Kit for application developers.

Nokia has four commercial contracts for Nokia IP Multimedia Subsystem. The Nokia IMS enables interactive IP-based applications for mobile users and forms the basis of future connectivity services. The Nokia IP Multimedia Subsystem uses SIP (Session Initiation Protocol) to establish IP connections between terminals.

The IP connection can then be used to carry any IP traffic, for example interactive game sessions, video sharing or push-to-talk communication. SIP is a protocol developed specifically as the session and service control protocol for multimedia sessions. IMS, as defined in 3GPP and 3GPP2 standardization bodies, provides the mechanism for SIP connectivity between mobile and also fixed devices.

The OMA standard for Push-to-Talk service will also support 3GPP IP Multimedia Subsystem.
The Nokia Push-to-Talk over Cellular (PoC) Release 2 solution will be according to the coming OMA standard and supported by 3GPP R5 compliant IMS systems.

The Nokia IP Multimedia Subsystem works with SIP capable mobile or fixed terminals, for example the currently available Nokia 6630. ******* Nokia's end-to-end offering includes application servers and system integration capability. This creates exciting opportunities for operators and application developers to offer new IP multimedia services in GPRS and 3G networks already today.

Nortel Networks believes that IMS success will be achieved with network convergence. Nortel Networks is leveraging its own unique data and network expertise across all markets – fixed, mobile, enterprise, optical – to build an access independent convergent solution able to deliver common services across various networks and media, bringing new value to the end-user experience and to the operators. Nortel Networks IMS infrastructure components are built on an established set of products (Nortel Networks Multimedia Communication Server portfolio) which have been field proven in both wireless and wireline networks. Nortel Networks has been trialling IP multimedia technology for more than two years with both wireless and wireline operators using PC and handset SIP clients with multimedia services. Initial IMS service offers will be an evolution of Nortel Networks commercial SIP solution, the MCS5200. The MCS5200 multimedia services like presence, instant messaging, collaboration, web push and click to call integrated in an IMS infrastructure were demonstrated at the 3GSM World Congress in February 2004 and CTIA in March 2004.

Siemens has deployed its commercially available IMS mobile multimedia service delivery solution in more than fifteen projects/trials around the globe. At CTIA in March 2004, it was announced that Siemens had successfully placed Internet Protocol-based (IP) Multimedia Subsystem (IMS) sessions on a live GPRS network in the U.S. These projects are able to deliver instant messaging, interactive mobile gaming, friend list/network presence detection, Push-to-Talk over Cellular (PoC), and a variety of other advanced multimedia services.

Future Evolution – UMTS Rel'6 and Rel'7

Future enhancements to 3GPP Rel'5 will mainly be driven by the need for improved user experience powered by packet-based services combining real-time and non-real-time components available in both stationary and mobile environments. Consequently, the next planned release of 3GPP, Release 6 (Rel'6), is focused on improving capacity, quality of service, service enabler and delivery for multimedia packet-based services. The content and scope of Rel'6 is expected to be frozen in fourth quarter 2004 and thus is very well defined at this point. At the present time, the scope, content and timeline of Release 7 (Rel'7) have yet to be formally defined. A report[16] on the general outlook of 3GPP evolution, published in September 2003, describes a long term, high level roadmap intended to guide the future work of 3GPP. The following sections of this paper will discuss the likely feature content of Rel'6 and some of the current study items in 3GPP that are expected to be considered for Rel'7.

Release 6 Overview

One key feature targeted for 3GPP Rel'6 is the Multimedia Broadcast Multicast Service (MBMS) feature, which defines capabilities to address the same information to many users in one cell using the same radio resources. The MBMS is a unidirectional point-to-multipoint service in which data is transmitted from a single source entity to multiple recipients. Transmitting the same data to multiple recipients allows network resources to be shared. By this, the MBMS architecture enables the efficient usage of radio-network and core-network resources, with an emphasis on radio interface efficiency. MBMS is provided over a broadcast or multicast service area which can cover the whole network or be a small geographical area such as a shopping mall or sports stadium allowing for region specific content distribution. Examples of broadcast services are advertisements for upcoming or ongoing Multicast services or localized advertisements such as ads for attractions or shops within the broadcast area. An example of a service using the multicast mode could be near real-time distribution of video clips from national and regional sports events for which a subscription is required.

Another significant feature targeted for Rel'6 is the Enhanced Uplink for Dedicated CHannels (EUDCH) feature. As the importance of IP-based services increases, demand to improve the coverage and throughput as well as reduce the delay of the uplink also increases. Applications that could benefit from an enhanced uplink may include services like video clips, multimedia, e-mail, telematics, gaming, video-streaming etc. The EUDCH feature investigates enhancements that can be applied to UMTS in order to improve the performance on the uplink dedicated transport channels.

[16] 3GPP TR 21.902: *"Evolution of 3GPP System"*, September 2003

To enhance uplink performance, features similar to those introduced for HSDPA in the downlink are being considered including:

- Adaptive modulation and coding schemes
- Hybrid ARQ protocols
- Node B controlled scheduling
- Physical layer or higher layer signalling mechanisms to support the enhancements
- Shorter frame size (TTI) and improved QoS

Other Rel'6 features include the Generic User Profile (GUP) framework, advanced receiver performance specifications (e.g. diversity receive at the terminal), access network sharing, trace management, remote control of electrical antenna tilt, IMS enhancements (e.g. to support messaging, conferencing, interworking with CS and PS networks), enhancements to support WLAN integration, QoS improvements, new SIP capabilities, Wideband AMR speech codec (i.e. to support wideband speech like music) and mechanisms to standardize IP flow based bearer level charging. Other enhancements for Rel'6 are aimed to better enable applications such as emergency services, Push-to-Talk over Cellular (PoC), presence, instant messaging, PS streaming services and Voice and Video over IP. Clearly there is rich Rel'6 feature content planned that will significantly enhance spectral/network efficiency and greatly enhance the end user experience.

Release 7 Overview
Increasing spectral efficiency of the radio interface is of paramount importance in order to make the most out of the limited suitable spectrum and the operators' investment in site resources. Multiple-Input multiple-output (MIMO) antenna systems, motivated by an information theoretic consideration, promise a considerable increase in spectral efficiencies. Therefore, support for MIMO systems is one key element considered for evolution of the UMTS radio interface. A large effort is expected to go into the maintenance and enhancement of the considerable new capabilities which have been introduced in the previous two releases. For example, IMS will further be enhanced, e.g. by explicit support for wireline access allowing fixed-mobile convergence. In addition the integration of alternative radio technologies such as WLAN will be considered, e.g. by allowing handover and closer integration with legacy voice services.

Conclusions
In 1991, a typical user of wireline data used only one megabyte per month. That grew dramatically to nearly 200 megabytes per month in 1999. Wireless data services are starting to follow a similar growth curve to that of wireline data as the performance and usability of mobile handsets improves and new wireless data services are rolled out. Higher data rates at lower cost and with ubiquitous coverage are expected to open up the mass market to wireless data services and drive demand for more graphically rich multimedia content. The cost advantages of 3G over 2G are stark with the cost per megabyte falling from several dollars to under $0.10 per megabyte. As the cost falls for operators and consumers alike, so will compelling services be deliverable at reasonable prices and critical mass can be reached.

UMTS has arrived at the scene to meet these growing wireless data demands, delivering the opportunity for high speed wireless data services to more than ten million customers today and is forecast to nearly triple that number by the end of 2005. The networks are in place. Currently, UMTS is commercially launched in 53 networks across 27 countries worldwide. There are an additional 87 operators in a total of 37 countries (22 other countries) now in pre-commercial status, in deployment or planned, trialing a UMTS network, or awarded UMTS licenses for their 3G deployments. In the U.S. marketplace, AT&T Wireless launched UMTS in six cities; Cingular Wireless will potentially launch the technology in 2005. This scope of UMTS networks across the world ensures the continuation of benefits offered by the GSM family of technologies including vast economies of scale and the opportunity for global roaming. Additionally, commitments by leading terminal manufacturers are being satisfied with commercial announcements of more than 75 UMTS devices to date and 50 more expected by the end of 2004.

With the commercial introduction of UMTS through R'99 well under way, and given the growing demands for wireless data services, the industry has begun to focus on further enhancements to UMTS that will deliver even greater speeds and capacity improvements with the evolution of UMTS to Rel'5 of the 3GPP standards. Rel'5 completed the standardization process in March 2002, introducing significant new feature content including: HSDPA for providing significant downlink data capacity/throughput improvements; the IMS for providing a flexible architecture enabling new and more advanced multimedia applications for operators; and IP UTRAN to realize network efficiencies and reduce cost. The benefits of UMTS Rel'5 have motivated prototype implementations of the key features that have been demonstrated by several vendors at tradeshows during 2003 and 2004. Testing of HSDPA by Cingular in its UMTS trial network in Atlanta is already underway, and commercial deployment is expected in 2H 2005. In Japan, NTT DoCoMo anticipates deployment of HSDPA in its FOMA systems by early 2005. Commercial availability of 3GPP Rel'5 HSDPA is expected in the mid-2005 timeframe. Siemens expects field trials in Europe and Japan to begin in Q2 2005 and commercially available network equipment and HSDPA PC card in Q4 2005. Clearly, UMTS Rel'5 has become a central focus in the UMTS industry and even further enhancements (e.g. improved uplink data capacity/performance, improved broadcast services, MIMO, etc.) are well under way in standards through Rel'6 and Rel'7 of 3GPP.

UMTS is rapidly gaining momentum, not only in deployment progress and the availability of terminals, applications and services for R'99, but also in its evolution to Rel'5 to provide significant data capacity, performance and feature functionality benefits. It won't be long before UMTS Rel'5 proves to be the next significant step delivering the indisputable merits and benefits of the GSM family of technologies -- GSM, GPRS, EDGE and UMTS -- to 1.18 billion wireless customers throughout the world.

Appendix A

Global UMTS Network Status		Networks In Service*		53
EMC World Cellular Database & UMTS Forum		Pre-Commercial		9
Updated: November 23, 2004		Planned / In Deployment		54
		Trial		14
		Status Unclear		2
		License Awarded		10
		License Revoked		7
		License Tendered		2
		Potential License		27
COUNTRY	**OPERATOR**	**STATUS**	**START DATE**	**OPENING**
NETWORKS IN SERVICE				
Australia	Hutchison 3G (3)	In Service	Apr 2003	
Austria	Connect Austria (ONE)	In Service	Dec 2003	
Austria	Hutchison 3G (3)	In Service	May 2003	
Austria	Mobilkom Austria (Vodafone)	In Service	Apr 2003	
Austria	T-Mobile Austria	In Service	Dec 2003	
Austria	tele.ring	In Service	Dec 2003	
Bahrain	MTC Vodafone Bahrain	In Service	Dec 2003	
Belgium	Belgacom Mobile (Proximus)	In Service	May 2004	
Denmark	Hi3G Denmark (3)	In Service	Oct 2003	
Finland	Elisa	In Service	Nov 2004	
Finland	TeliaSonera	In Service	Oct 2004	
France	SFR (Vodafone)	In Service	Jun 2004	
Germany	E-Plus (KPN)	In Service	Jun 2004	
Germany	O2	In Service	Apr 2004	
Germany	T-Mobile	In Service	May 2004	
Germany	Vodafone D2	In Service	May 2004	
Greece	COSMOTE	In Service	May 2004	
Greece	STET Hellas (TIM)	In Service	Jan 2004	
Greece	Vodafone (Panafon)	In Service	Aug 2004	
Guernsey	Wave Telecom	In Service	Jul 2004	
Hong Kong	Hutchison (3)	In Service	Jan 2004	
Ireland	Vodafone Ireland	In Service	Jun 2004	
Israel	Cellcom Israel	In Service	Jun 2004	
Italy	H3G (3)	In Service	Mar 2003	
Italy	TIM	In Service	May 2004	
Italy	Vodafone Omnitel	In Service	May 2004	
Japan	NTT DoCoMo	In Service	Oct 2001	
Japan	Vodafone K.K.	In Service	Dec 2002	

Japan - Chugoku	NTT DoCoMo	In Service	Apr 2002	
Japan - Chugoku	Vodafone	In Service	Dec 2002	
Japan - Hokkaido	NTT DoCoMo	In Service	Apr 2002	
Japan - Hokkaido	Vodafone	In Service	Dec 2002	
Japan - Hokuriku	NTT DoCoMo	In Service	Apr 2002	
Japan - Hokuriku	Vodafone	In Service	Dec 2002	
Japan - Kansai	NTT DoCoMo	In Service	Dec 2001	
Japan - Kansai	Vodafone	In Service	Dec 2002	
Japan - Kyushu & Okinawa	NTT DoCoMo	In Service	Apr 2002	
Japan - Kyushu & Okinawa	Vodafone	In Service	Dec 2002	
Japan - Shikoku	NTT DoCoMo	In Service	Apr 2002	
Japan - Shikoku	Vodafone	In Service	Dec 2002	
Japan - Tohoku	NTT DoCoMo	In Service	Apr 2002	
Japan - Tohoku	Vodafone	In Service	Dec 2002	
Japan - Tokai	Vodafone	In Service	Dec 2002	
Japan - Tokyo	NTT DoCoMo	In Service	Oct 2001	
Japan - Tokyo	Vodafone	In Service	Dec 2002	
Korea	KTF	In Service	Dec 2003	
Korea	SK Telecom	In Service	Dec 2003	
Luxembourg	P&T Luxembourg (LUXGSM)	In Service	Jun 2003	
Luxembourg	Tango (Tele2)	In Service	July 2004	
Netherlands	KPN Mobile	In Service	Jul 2004	
Netherlands	Vodafone Libertel	In Service	Jun 2004	
Poland	Polkomtel (Plus GSM)	In Service	Sep 2004	
Portugal	Optimus	In Service	Jun 2004	
Portugal	TMN	In Service	Apr 2004	
Portugal	Vodafone Telecel	In Service	May 2004	
Slovenia	Mobitel	In Service	Dec 2003	
Spain	Amena	In Service	Oct 2004	
Spain	Telefonica Moviles	In Service	May 2004	
Spain	Vodafone Espana	In Service	May 2004	
Sweden	Vodafone	In Service	Feb 2004	
Sweden	Hi3G (3)	In Service	May 2003	
Sweden	Tele2Comviq	In Service	Jun 2004	
Sweden	TeliaSonera (JV with Tele2) (formerly Svenska UMTS-Nät)	In Service	Mar 2004	
Switzerland	Swisscom Mobile (Vodafone)	In Service	Nov 2004	
UAE	Etisalat	In Service	Jan 2004	
UK	Hutchison 3G (3)	In Service	Mar 2003	
UK	Orange	In Service	Jul 2004	
UK	T-Mobile	In Service	May 2004	
UK	Vodafone	In Service	May 2004	
USA	AT&T Wireless (now Cingular)	In Service	Jul 2004	

PRE-COMMERCIAL NETWORKS				
France	Orange France	Pre-commercial	Q4 2004	Q3 2004
Ireland	Hutchison Whampoa	Pre-commercial		Q2 2004
Ireland	O2	Pre-commercial		Q3 2004
Isle of Man	Manx Telecom	Pre-commercial		Q3 2004
Malaysia	Maxis Communications	Pre-commercial	Q1 2005	Aug 2004
Malaysia	Telekom Malaysia	Pre-commercial		Sep 2004
Monaco	Monaco Telecom	Pre-commercial		Q4 2004
Singapore	MobileOne	Pre-commercial		Oct 2004
UK	O2	Pre-commercial		Q3 2004
NETWORKS PLANNED OR IN DEPLOYMENT				
Andorra	STA	Planned/In Deployment		Q4 2005
Australia	Optus	Planned/In Deployment		Sep 2005
Australia	Telstra	Planned/In Deployment		Dec 2005
Australia	Vodafone	Planned/In Deployment		Jun 2005
Belgium	BASE	Planned/In Deployment		Q1 2005
Belgium	Mobistar	Planned/In Deployment		Q4 2004
Czech Republic	Eurotel Praha	Planned/In Deployment		Q1 2006
Czech Republic	T-Mobile	Planned/In Deployment		Q1 2006
Denmark	Orange Denmark	Planned/In Deployment		Q4 2004
Denmark	TDC Mobil	Planned/In Deployment		Q4 2004
Denmark	Telia Denmark	Planned/In Deployment		Q4 2004
Estonia	EMT	Planned/In Deployment		Q4 2005
Estonia	Radiolinja	Planned/In Deployment		Q4 2006
Estonia	Tele2	Planned/In Deployment		Q4 2006
Finland	Finnish 2G	Planned/In Deployment		Q1 2004
Finland	Finnish 3G	Planned/In Deployment		Q1 2004
Finland - Republic of Åland	Alands Mobiltelefon	Planned/In Deployment		Q4 2004
Finland - Republic of Åland	Song Networks	Planned/In Deployment		Q4 2004
France	Bouygues Telecom	Planned/In Deployment		Q4 2005
Hong Kong	Hong Kong CSL	Planned/In Deployment		Q2 2004
Hong Kong	SmarTone	Planned/In Deployment		Q1 2005
Hong Kong	Sunday	Planned/In Deployment		Q1 2005
Israel	Partner Communications (Orange)	Planned/In Deployment		Q4 2004
Italy	Wind	Planned/In Deployment		Q2 2004
Latvia	LMT	Planned/In Deployment		Q4 2004
Latvia	Tele2	Planned/In Deployment		Dec 2004
Liechtenstein	Orange	Planned/In Deployment		Q1 2005
Liechtenstein	Tele2	Planned/In Deployment		Q1 2005
Luxembourg	LuXCommunications (VOX.mobile)	Planned/In Deployment		Q4 2004
Luxembourg	Orange Communications	Planned/In Deployment		Q4 2004
Malta	MobIsle Communications	Planned/In Deployment		Q4 2004

Malta	Vodafone	Planned/In Deployment		Q4 2004
Mauritius	Emtel	Planned/In Deployment		Dec 2004
Netherlands	Orange	Planned/In Deployment		Q4 2004
Netherlands	Telfort	Planned/In Deployment		Q4 2004
Netherlands	Vodafone Libertel	Planned/In Deployment		Q4 2004
New Zealand	Vodafone New Zealand	Planned/In Deployment		Q1 2005
Norway	Netcom	Planned/In Deployment		Q4 2004
Norway	Telenor Mobil	Planned/In Deployment		Q3 2004
Poland	Centertel	Planned/In Deployment		Q1 2006
Poland	Polska Telefonia Cyfrowa	Planned/In Deployment		Q1 2006
Singapore	Singapore Telecom	Planned/In Deployment		Nov 2004
Singapore	StarHub	Planned/In Deployment		Dec 2004
Slovak Republic	EuroTel Bratislava	Planned/In Deployment		Q1 2006
Slovak Republic	Orange	Planned/In Deployment		Q1 2006
South Africa	Vodacom	Planned/In Deployment		Q1 2005
Spain	Xfera	Planned/In Deployment		Q2 2004
Switzerland	Orange	Planned/In Deployment		Q4 2004
Switzerland	TDC dSpeed	Planned/In Deployment		Q4 2004
Taiwan	Chunghwa Telecom	Planned/In Deployment		Q3 2004
Taiwan	FarEasTone	Planned/In Deployment		Q3 2004
Taiwan	Taiwan Cellular Corporation	Planned/In Deployment		Q3 2004
Taiwan	Taiwan PCS	Planned/In Deployment		Q3 2004
USA	Cingular Wireless	Planned/In Deployment		2H 2005
NETWORKS IN TRIAL				
China - Beijing	Beijing Mobile	Trial		
China - Beijing	Beijing Netcom	Trial		
China - Beijing	China Railcom	Trial		
China - Guangdong	Guangdong Mobile	Trial		
China - Guangdong	Guangdong Telecom	Trial		
China - Guangdong	Guangdong Unicom	Trial		
China - Shanghai	China Railcom	Trial		
China - Shanghai	Shanghai Netcom	Trial		
China - Shanghai	Shanghai Telecom	Trial		
China - Shanghai	Shanghai Unicom	Trial		
Croatia	VIPnet	Trial		Q4 2006
Lithuania	Omnitel	Trial		Q2 2007
South Africa	MTN	Trial		Q2 2005
Vietnam	MobiFone	Trial		
STATUS UNCLEAR				
Canada	Microcell Telecommunications	Status Unclear		
Germany	Group 3G	Status Unclear		

LICENSES AWARDED				
Croatia	T-Mobile Croatia	License Awarded		Q4 2006
Croatia	VIPNet	License Awarded		Q4 2006
Italy	Ipse 2000	License Awarded		
Netherlands	T-Mobile Netherlands	License Awarded		Q4 2004
Norway	Hi3G Access Norway	License Awarded		Q4 2005
Romania	MobiFon (CONNEX GSM)	License Awarded		Q4 2005
Romania	Orange Romania	License Awarded		Q4 2005
Switzerland	Team 3G	License Awarded		
Thailand	CAT	License Awarded		Q4 2006
Thailand	TOT	License Awarded		Q4 2005
LICENSES REVOKED OR SOLD				
Austria	3G Mobile	License Revoked/Sold		Q4 2003
	Note: Telefonica Moviles sold 3G Mobile license to Mobilkom Austria			
Germany	MobilCom Multimedia	License Revoked/Sold		Dec 2003
	MobilCom voluntarily hands back UMTS license			
Norway	Broadband Mobile	License Revoked/Sold		Nov 2002
	Declaration of bankruptcy			
Norway	Tele2 Norway	License Revoked/Sold		
	Tele2 gives up UMTS plans - returns license			
Portugal	OniWay	License Revoked/Sold		Q3 2003
	Operator extinct. Spectrum split between 3 remaining Portuguese operators			
Slovak Republic	Profinet	License Revoked/Sold		
	License withdrawn by regulator - payment failure			
Sweden	Orange Sweden	License Revoked/Sold		2003
	Orange exits UMTS market - sells license to consortium of TeliaSonera and Tele2			
LICENSE TENDER				
Estonia	-tba-	License Tender		Q2 2008
Norway	-tba-	License Tender		Dec 2004
POTENTIAL LICENSE				
Belgium	-tba-	Potential License		Q4 2008
Bulgaria	-tba-	Potential License		Q2 2007
Cyprus	-tba-	Potential License		Q1 2007
Czech Republic	-tba-	Potential License		Q2 2008
France	-tba-	Potential License		Q4 2008
Hungary	-tba-	Potential License		Q4 2007
Hungary	-tba-	Potential License		Q4 2007
Hungary	-tba-	Potential License		Q4 2007
Latvia	-tba-	Potential License		Jun 2007
Lithuania	-tba-	Potential License		Q2 2007
Lithuania	-tba-	Potential License		Q2 2007
Lithuania	-tba-	Potential License		Q2 2007

Poland	-tba-	Potential License		Q4 2006
Romania	-tba-	Potential License		Q3 2006
Romania	-tba-	Potential License		Q3 2006
Russia	-tba-	Potential License		Q4 2005
Russia	-tba-	Potential License		Q4 2005
Russia	-tba-	Potential License		Q4 2005
Saudi Arabia	-tba-	Potential License		Q2 2007
Serbia	Telekom Srbija	Potential License		Q2 2005
Singapore	-tba-	Potential License		Q1 2006
Slovenia	-tba-	Potential License		Q2 2007
Slovenia	-tba-	Potential License		Q2 2007
Turkey	-tba-	Potential License		Q4 2006
Turkey	-tba-	Potential License		Q4 2006
Turkey	-tba-	Potential License		Q4 2006
Turkey	-tba-	Potential License		Q4 2006

In Service: Operator has commercially launched its network to both consumer and enterprise market, with handsets available in retail outlets.
Pre-commercial: Operator has launched limited non-commercial trials, including those with "friendly" users. This includes the recent launch of 3G data cards targeted at the enterprise market by some European operators.
Planned/in deployment: Licensee is in planning stages of deploying network or is actually building the network.
Trial: Operator is conducting a network trial. This is to be used when the operator has no specific license, but is conducting some sort of network trial. Most cases this is likely to be 3G.
Status Unclear: Refers to disputed license awards or instances when EMC is unclear of what is happening.
License Awarded: License has been awarded, but licensee currently shows no inclination to deploy network or has announced no roll-out. Examples of this include some UMTS operators in Europe.
License Revoked/Surrendered: Licensee/operator involuntarily/voluntarily hands back license.
License Tender: Government has gone beyond setting out framework for license award and has also set a time schedule with proposed tender dates and number of licenses.
Potential License: Small level of speculation. Government policy or privatization process indicates that licensing opportunity may become available.
Abandoned: Licensee/operator abandons project/trial.
Closed: Operator closes network at end of license period or technology migration TACS to GSM etc. (i.e. not abandoned).
Merged: Operators merging or single band networks becoming dual-band (e.g. GSM 900 becoming GSM 900/1800).
Private: Operator runs non-commercial network.

Source: Information compiled from EMC World Cellular Database and The UMTS Forum

Appendix B: Global EDGE / UMTS Commitments

Bahrain	MTC Vodafone
Croatia	VIPNet
Cyprus	Investcom/Scancom
Czech Republic	EuroTel Praha, T-Mobile
Finland	TeliaSonera, DNA Finland, Elisa
France	Bouygues Telecom
Greece	STET Hellas (TIM)
Hong Kong	CSL, Sunday
Israel	Cellcom
Italy	TIM
Libya	GPTC
Malaysia	DiGi
Netherlands	Netcom,Telenor Mobile
Norway	Telenor Mobile, Netcom
Poland	Polkomtel/Plus GSM
Slovak Republic	Eurotel Bratislava
South Africa	MTN
Switzerland	Swisscom Mobile
USA	Cingular/AT&T Wireless
Vietnam	Mobifone

Appendix C: Global UMTS Device List **(Updated November 23, 2004)**

Manufacturer	Model	Technology	In Market
Fujitsu	F901ic	UMTS	Nov-04
Fujitsu	FOMA Raku Raku F880iES	UMTS	Sep-04
Fujitsu	F900ic	UMTS	Aug-04
Fujitsu	FOMA F2402	UMTS	Jun-04
Fujitsu	FOMA F900iT	UMTS	Jun-04
Fujitsu	FOMA F900i	UMTS	Feb-04
Fujitsu	FOMA F2402	UMTS	Sep-03
Fujitsu	FOMA F2102V	UMTS	Jun-03
Fujitsu	FOMA F2051	UMTS	Jan-03
Fujitsu	FOMA F504is	UMTS	Dec-02
Fujitsu	FOMA F2611	UMTS	Apr-02
Huawei	D208	UMTS	Sep-03
Huawei	D618	UMTS	Sep-03
LG	LG-U8120	GSM/UMTS	Aug-04
LG	LG-U8110	GSM/UMTS	May-04
LG	LG-U8150	GSM/UMTS	Oct-03
LG	LG-KW2000	CDMA/UMTS	Dec-03
Mitsubishi	D901i	UMTS	Nov-04
Mitsubishi	FOMA D900i	UMTS	Jun-04
Mitsubishi	FOMA D2101V	UMTS	Mar-02

Manufacturer	Model	Technology	In Market
Motorola	Vodafone 702MO, V980	GSM/UMTS	Nov-04
Motorola	A1000	GSM/UMTS	Nov-04
Motorola	E1000	GSM/UMTS	Nov-04
Motorola	A845	GSM/UMTS	Jul-04
Motorola	V1000	GSM/UMTS	Apr-04
Motorola	C975	GSM/UMTS	Nov-04
Motorola	V975	GSM/UMTS	Available soon
Motorola	C980	GSM 9/18/19/UMTS	Dec-04
Motorola	V980	GSM 9/18/19/UMTS	Dec-04
Motorola	A925	GSM/UMTS	Jan-04
Motorola	A835	GSM/UMTS	Oct-03
Motorola	A920	GSM/UMTS	Aug-03
Motorola	A830	GSM/UMTS	Mar-03
NEC	e228	GSM/UMTS	Aug-04
NEC	c313	GSM/UMTS	Feb-04
NEC	e313	GSM/UMTS	Feb-04
NEC	e338	GSM/UMTS	Available soon
NEC	c616	GSM/UMTS	Dec-03
NEC	e616	GSM/UMTS	Dec-03
NEC	802	GSM 9/18/UMTS	Available soon
NEC	e808N	GSM/UMTS	Jul-03
NEC	e808S	GSM/UMTS	Jul-03
NEC	e808Y	GSM/UMTS	Jul-03
NEC	e606	GSM/UMTS	Mar-03
NEC	e808	GSM/UMTS	Mar-03
NEC	338	UMTS	Nov-04
NEC	N901iC	UMTS	Nov-04
NEC	e909	UMTS	Available soon
NEC	FOMA N900iL	UMTS	Nov-04
NEC	e802	UMTS	Oct-04
NEC	FOMA N900iS	UMTS	Jun-04
NEC	FOMA N900i	UMTS	Feb-04
NEC	FOMA N2102V	UMTS	Jul-03
NEC	FOMA N2051	UMTS	Jan-03
NEC	FOMA N2002	UMTS	Nov-01
NEC	FOMA N2001	UMTS	Oct-01
NEC	FOMA V-N701	UMTS	N/A
NEC	FOMA N2701	PDC/UMTS	Jun-03
Nokia	Voda/6630	GSM/UMTS	Sep-04
Nokia	6630	UMTS/EDGE	Oct-04
Nokia	6650	GSM/UMTS	Jul-03
Nokia	6651	GSM 8/19 /UMTS	Jul-04
Nokia	7600	GSM/UMTS	Sep-03

Manufacturer	Model	Technology	In Market
Novatel Wireless	Merlin U530	GSM/UMTS	Jan-04
Novatel/Lucent	Nconnect Card	UMTS PC Card	N/A
Novatel/Lucent	Merlin U520 PC Card	UMTS PC Card	Jul-04
Novatel/Lucent	Merlin U530 PC Card	UMTS PC Card	Jul-04
Panasonic	p901i	UMTS	Nov-04
Panasonic	FOMA P900iV	UMTS	Jul-04
Panasonic	FOMA P900iV	UMTS	Feb-04
Panasonic	FOMA P2402	UMTS	Nov-03
Panasonic	FOMA P2102V	UMTS	Mar-03
Panasonic	FOMA P2002	UMTS	Jun-02
Panasonic	FOMA P2101V	UMTS	Oct-01
Panasonic	FOMA P2401	UMTS	Oct-01
Samsung	SGH-Z105	GSM/UMTS	Mar-04
Samsung	SGH-Z105U	GSM/UMTS	Feb-04
Samsung	SCH-W110	CDMA/UMTS	Dec-03
Samsung	SCH-Z100	GSM/UMTS	Available soon
Sanyo	Vodafone V801SA	GSM/UMTS	Dec-03
Sanyo	Vodafone VSA701	UMTS	Dec-02
Seiko	VC701Si/ Compact Flash	UMTS	Apr-04
Sharp	Vodafone V801SH	GSM/UMTS	Apr-04
Sharp	801SH	GSM/UMTS	N/A
Sharp	SH901ic	UMTS	Nov-04
Sharp	SH2101v	UMTS	N/A
Sharp	802	GSM 9/18/19/UMTS	Jul-04
Sharp	902	GSM 9/18/19/UMTS	N/A
Sharp	FOMA SH900i	UMTS	Mar-04
Sharp	Vodafone J-SH010	UMTS	Mar-03
Sharp	FOMA SH21010V	UMTS	Jul-02
Siemens	U15	GSM/UMTS	Feb-04
Siemens	U10	GSM/UMTS	Apr-03
Sony Ericsson	V8000	GSM/UMTS	Nov-04
Sony Ericsson	V800	GSM 9/18/19/UMTS	Available soon
Sony Ericsson	802SE	GSM 9/18/19/UMTS	Available soon
Sony Ericsson	Z1010	GSM/UMTS	Feb-04
Toshiba	FOMA T2101V	UMTS	Sep-02
Toshiba	FOMA V601T	UMTS	N/A
ZTE	F808	UMTS	Nov-04
Vodafone	Datacard	GSM/UMTS	N/A

Acknowledgments

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