Mobile Broadband:

The Global Evolution of UMTS/HSPA

3GPP Release 7 and Beyond

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Acronym List

1xEV-DO	1x EVolution Data Optimized
1xEV-DV	1x EVolution Data Voice
3GPP	3rd Generation Partnership Project
AGPS	Assisted Global Positioning System
AMR	Adaptive Multi-Rate
ARPU	Average Revenue Per User
BTS	Base Transceiver Station
CQI	Channel Quality Indications
CS	Circuit Switched
CSI	Combination of Circuit Switched and Packet Switched services
CSCF	Call Session Control Function
CTIA	Cellular Telecommunication Industry Association
D-TxAA	Double Transmit Adaptive Array
DCH	Dedicated Channel
E2E	End to End
E-DCH	Enhanced Dedicated Channel (also known as HSUPA)
E-DPCCH	Enhanced Dedicated Physical Control CHannel
E-DPDCH	Enhanced Dedicated Physical Data CHannelCHannel
EDGE	Enhanced Data for Global Evolution
ETSI	European Telecommunication Standards Institute
EUTRA	Evolved Universal Terrestrial Radio Access
EUTRAN	Evolved Universal Terrestrial Radio Access Network
FBC	Flow Based Charging
FBI	Fixed Broadband access to IMS
FDD	Frequency Division Duplex
GPRS	General Packet Radio System
GSM	Global System for Mobile communications
GUP	Generic User Profile
HARQ	Hybrid Automatic Repeat Request
HLR	Home Location Register
HS-SCCH	High-Speed Shared Control Channel
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access (HSDPA + HSUPA)
HSPA +	High Speed Packet Access Plus (also known as HSPA Evolution)
HSS	Home Subscriber Server
HSUPA	High Speed Uplink Packet Access
HTML	Hyper-Text Markup Language
IMS	IP Multimedia Subsystem
IP	Internet Protocol
ISIM	IMS SIM
ISP	Internet Service Provider
ISUP	ISDN User Part
ITU	International Telecommunication Union
J2ME	Java 2 Micro Edition
LCS	LoCation Service
LMMSE	Least Minimum Mean Squared Error
LTE	Long Term Evolution (Air Interface Evolution)
M2M	Machine to Machine
MAC	Media Access Control
MBMS	Multimedia Broadcast/Multicast Service
MITE	IMS Multimedia Telephony Communication Enabler
MRFP	Multimedia Resource Function Processor
MME	Mobility Management Entity
MMS	Multimedia Messaging Service
NGN	Next Generation Network
OMA	Open Mobile Architecture
OTA	Over The Air
PAR	Peak to Average Ratio
PARC	Per-Antenna Rate Control

PCC	Policy and Charging Convergence
PCMCIA	Personal Computer Manufacturers’ Card Interface Adapter
PCS	Personal Communication System
PoC	Push-to-talk over Cellular
PLMN	Public Land Mobile Network
POTS	Plain Old Telephone Service
PS	Packet Switched
PSI	Public Service Identities
PSTN	Public Switched Telephone Network
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
QoS	Quality of Service
RAB	Radio Access Bearer
RAT	Radio Access Technology
RNC	Radio Network Controller
RRC	Radio Related Signaling
SAE	System Architecture Evolution
SBLB	Service Based Local Policy
SDMA	Spatial Division Multiple Access
SIM	Subscriber Identity Module
SIP	Session Initiated Protocol
SMS	Short Message Service
SRNC	Serving Radio Network Controller
STTD	Space-Time Transmit Diversity
TFC	Transport Format Combination
TTI	Transmission Time Interval
UE	User Equipment
UMTS	Universal Mobile Telecommunication System, also known as WCDMA
UPE	User Plane Entity
USIM	UMTS SIM
UTRA	Universal Terrestrial Radio Access
UTRAN	UMTS Terrestrial Radio Access Network
VCC	Voice Call Continuity
VoIP	Voice over Internet Protocol
VPN	Virtual Private Network
WAP	Wireless Application Protocol
WCDMA	Wideband Code Division Multiple Access
WIM	Wireless Internet Module
WLAN	Wireless Local Area Network

Preface

The growing commercialization of Universal Mobile Telecommunications System (UMTS), also known as Wideband Code Division Multiple Access (WCDMA), has been the topic of an annual white paper by 3G Americas since 2003, when the focus was Third Generation Partnership Project (3GPP) Release '99. With both the rapid progress of the evolutionary 3GPP roadmap for UMTS to HSPA from Release 5 (2004 white paper) to Release 6 (2005 white paper) and now Release 7, and the commercial deployment of 107 UMTS/WCDMA networks worldwide with nearly 75 million customers at the writing of this paper, the need for semi-annual updates has become necessary in order to provide reasonably current information.

In fact, on December 6, 2005, Cingular Wireless launched UMTS enhanced with High Speed Downlink Packet Access (HSDPA) in 16 major markets throughout the U.S., becoming the first operator in the world to launch this enhanced UMTS technology on a wide-scale basis. Already there are 41 operators offering HSDPA services in 31 countries of the world, with additional commitments from 62 more operators as of July 7, 2006 (see Appendix D).

3G Americas' first UMTS white paper, *UMTS to Mobilize the Data World* reported on the progress of UMTS: from its inception in 1995, to standardization by ETSI[1] in January 1998, to the commercial launch by Japan's NTT DoCoMo and other operator trial launches. 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.

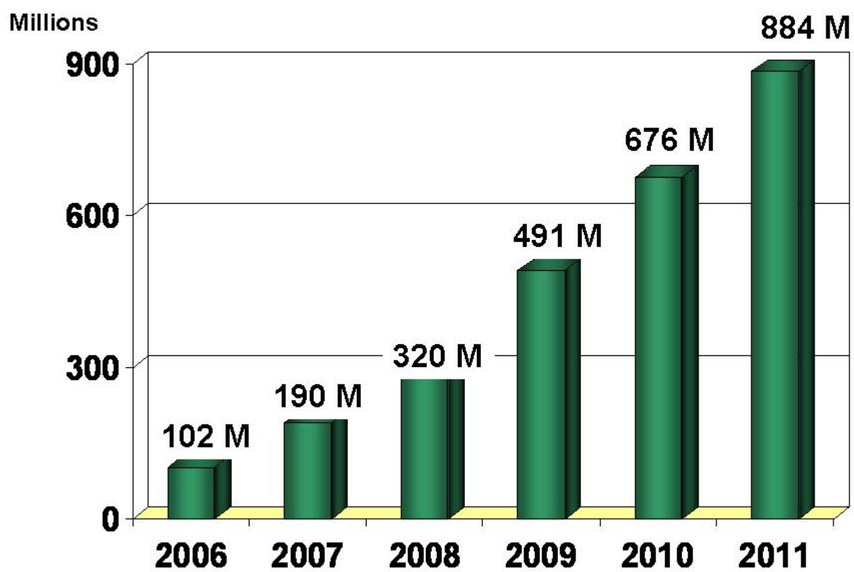

Figure 1. Global UMTS Subscriber Growth Forecast[2]

The rapid growth of UMTS led to a focus on its next significant evolutionary phase, namely, Release 5 (Rel-5). 3GPP Rel-5, initially deployed in 2005, has many important enhancements that are easy upgrades to the initially deployed Release 1999 (Rel-99) UMTS networks. Rel-5 provides wireless operators the improvements they need for offering customers higher-speed wireless data services with vastly improved spectral efficiencies through the HSDPA feature. It is expected that HSDPA Rel-5 will provide a 50 percent reduction in cost per megabit versus Rel-99, and HSDPA Rel-6 will further build upon reductions in the cost per megabit. In addition to HSDPA, Rel-5 introduces the IP Multimedia Subsystem (IMS) architecture that promises to greatly enhance the end-user experience for integrated multimedia applications and offer mobile operators a more efficient means for offering such services.

[1] ETSI: European Telecommunications Standards Institute
[2] Informa Telecoms and Media, World Cellular Information Service, June 2006

UMTS Rel-5 also introduces the IP UTRAN concept to realize transport network efficiencies and reduce transport network costs.

The 3G Americas white paper titled *The Evolution of UMTS – 3GPP Release 5 and Beyond* was published in June 2004, updated in November 2004, and provided an overview and status update of the key 3GPP Rel-5 specifications and features discussed above. *The Global Evolution of UMTS/HSDPA - 3GPP Release 6 and Beyond* December 2005 white paper provided information on the commercialization and industry progress towards the evolution of UMTS to Release 6 (Rel-6) with discussion of future evolutions of the technology.

Mobile Broadband: The Global Evolution of UMTS/HSPA Release 7 and Beyond takes the step forward to Release 7 (Rel-7) and the future beyond HSPA. In this new paper, we explore UMTS/HSDPA commercialization status and its continuing standards developments, focusing on Rel-7 and looking at what lies beyond with the Long Term Evolution (LTE) and System Architecture Evolution (SAE) initiatives. We also explore the growing demands for wireless data and successes already indicated for a variety of wireless data applications: the increasing Average Revenue Per User (ARPU) for wireless data services by operators worldwide, the cost per byte of UMTS data service, and technology benefits. The appendices include lists of both commitments and deployments for EDGE, UMTS and HSDPA, as well as the progress of leading UMTS vendors. UMTS evolution is ongoing with a clear roadmap well into the near future, and this white paper provides the guide for its readers to understand the evolutionary process.

This paper has been prepared by a working group of 3G Americas' member companies. The material represents the combined efforts of many experts from the following companies: Andrew Corporation, Cingular Wireless, Ericsson, Gemalto, Hewlett-Packard, Lucent Technologies, Motorola, Nokia, Nortel, and Siemens.

1 Introduction

Wireless data revenues are picking up and have now passed 10% of the total revenues for many operators. Today the most popular applications are text messaging (SMS), Web and WAP access, multi-media messaging (MMS) and content downloads, e.g., ring tones, music and video clips, with more than 50% of the mobile subscribers using these basic data services. With the introduction of UMTS, data revenues will play an increasingly important role for operators. Most UMTS operators today are offering some kind of mobile broadband service and several PC vendors offer laptops with built-in HSDPA capabilities that will boost data usage even further. Other services, with less penetration today but with high expectations for future growth, include mobile email access, mobile TV, mobile gaming and full track music downloads.

While earlier 3GPP releases already provide efficient support for these services, 3GPP Rel-7 focuses on providing improved support and performance for real-time conversational and interactive services such as Push-to-talk Over Cellular, picture and video sharing, and Voice and Video over IP. These services are starting to become available as operators deploy IP Multimedia Subsystem (IMS) based on 3GPP Rel-5.

The radio interface enhancements in 3GPP Rel-7 will provide improved capacity in terms of the number of packet data users that can be connected simultaneously as well as improved state transition delays in order to shorten initial delays for service establishment or re-activation. The introduction of Multiple Input Multiple Output (MIMO) will further enhance mobile broadband offerings by taking theoretical peak rates well above today's 14 Mbps as well as improving the average cell throughput.

3GPP Rel-7 also provides new and enhanced Core Network and IMS features. IMS is extended to wireline subscribers to make it the common platform for both fixed and mobile networks going forward. IMS Multi-media Telephony defines a telephony service for Voice and Video over IP, allowing operators to provide telephony services in the packet switched (PS) domain that is consistent with the already existing services in the CS domain. Voice Call Continuity provides seamless mobility between the voice component of the IMS Multi-media Telephony and CS voice. CSI provides the means for a mobile station to combine a CS voice call with PS-based IMS services between the same two users, enabling picture and video sharing with CS voice calls in order to provide enriched voice services. Policy and Charging Convergence (PCC) allows operators to perform advanced dynamic QoS control and charging for packet data services.

Looking further ahead, 3GPP is working on a new radio interface and new system architecture in order to cope with the rapid growth in IP data traffic and ensure competitiveness for the next ten years and beyond. The evolution of the technology will bring theoretical peak rates to above 100 Mbps for downlink and 50 Mbps for uplink, and reduce latency to levels comparable with fixed broadband Internet, e.g., less than 5 ms in ideal conditions. In order to achieve this, an evolution or migration of the network architecture, as well as an evolution of the radio interface is studied in the System Architecture Evolution (SAE), Long Term Evolution (LTE) and HSPA Evolution (HSPA+) Study Items.

2 Progress of Rel-99/Rel-5/Rel-6 UMTS

At the time of this writing, 3GPP Rel-99 through Rel-4 and Rel-5 UMTS are considered mature specifications, with Rel-99 initially standardized in early-mid 1999 and published by 3GPP in March 2000, Rel-4 completed in March 2001, and Rel-5 published in March 2002. The Rel-99 UMTS specifications provided an evolution path for the GSM, GPRS and EDGE technologies that enabled more spectrally efficient and better performing voice and data services through the introduction of a 5 MHz UMTS carrier. Commercial deployments of Rel-99 UMTS networks began several years ago and the number of commercially deployed UMTS systems has grown rapidly since then, as substantiated in the 107 commercial UMTS networks in the deployment status listing in Appendix B of this paper. Rel-4 introduced call and bearer separation in the Core Network, and Rel-5 introduced some significant enhancements to UMTS including HSDPA, IMS and IP UTRAN.[3]

Rel-6 was completed in March 2005 introducing further enhancements to UMTS including HSUPA (or E-DCH), MBMS and Advanced Receivers.[4] The first commercial deployments of HSDPA occurred in Q4 2005, while initial deployments of IMS are already underway. There have also been numerous trials and demos of Rel-6 features such as HSUPA in 1Q-2Q 2006. Leading manufacturers worldwide support UMTS and to illustrate the rapid progress and growth of UMTS, detailed descriptions of recent accomplishments from each of the 3G Americas' participating vendors on Rel-99, Rel-5 and Rel-6 UMTS are included in Appendix A of this white paper. As there are many technology milestones to report, a summary of some of the key technology milestones and developments is provided in this section. However, Appendix A has individual reports from leading vendors on their recent demonstrations, trials, product releases and contracts.

Progress Timeline

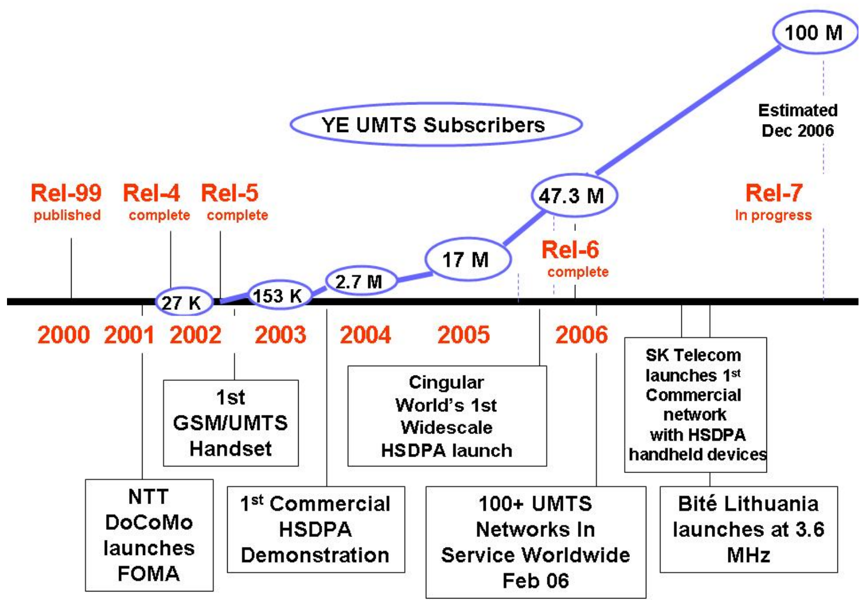

Figure 2. 3GPP UMTS Timeline[5]

[3] 3GPP Rel-5 and Beyond - The Evolution of UMTS, November 2004, 3G Americas, http://www.3gamericas.org/pdfs/umtsrel5_beyond_update-nov2004.pdf
[4] The Global Evolution of UMTS/HSDPA - 3GPP Release 6 and Beyond, December 2005, 3G Americas, http://www.3gamericas.org/pdfs/UMTS_Rel6_Beyond-Dec2005.pdf
[5] 3G Americas, June 2006

In November 2003, HSDPA was first demonstrated on a commercially available UMTS base station in Swindon, U.K. HSDPA was first commercially launched on a wide scale by Cingular Wireless in December 2005, followed closely thereafter by Manx Telecom and Telekom Austria. In June 2006, "Bitė Lietuva" of Lithuania became the first operator to launch HSDPA at 3.6 Mbps, a record speed. At this time, there are 41 commercial HSDPA networks with an additional 62 operators committed to deploying HSDPA. It is expected that almost all UMTS operators will deploy HSDPA.

In early 2006, leading infrastructure vendors launched a new generation of base stations allowing for fewer sites, increasing capacity by 50-150 percent and optimized for cost efficiency at every site. Power consumption was cut further by 35-55 percent thereby enhancing power efficiency. These base stations allow GSM to be seamlessly upgraded to UMTS and operate in both GSM and UMTS networks in parallel. Frequency bands are currently supported in the 850, 1900 and 2100 MHz bands and will also support all coming frequency bands, including 900, 1700, 1800, 1700/2100 and 2500 MHz. The 700 MHz band will be introduced in time to support the rollouts when the 700 MHz band has been auctioned and cleared. One vendor cites the mobile-data throughput capability of the most cost-effective base station is more than 400 GB per day, resulting in a broadband radio network at a cost close to $1 per GB. With reportedly up to 70 percent lower base station site expenditures, the GSM/UMTS infrastructure costs are encouraging operators to deploy 3G UMTS technology today. Most vendors' HSDPA solutions require software-only upgrades, which can be downloaded remotely to the UMTS RNC and Node B.

At 3GSM 2006 in Barcelona, infrastructure vendors demonstrated live HSDPA data downloading at a speed of 3.6mbps. HSDPA on-air tests have shown 950kbps with 80mph in a live UMTS network. Delivery of HSUPA is expected in 1Q2007, compliant to Rel-6.

Handset manufacturers have already shipped the world’s first handsets that support HSDPA, and, in May of this year, the first commercial network with HSDPA handhelds was launched in South Korea. In addition to allowing data to be downloaded at up to 1.8 Mbps, the initial handsets offer such applications as satellite-transmitted Digital Multimedia Broadcasting (DMB) TV programs, have two to-three-megapixel cameras, Bluetooth, radios and stereo speakers. Many new devices are anticipated for launch in 2H 2006; Cingular has expectations to offer their customers several devices in mid-year. HSDPA data cards support different UMTS frequency bands, and can be used in both the U.S. and Europe. Some vendors’ wireless modules are expected to introduce more UMTS/HSDPA data capabilities in 2006 through enabling the machine-to-machine (M2M) market and further improving the diversity of possible applications. The world’s first HSDPA demonstrations with Multiple Input Multiple Output (MIMO) technology using a commercial radio base station were in April at CTIA Wireless 2006, and data rates were doubled from 10 to 20 Mbps. HSUPA technology was demonstrated live at several global trade shows in early 2006, with speeds peaking at more than 4Mbps, enabling the use of many more applications. Some vendors plan to have HSUPA for enhanced uplink data speeds available as early as the first quarter of 2007, in compliance with 3GPP Rel-6.

Beyond HSPA, leading vendors are actively developing and testing IMS device implementation. The GSMA’s IMS (Videoshare) Interoperability Test Sessions yielded important early successes in demonstrating IMS functionality, as well as ensuring interoperable solutions that will increase the take-up of this next step in the GSM/UMTS evolution. Vendors are also supporting IMS development across multiple frequency bands to deliver valuable applications and services. Vendors have signed commercial IMS agreements throughout the world and are conducting hundreds of trials of various IMS network elements. IMS developer programs are available in Germany, USA, China and Singapore to encourage the creation of advanced IMS applications and services.

Some vendors have announced plans to make their current infrastructure reusable for Long Term Evolution (LTE), for example, by introducing new modules that can be integrated into the existing base stations. These future network infrastructure architectures will find their way into the market around 2008 or 2009.

Technology milestones and advances in the evolution of UMTS continue to develop as the number of 3G customers grows at a rapidly increasing rate. With the structure for services and applications beginning to grow more secure, the demand for wireless data services and other advance voice applications is showing a growth trend as well. Reference Appendix A for more detailed information on the progress of the GSM to HSPA evolution and beyond.

3 The Growing Demands for Wireless Data Applications

As 3G networks continue their rollout worldwide, manufacturers are enabling a slew of applications that are driving innovations in mobile handsets, and crossing barriers into a wide variety of vertical enterprise markets. Consumers are likewise driving the mobile content for entertainment, advertising, and MMS services. As these applications proliferate, voice is becoming a secondary factor when purchasing a mobile device, according to Naqi Jaffery, Telecom Trends International.[6] High-speed wireless data services have elevated what Motorola calls "the device formerly known as the cell phone" to much more. Wireless-phone makers offer a new generation of handsets that combine a variety of functions in a single device. Handsets can send email, store music on removable memory, store video clips, check satellite positioning and even monitor a user's stress level. A wireless device is now a must-have device for lifestyle–conscious consumers as well as world travelers and business people.

Wireless Data Trends and Forecasts

"Each year, more and more consumers are experiencing the incredible benefits that only wireless can offer," said CTIA President, Steve Largent. "The mobile communications revolution is in full swing, and now nearly 70% of America is taking part in it." According to a CTIA survey, revenues from wireless data services jumped more than 86% in the past year, amounting to more than $8.58 billion in 2005, up from $4.6 billion in 2004. American customers sent nearly 50 billion text messages in the six month period ending December 2005, and consumed nearly 1.5 trillion wireless minutes in the year 2005. These two measurements represented a 97% and a 36% increase respectively.

With the U.S. adding more than 25 million new subscribers in 2005, the U.S. wireless industry had a stellar 2005, passing the 200 million subscriber mark and 70% market penetration thresholds, receiving positive market response to both PC cards and the first handset-based 3G applications, and with providers reporting they had crossed the 10% data ARPU level.

"Total voice service revenue declines late in the forecast period [U.S. wireless industry in 2008-2009] will jolt an industry accustomed to 25 years of voice revenue growth and further emphasize the importance of data services to the future of the industry," observed Scott Ellison, IDC.[7]

Wireless Data Revenue

U.S. data revenue is expected to grow 45% to $12.6 billion in 2006 from the previous year, according to research firm Ovum.[8] In comparison, Ovum expects total wireless revenue to grow 10% to $135.86 billion in 2006.

On a global basis, Kagan Research forecasts total wireless data revenues will be the wireless industry's quickest growth area, increasing from $8.4 billion in 2005 to $46.6 billion by 2014[9]. That would account for about 24 percent of a total $191 billion in 2014 wireless service revenues, against just 7 percent in 2005. Kagan also suggests that interactive applications for games, t-commerce and advertising will become an increasing portion of subscriber-related multi-channel revenue at 3.2 percent by 2015. Including video on demand and pay per view revenues will further increase the sector to nearly 10 percent in the ten year outlook.

In November 2005, Yankee Group launched the Global Wireless/Mobile Premium Forecast, predicting that data services would comprise 21% of total worldwide wireless operator service revenue of US$698 billion by 2009. Text messaging revenue will top US$36 billion in 2009, ringtone revenue to carriers and content providers will reach almost US$28 billion.[10]

Carriers are beginning to reap the benefits of faster networks and "devices formerly known as the cell phone". Cingular Wireless, the largest carrier in the U.S., added a record 1.8 million net subscribers in Q4 2005. Driven by its best ever overall churn performance and record gross additions, the company ended the year 2005 with 54.1 million customers. Cingular reported that ARPU reflects continued pressure on voice revenues as the wireless market becomes more penetrated and lower-revenue

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[6] "*The Future of Mobile Handsets*," Telecom Trends International report, May 1, 2006

[7] *IDC Forecast Anticipates Decline in Total Voice Revenue in 2008-2009 for the U.S. Consumer Wireless Industry*, IDC press release, March 29, 2006

[8] *3G Retains its Buzz but Potential Remains Unclear*, Dow Jones NY, January 27, 2006

[9] *Media Trends 2006*, Kagan Research, April 2006

[10] Global Wireless/Mobile Premium Forecast, Yankee Group report, November 2005, © Copyright 1997-2006. Yankee Group Research, Inc. All rights reserved.

customers enter the category, *though these impacts were substantially offset by continued increase in data ARPU*. The company's data ARPU was up 63% over the year-ago fourth quarter at $4.71 and represented 10.4% of overall revenue.

For T-Mobile USA, data revenues now represent 9.6% of postpaid ARPU, or $5.21 per customer, compared to 8.8% in the third quarter of 2005 and 6.6% in the fourth quarter of 2004. Central to the growth in data services revenue was a net increase in postpaid converged device users of more than 123,000 during 4Q 2005. In total, T-Mobile USA had 1.1 million converged device users at the end of 2005 including both the Blackberry and T-Mobile Sidekick devices.

Rogers Wireless in Canada reported in 1Q 2006 that wireless postpaid voice and data subscriber ARPU increased in Q1 2006 to $62.20, an increase of 5.1% over first quarter 2005. Data revenues increased 72% and roaming revenues increased 33.1% in the first quarter year over year. Data revenue totaled $98.5 million for the first three months of 2006 or approximately 10.3% of Rogers total wireless network revenue compared to 7.1% in the same period of 2005. Rogers stated this increase reflects the continued rapid growth of Blackberry, text and multimedia messaging services, wireless Internet access, downloadable ring tones, music and games, and other wireless data services and applications.

Telcel, the América Móvil operation that is market leader in Mexico, reports year end 2005 data ARPU at 11% of total company revenues, up from 9% in 2004, with a "vision of a steady pace of growth as new applications and services (i.e. mobile payments) are launched and the usage of GPRS/EDGE networks elevates".

Informa Telecoms & Media's Data Metrics offers a look at the 20 global operators leading the market with data as the largest percentage of total revenue. As of March 2006, Filipino operators Smart and Globe continue to report the highest percentage of revenue for data on a global bases, 50% and 38% of revenue from data respectively in 4Q 2005. As of March 2005, Globe commercially launched HSDPA, enabling them to reduce their cost per bit for data services.

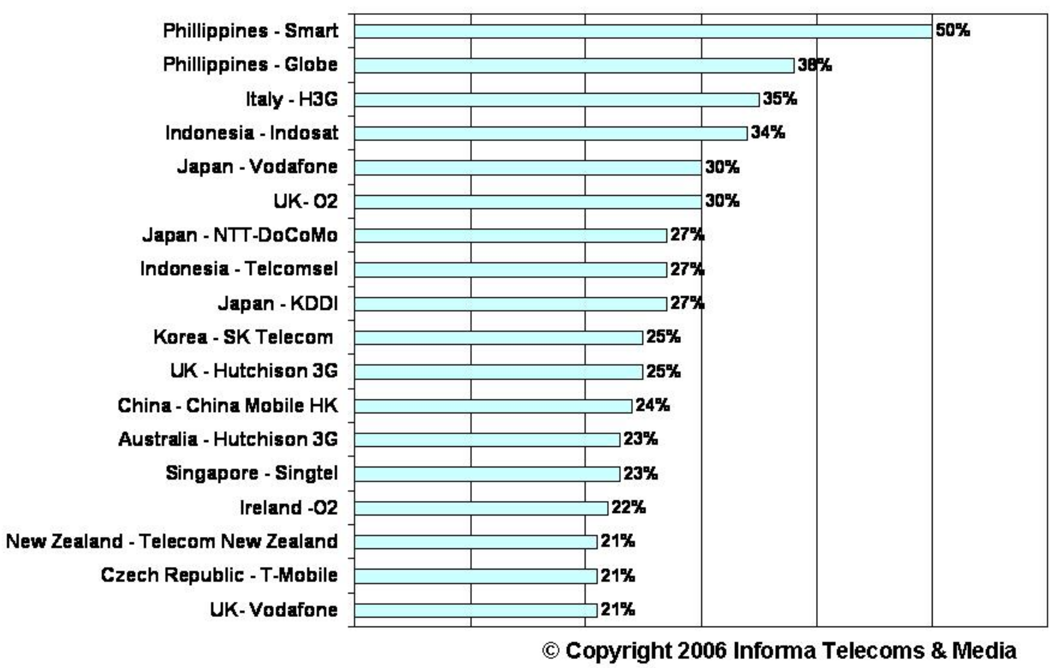

Figure 3. Global Data Percentage of Revenue[11]

Some analysts are predicting that mobile data revenues worldwide will represent up to 35% of total monthly ARPU by 2010. It is no surprise that NTT DoCoMo is among the leaders, having done the

[11] Informa Telecoms and Media, World Cellular Information Service, June 2006

groundbreaking work in this space since 1998. NTT DoCoMo earns more than $1 billion per month from data services with a stated goal to derive 80% of their revenues from data services by 2010.

3G Devices

Gartner predicts that sales of HSDPA handsets will reach 2.1 million this year and will jump to 89.3 million by 2009.[12] In a bid to encourage mobile customers to show more interest in multimedia services and applications, two device vendors have taken a more pro-active stance. Motorola has a flash new mobile music and video messaging application (which uses Flash) and Nokia has launched an interactive online community for mobile movies. Motorola's StudioMOTO is a free online music studio that lets users create their own multimedia for their mobile and Nokia's Nseries Studio enables filmmaking with mobile devices.

In addition to handsets, soaring notebook PC shipments reflect strong demand for mobility on the computer market and generate rapid growth in the device population, claimed a Berg Insight report in January 2006. According to the study, HSDPA is the best suited wireless broadband technology for most regular users. T-Mobile (Germany) already began shipping HSDPA-ready PC data cards in late 2005, as did Cingular Wireless (US). Tobias Ryberg of Berg Insight said, "One of the key issues for the telecom industry is how [notebook PCs] should be connected to the Internet. There is much talk about various emerging technologies, but HSDPA is actually here right now and combines high performance with good coverage. No other technology can be expected to achieve the same footprint in the near future." Ryberg said that European mobile operators were aiming to connect 50 million notebook PCs to the Internet via HSDPA. According to the report there are currently more than one million 3G data card users worldwide. Virtually all 3G network operators in Europe offer mobile broadband services. Beginning in the first half of this year, PC vendors including HP, Dell, Lenovo and Fujitsu will offer notebook computers with optional integrated HSDPA wireless broadband capability, which will boost current 3G download speeds by approximately four times.

This was further supported by ABI Research which reported that the spread of high speed mobile data services is driving the increased adoption of wireless modems in laptop computers. The original wireless modems for laptops were add-ons in the shape of PC cards, and according to Phil Solis, senior analyst at ABI Research, "there are still several good years left in the PC card market." Now, progressively more wireless modems are being built right into the computer, and it is there that the long term opportunity lies. This will produce a change in the dynamics of the market. ABI Research estimates that shipments of embedded modems will equal those of PC cards by 2009.

Internet access via the mobile phone threatens to overtake wireless access from a notebook PC, according to the annual *Face of the Web* study of Internet trends from Ipsos Insight. The massive install base of mobile phones throughout the world is driving mobile access at a phenomenal rate.[13]

"In cellular's early years, the primary focus was the cellular modem, and on improving its design," according to Alan Varghese of ABI Research. "In later years, as cellular networks switched on high-speed data, the design focus veered away from the modem and towards applications such as digital imaging, music and video. Thus, it is no longer an either/or game: the chipset design focus has to be on both the modem and the applications in order to enable robust wireless connections, low power consumption and enjoyable user-experiences. 3G chipset architects find they have a full plate on their hands."[14]

3G Applications

Telephia reports that mobile data usage in the U.S., such as text and multimedia messaging, mobile Web, and downloads reached the 50% adoption mark in Q4 2005, rising seven percentage points since the beginning of the year. According to the latest data from Telephia's Customer Value Metrics report, SMS activity leads the way for all mobile data usage with 41% of wireless subscribers using text messaging on their cell phones at the end of 2005. During Q4 2005, 22% of all cell phone users paid for accessing the Web via cell phone, 13% used MMS services (which raised 5 percentage points since Q1 2005), and 11% downloaded content from their cell phones (up 3 percentage points from the beginning of the year).[15] The global market for mobile-phone premium content, including music, gaming and video, is expected to

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[12] *Forecast: Mobile Terminals, Worldwide, 2000-2009 (4Q05 Update)* Gartner, January 12, 2006
[13] *Mobile Phones to Rival PC for Internet Access*, iTWire, Stan Beer, April 20, 2006
[14] *3G Chipset Design for Music, Gaming, Video and TV: No Longer an Either/Or Game*, ABI Research press release, February 23, 2006
[15] *American Mobile Data Usage Surges*, Telephia, April 7, 2006, www.cellular-news.com/story/16879.php

expand to more than $43 billion by 2010, rising at a compound annual growth rate of 42.5 percent from $5.2 billion in 2004, iSuppli Corp. predicts.[16]

Downloading music to a mobile handset, accessing and editing e-mails on a mobile handset, watching television or the person at the other end on the display during a phone call -- which services will wireless customers be using in the future, and what will they be willing to pay for them? To find the answers, Siemens surveyed over 5,300 mobile communication subscribers in eight countries about innovative wireless applications and their expectations with respect to the content and functionality of these applications.[17] A few trends are clear; mobile television and e-mail access on a mobile handset number among the most popular applications. The survey on "innovative wireless services" was conducted in Brazil, Canada, China, Germany, Italy, Korea, Russia and the United States. It was found that consumers across all countries and continents are keenly interested in mobile e-mail access -- on average, 74 percent of the surveyed wireless users want to be able to send, receive and edit e-mails on their wireless devices. Users in North America and Europe, in particular, have high expectations with respect to mobile e-mail access. Although the focus is on using this technology in connection with their work, many wireless subscribers would also consider personal usage. In many countries, Mobile TV is one of the most attractive applications - with an average of 59% of all respondents expressing interest in utilizing this application. This application is especially interesting to wireless providers due to the strong willingness on the part of users to pay for it. In Korea, where Mobile TV is already being offered, more than 90% of all respondents voiced their interest in mobile television. The study shows that the ability to download music tracks to mobile handsets also offers high potential with 62% of all respondents indicating they would download music files to their wireless devices. In all of the countries in which the survey was conducted, mobile music downloads numbered among the three most popular applications. Other applications that rank high-- particularly among the young generation-- include Mobile Gaming as well as the IMS-based services Group Communication, Enriched Voice Calling and File Sharing.

A new report by Datamonitor expects the number of mobilized email accounts to explode over the next three years. According to the report there are roughly 650 million corporate email inboxes worldwide today. Based on the assumption that at least 35-40% of these inboxes could potentially be mobilized, Datamonitor estimates the global addressable market for enterprise mobile email at around 260 million subscriptions. According to Datamonitor, mobile operators are in a position to make the most of the upsurge in growth anticipated for mobile email.[18]

Motorola is developing a chip that would allow users to pay at cash registers by swiping their cell phones. Such payments already are prevalent in Asia, where customers can buy groceries, movie tickets and train fare with their mobile phones.[19] With people spending billions on ringtones, wallpaper and games for their phones, analysts and retail executives say they believe it will not be much of a leap to get them to use their phones to buy shoes, books and laptops. “This will show up on the radar screen in 2006,” said Roger Entner, Ovum. “The more different pieces we add to these Swiss Army phones, the easier it is to get user acceptance for the next application. And especially around next Christmas, the convenience of shopping on a computer or a cell phone will beat the mall hands down.” [20]

Trip Hawkins, PC-gamer pioneer and founder and CEO of start-up Digital Chocolate is helping to shape the nascent mobile gaming industry.[21] Hawkins considers mobile gaming a community experience—the mobile phone is a social computer. What started on the Internet with dating services, chat and IM has spread like wildfire to the mobile phone with messaging, mobile email, and personalization—all about social identity. “The mobile phone is in a position to be the dominant platform in the same way the PC turned out to be the dominant platform of desktop computing. What the mobile phone has going for it as the social computer is ubiquity, because everyone has one, and because it supports a mobile lifestyle,” states Hawkins. “On the regular Internet, people are used to getting everything for free. But with the mobile phone, people are willing to pay for services. So there’s a huge business opportunity.” Hawkins sees the next important change as faster networks as there will be a quantum leap as we go from 2G to 3G networks meaning the gaming experience will get a lot better.

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[16] iSuppli Corp, March 8, 2006, www.cellular-news.com/story/16425.php

[17] *End-User Requirements & Expectations*, presentation, Siemens Network Evolution Forum, 3GSM World Congress 2006, Barcelona

[18] *Mobile Email on the Verge of Mass Market Adoption*, Datamonitor press release, February 2, 2006, www.datamonitor.com

[19] *Mobile Phones the Next Wave in Contactless Payments*, CTIA Smartbrief, February 8, 2006

[20] *“Those Born to Shop Can Now Use Cellphones,”* Bob Tedeschi, New York Times, January 2, 2006

[21] *Get Your Digits in Shape: Mobile Games are Hot and Getting Hotter*, Business Week, Business News Online Newsmaker Q&A, Steve Hamm, April 3, 2006

UK- based Juniper Research predicts that worldwide revenues for mobile gaming, which is composed of casino-style games, sports betting and lotteries will reach $19.3 billion by 2009. Juniper expects mobile gaming to make up roughly a third of the entire estimated $60 billion mobile entertainment market for that year. Mobile gaming already hit $468 million in 2004, and is projected at $2.07 billion at the end of 2005.[22] Telephia found the mobile gaming industry is "soaring" with wireless customers buying more than 8.2 million mobile games in March 2006, up 53% from 5.4 million in January 2006 according to their report. Unique buyers also "surged" from an estimated 3.5 million in January to 5 million in March 2006 according to Telephia's report. [23]

In August 2005, the Pelorus Group predicted that mobile Web connectivity and services would grow from $1 billion to $15.3 billion in five years time (2005-2010).[24] Social networking websites such as MySpace.com, which will soon go mobile, and others like Flickr for photo-sharing, Facebook.com for college students, or Rabble which lets users create profiles so they can share photos, videos and blogs with other members of the Rabble group, could become key applications drivers for new 3G wireless networks. Cell phones are the ideal tools for social networking and building online communities, because not only are people rarely without their phones, but today's handsets also come equipped with sophisticated features such as cameras, digital music and video players and recorders that can be used for documenting one's life. Mobile-handset makers Nokia and Sony Ericsson are even embedding technology into some of their phones to make it easier for users to upload pictures and text to blogs. This makes the mobile phone a great tool for users to create their own content.

The market for full track music downloads to mobile devices was twenty times larger at the end of 2005 than it was twelve months earlier noted ABI Research in its "Mobile Music Services" survey of world markets. Global revenues from over-the-air downloaded full track songs last year were $251 million up from $12.4 million in 2004.[25] Nearly a quarter of Americans have downloaded a ringtone to their mobile phone, according to Ipsos Insight in TEMPO, their quarterly study of digital music behaviors since 2002 published in August 2005. This marked a dramatic increase from the 5 percent who had downloaded music one year earlier (in 2004).[26]

Mobile music now accounts for approximately 40% of record company digital revenues (which totaled $1.1 billion in 2005, up from $380 billion in 2004). Record companies are seeing sharply increased sales of master ringtones which account for the bulk of their $400 million plus mobile music revenues.[27]

Adoption of mobile video on phones has been somewhat low to date with only 2% of users claiming a subscription. JupiterResearch has found that 41% of mobile phone users are interested in some form of video service on their mobile phones. JupiterResearch expects the growing demand for video to generate $501 million in revenues by 2010 from $62 million in 2005. Among mobile subscribers today, 17% were interested in watching 'live TV' on their phones while 11% indicated interest in short video clips.[28]

Mobile advertising had $45 million in US ad revenue in 2005, but this is expected to grow to $1.26 billion in three years, according to Ovum's forecast, and then carry on growing.[29] Mobile ad budgets for Third Screen company had risen from an average of $20,000 for a campaign a year ago to ranges of $150,000 to $250,000 today. In January 2006, Third Screen signed a $1.6 million contract for a one-year campaign. One reason for the growing interest in cell phone ads is the relatively high click-through rate -- around 4 percent for mobile phones compared to 1 percent on the internet.[30]

Another tremendous area of growth for wireless data will be in machine-to-machine (M2M) wireless mobile connections. In Europe alone, Berg Insight predicts at least 25 million machines with connectivity to mobile networks by 2009.[31] This number is currently estimated at 5 million. Although the use of these

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[22] *Interactive Games Announces Launch of Cell Phone Gaming Division and Strategic Alliance with Via-Cell*, Market Wire, April 28, 2005

[23] *Metric: Mobile gaming purchases up 53%,* Fierce Wireless, March 8, 2006

[24] *Mobile Web Market to Hit $15.3B*, Fierce Wireless, August 31, 2005

[25] *Ringing in the Changes: The Explosive Growth of Mobile Music Downloads*, ABI Research press release, March 28, 2006

[26] *More Americans Download Music*, Fierce Wireless, August 10, 2005

[27] *Mobile Music Downloads Soar*, Cellular News, January 24, 2006

[28] *JupiterResearch Predicts the Mobile Video Market will Generate Revenues of Over $500 Million by 2010 as a Result of Expanded Video Offerings on Mobile Phones,* JupiterResearch press release, March 28, 2006

[29] "*We'll Be Returning You to our Mobile Phone Call-Right After These Important Messages*," Telecom TV, Martyn Warwick, January 18, 2006

[30] "*Marketers Want to Appear on Small Screen"* New York Times, Matt Richtel January 16, 2006

[31] *Mobile M2M connections to hit 25 million by 2009*, CNET Networks, Jo Best, May 11, 2006

nodes is largely for GSM/GPS tracking technology, other growth areas will be in the security and retail sectors. This will include use of 3G applications and services. Robin Duke-Woolley of Harbor Research predicts that revenues from M2M networking devices will grow 27% annually, and could reach $10.6 billion worldwide by 2011.[32]

IP Multimedia Subsystem (IMS)
It has been estimated that by the end of the decade, more than 400 million people will regularly use SIP-based services across IP multimedia networks. IMS Research conducted an assessment of the trends affecting the uptake, including the timeline for IMS deployment. The assessment concluded that after initially slow uptake, the most popular service will be 'push to talk' followed by picture and video sharing, also known as 'push to' service.[33] Services included in the assessment were conferencing, instant messaging, interactive gaming, location services and mapping, mo-blogging and voice over WLAN among others. Total revenues for these services on cellular networks enabled with IP multimedia subsystems were estimated by IMS Research to ramp up to exceeding $50 billion by 2010. Report author John Devlin said, "The biggest single factor affecting the uptake of services on cellular networks will be operator strategy with regard to the positioning and pricing of these services and also the upgrade path to 3G and beyond. IMS is seen by some operators in the industry as an enhancement for 3G networks and they are intending to use it as an enabler to encourage subscriber migration and service uptake."

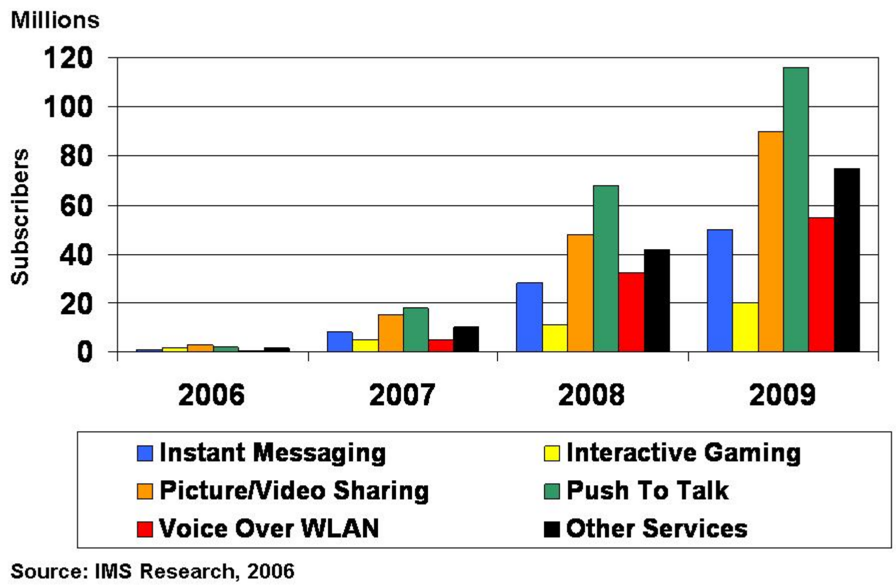


Figure 4. Worldwide Uptake of IMS Services In Terms of Subscriber Numbers[34]

The IMS market is expected to peak in 2010 when investments in IMS equipment are expected to reach $4.5 billion, according to Informa Telecoms & Media.[35] Informa predicts that successful services running on IMS will include VoIP and IPTV in the fixed environment and Push-to-talk over Cellular (PoC) and Instant Messaging in the mobile market. In the fixed market, Informa predicts that 39 million users will be enjoying IMS enabled services by 2011 compared with the 188 million users in the mobile sector. The next two years will be pivotal to the adoption of IMS worldwide. As of early April 2006, there were more than 50 contracts and 100 ongoing trials, and operators are expected to form strategies within the next two years. Operators are expected to enjoy cost savings from the layered architecture that IMS offers while maintaining a future-proof network. In the mobile domain, Informa expects that PoC will be a major

[32] *Harbor Research M2M Forecast, 2006*
[33] *"Push To" Services take the Lead*, IMS Research press release, March 16, 2006
[34] IMS Research, *Worldwide Uptake of Wireless Services*, Wm. Morelli, May 2006
[35] *IMS Opportunities and Challenges*, Informa Telecoms & Media report, March 2006

driver for IMS adoption while video sharing is already operating over IMS networks in a handful of cases around the world.

VoIP over Cellular

Industry interest in 'VoIP over cellular' is increasing. Reasons include the prospects of higher ARPU through richer communication (evolution currently driven by Internet players); lower OPEX through the offering of all mobile services from a common PS platform; and fixed/mobile convergence. The movement is to standardize an 'IMS Multimedia Telephony' service in 3GPP for many reasons: standardized services have benefits over proprietary solutions in terms of mass market potential; IMS is the standardized IP service engine for 3GPP access; and the service should make use of IP's multimedia capability and flexibility, while retaining key telephony characteristics. 3GPP is the body with major mobile telephony expertise to accomplish this standardization process.

The market indicators described in this section are representative of anticipated growth in the demand for wireless data services. The 3G networks and devices, applications and business strategies for IMS and UMA are in place or in development and researchers agree that the industry is poised for an explosion in the area of wireless data. Recent industry progress of UMTS from Rel-5 towards Rel-6 clearly supports the market trend claims reported in this section.

4 Overview of 3GPP Rel-7

As demonstrated in the previous 3G Americas' white papers on UMTS/HSDPA [Ref 3, Ref 4], Rel-5 and Rel-6 introduced several features that provided significantly larger capacity and better performance compared to Rel-99. Rel-7 continues to build on the strong foundation of Rel-5/Rel-6 by introducing further capacity enhancing features such as MIMO for HSDPA. Moreover, Rel-7 focuses on RAN enhancements such as Continuous Connectivity, Gaming over IP (GoIP) and Delay Optimizations that enhance the capabilities for providing efficient and optimized real-time services such as VoIP, gaming and push-to-talk (PTT). Finally, Rel-7 also introduces IMS/Core Network enhancements related to multi-media telephony, combining of circuit and packet switched services (CSI), policy and charging and voice call continuity. It is proposed to keep the current Radio Network and Core Network separation to enable fast rollouts and easy implementation to terminals. This section provides an overview of the Rel-7 features discussed above.

4.1 MIMO on HSDPA

The term "MIMO" is an acronym for multiple-input, multiple-output, and it is used to refer to any wireless system with multiple antennas at the transmitter and receiver. At the transmitter, multiple antennas can be used to mitigate the effects of fading via transmit diversity and to increase throughput via spatial division multiple access (SDMA). Beamforming and sectorization are two examples of SDMA. Beamforming can also be used for range extension. At the receiver, multiple antennas can be used for receiver combining which provides diversity and combining gains. If multiple antennas are available at both the transmitter and receiver, then different data streams can be transmitted from each antenna, with each stream carrying different information but using the same frequency resources. This technique, known as spatial multiplexing (SM), can potentially increase a user's peak data rate compared to conventional single-stream transmission.

In the context of HSDPA Rel-7, MIMO specifically refers to SM. In this section, we first describe basic principles of spatial multiplexing followed by a discussion of the two main MIMO proposals that were investigated for Rel-7. We then describe how MIMO is used in a system context and the network environments that are best-suited for MIMO. We assume throughout that the MIMO mode uses two Node B antennas and two antennas per user equipment (UE).

HSDPA uses rate adaptation based on a user's channel quality information (CQI), which is fed back from the UE to the Node B. In conventional single-antenna HSDPA, the highest rate achievable under realistic conditions employs 16QAM and coding rate 1/2. Using a spreading period of 16 chips per symbol and 15 parallel codes for the HSDCH, this yields 7.2 Mbps (3.84Mchips per sec * 15 codes / 16 chips per code * 4 bits per symbol * 1/2 information bit per coded bit). Spatial multiplexing achieves higher data rates by reusing spectral resources over multiple spatial dimensions. For example, using two transmit antennas, one could transmit two separate data streams, each with data rate 7.2 Mbps resulting in a peak rate of 14.4Mbps. Because the two data streams are modulated in the same bandwidth using the same set of spreading codes, MIMO for HSDPA is sometimes called "code reuse". At the receiver, multiple antennas are required to demodulate the data streams based on their spatial characteristics. In general, the minimum number of receiver antennas required is equal to the number of separate data streams. Different receiver techniques can be used, but they typically employ a minimum mean-squared error (MMSE) linear processor followed by a non-linear interference canceller.

The two specific MIMO proposals for Rel-7 are Per-Antenna Rate Control (PARC)[R1-010879] and [R1-060708] and Double Transmit Adaptive Array (D-TxAA) [R1-030556]. Their baseband block diagrams are shown in Figures 5 and 6, respectively. Each MIMO proposal consists of a single-stream mode and a SM mode. For PARC, the single-stream mode uses space-time transmit diversity (STTD) block coding following the channel coding, interleaving, mapping to symbols, and spreading (C.I.M.S.) of the information bits. In the SM mode, the information bits are first demultiplexed, prior to coding. Because the rate for each antenna can be adapted independently, the number of bits sent to each antenna can be different. For D-TxAA, the single-stream mode uses Rel-99 TxAA to achieve closed-loop transmit diversity. The signals for each antenna are weighted by a complex amplitude chosen to best match the instantaneous channel characteristics. The pairs of amplitudes are chosen from a pre-defined set. Spatial multiplexing for D-TxAA transmits two simultaneous streams whose weight vectors are mutually orthogonal. Simulation results from various companies have shown similar performance for the PARC and D-TxAA schemes. In Rel-7, MIMO based on PARC has been adopted for UTRA TDD mode and Dual-codeword MIMO based on D-TxAA (with weights being signaled on the HS-SCCH in the downlink) has been adopted for UTRA FDD mode.

In PARC, channel quality information is fed back from the UE to the NodeB to indicate which transmission mode to use and what data rate(s) can be supported. D-TxAA requires additional feedback to indicate which weighting vector(s) to use. D-TxAA could potentially achieve slightly higher throughput than PARC for low mobility channels.

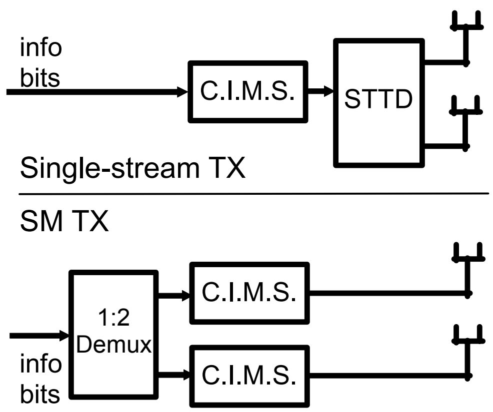


Figure 5. PARC[36]

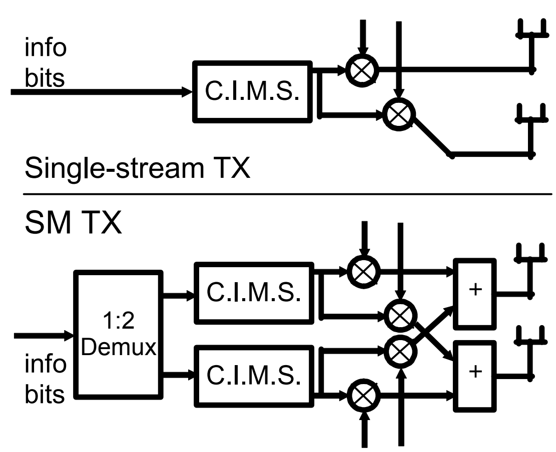


Figure 6. D-TxAA[37]

To demonstrate performance of these MIMO techniques, Figure 7 and Figure 8 depict the average cell throughput and CDF of user throughput respectively for a 2x2 D-TxAA system compared to a reference 1x2 Linear Minimum Mean Square Error (LMMSE) system when using a space-time channel model (SCM). The scenario used in the evaluation is a micro cellular network scenario according to the model for the “Urban Micro” environment. The inter-site distance was 1000 meters without additional penetration loss. It can be observed that 2x2 D-TxAA MIMO provides some gain (approximately 10%) over the reference 1x2 LMMSE system in average cell throughput and increases the peak throughputs of the individual users. The results are expected to be comparable to PARC.

[36] TSG-R1(01)0879, 3GPP TSG RAN WG1, Turin, Italy, Aug 27-31, 2001
[37] TSGR1#32(03)0556, 3GPP TSG RAN WG1, Marne la Vallee, France, May 19-22, 2003

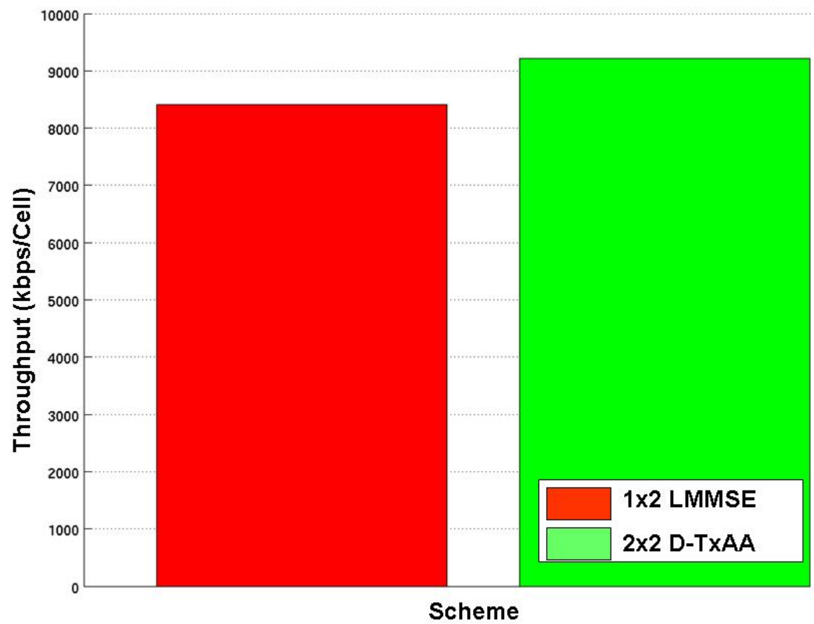


Figure 7. Average cell throughput in SCM Urban Micro, RR scheduler[38]

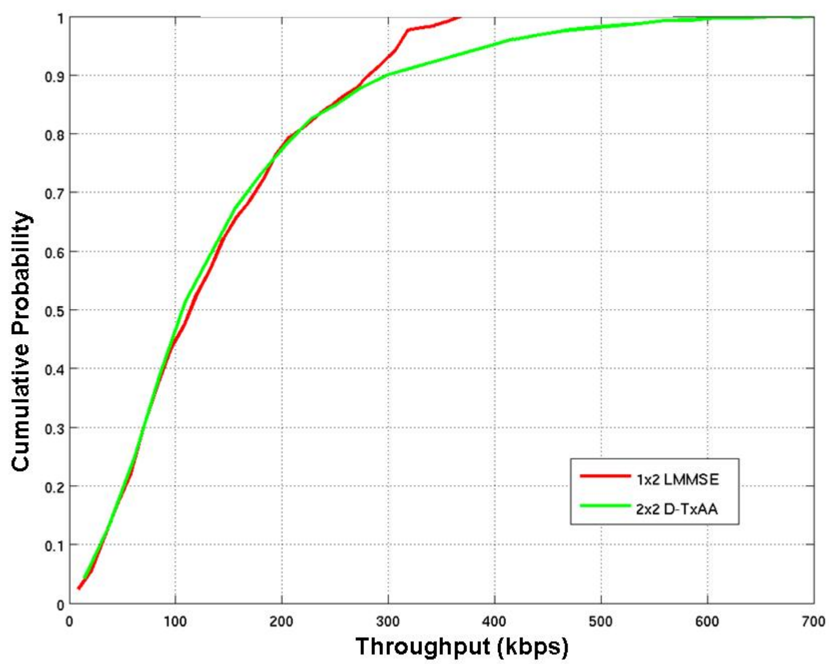


Figure 8. CDF of user throughput[39]

It should be noted that the spatial multiplexing techniques discussed above could also be used for lower data rates by reducing the coding rate and using smaller data constellations. For example, one could

[38] Nokia, " WCDMA MIMO performance", March 27-31, 2006, Athens, Greece, 3GPP TSG RAN WG1 Meeting #44bis, Tdoc R1-060799

[39] 3GPP RAN WG1 #45, R1-061451, Lucent Technologies

transmit two data streams, each with QPSK and coding rate ¼. The same data rate could be achieved with a single data stream using QPSK and coding rate ½. For lower data rates, it is more efficient to transmit using a single stream rather than with spatial multiplexing. In other words, for a given low rate and a given total transmit power, single stream transmission achieves a lower frame error rate. Therefore MIMO for HSDPA uses single-stream transmission for lower data rates and spatial multiplexing for only the higher data rates. Because multiple antennas are available at the Node B, transmit diversity can be used for single-stream transmission.

The "crossover point" at which it becomes more efficient to transmit with spatial multiplexing depends on many factors including the number of UE antennas. For dual-antenna UEs, the crossover point is typically about 5dB SINR (geometry), corresponding to an achievable data rate of about 4Mbps. In conventional cellular networks with fully loaded 3-sector cells and universal frequency reuse, the geometry is greater than 4dB in about 35% of the locations. Therefore SM is used about 35% of the time, and the fraction of users that achieve a peak rate equal or higher than the single-stream peak rate of 7.2 Mbps is about 25%. This is compared to the 15% that can achieve 7.2 Mbps in a conventional baseline HSDPA system with dual-antenna UEs. In terms of total average cell throughput, MIMO provides about a 33% improvement over this baseline. If cell throughput is a more important performance metric than peak data rate, it is much more efficient to use sectorization instead of SM. Using 6-sector cells each with a single antenna, the throughput improvement over the baseline is about 80%, but the tradeoff is that the peak rate remains the same since only a single antenna is used in each sector. Because the gains of MIMO are relatively modest for conventional networks with fully loaded cells, Rel-7 MIMO studies are now done in the context of "contained" environments where the intercell interference is limited. Examples of these environments include malls, academic campuses, and airports. In these environments, MIMO performance gains are improved, in terms of the fraction of time SM is used and overall throughput.

Figure 9 shows a system-level comparison between conventional single-antenna and MIMO systems for the case of isolated cells and a conventional interference-limited environment[39]. The MIMO system used in these simulations is a PARC system (described below); however, similar results are expected for a D-TxAA system. Note that the peak rate and cell edge rates are defined as the 90% and 10% points of the cumulative distribution of achievable rates.

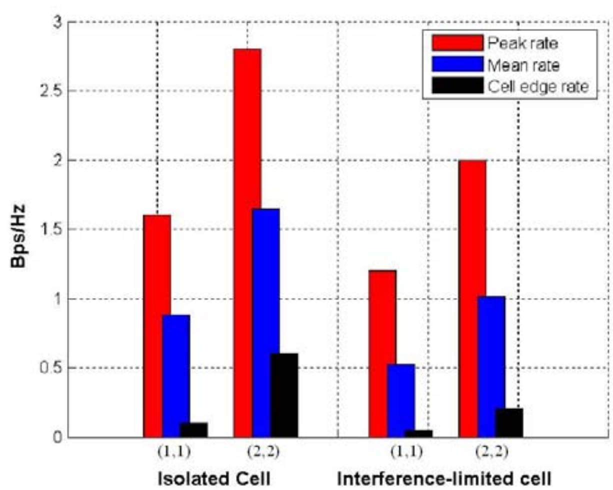


Figure 9. MIMO system-level performance[40]

Operators Perspective on MIMO

Wireless network operators see a need for MIMO (Multiple-Input Multiple-Output) due to its many advantages. Wireless systems using MIMO represent an economical way to increase user capacity, range and throughput in a variety of environments, most notably those which are enclosed and having low radio interference such as small and/or isolated cells. MIMO has been variously defined as "*two or more unique radio signals, in the same radio channel, where each signal carries different digital*

[40] 3GPP RAN WG1 #45, R1-061451, Lucent Technologies

information" and "*two or more radio signals which use beam-forming, receive combining, and spatial multiplexing*".

The use of multiple antennas at both transmitter and receiver allows:

- Multiplicative increase in peak data rate
- Significantly higher spectrum efficiency, especially in low-interference environments
- Increased system capacity (number of users)

In UMTS systems, operators see a great need for MIMO in "contained environments" such as:

- Hot spots similar to those serviced by today's WiFi systems (airports, hotel lobbies, etc)
- Academic campuses, in various self-contained areas (quads, auditoriums, cafeterias, etc)
- Stadiums and arenas, again, which offer self-contained environments
- Malls and shopping areas, favored by large numbers of younger, internet-savvy users
- Mass transportation (trains, etc) with users looking for interaction and entertainment
- Enclosed parks and recreation areas
- Residential homes, supplanting DSL/Cable services

Operators believe that, notwithstanding the basic differences in the physical layers used by UMTS and LTE, the benefits envisioned from MIMO in LTE, can also be obtained from MIMO in UMTS systems, starting in Rel-7.

4.2 RAN Enhancements

Continuous Connectivity for Packet Data Users

Packet-oriented features like HSDPA and HSUPA (HSPA) in UMTS systems provide high data rates for both downlink and uplink. This will promote the subscribers' desire for continuous connectivity, where the user stays connected over a long time span with only occasional active periods of data transmission, and avoiding frequent connection termination and re-establishment with its inherent overhead and delay. This is the perceived mode to which a subscriber is accustomed in fixed broadband networks (e.g., DSL) and may make a significant difference to the user experience.

The Fractional-DPCH feature was introduced in Rel-6 to support a high number of HSDPA users in the code limited downlink, where effectively a user in the active state, not being transmitted with any data, is consuming only a very small portion of the downlink capacity.

In the uplink, the limiting factor for supporting a similarly high number of users is the noise rise. For such a high number of users in the cell it can be assumed that many users are not transmitting any user data for some time (e.g., for reading during web browsing or in between packets for periodic packet transmission such as VoIP). The corresponding overhead in the noise rise caused by maintained control channels will limit the number of users that can be efficiently supported.

Since completely releasing the dedicated connection during periods of traffic inactivity would cause considerable delays for reestablishing data transmission and a correspondingly worse user perception, the Continuous Connectivity for Packet Data Users intends to reduce the impact of control channels on uplink noise rise while maintaining the connections and allowing a much faster reactivation for temporarily inactive users. This is intended to significantly increase the number of packet data users (i.e. HSPA users) in the UMTS FDD system that can stay in the active state (Cell_DCH) over a long time period, without degrading cell throughput. The objective aims also at improving the achievable UL capacity for VoIP users with its inherent periodic transmission through reducing the overhead of the control channels.

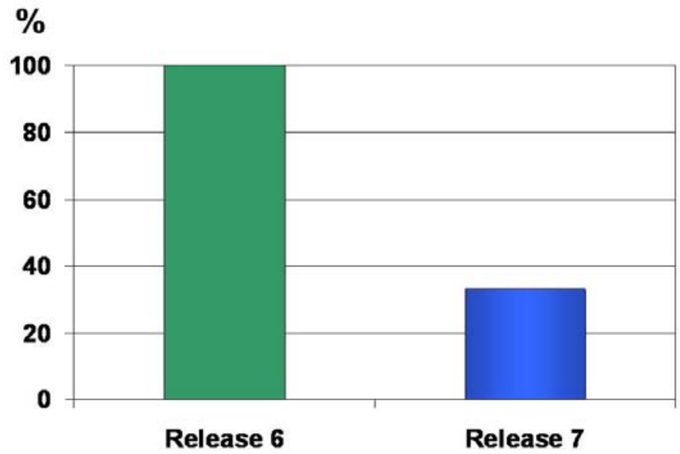


Figure 10. Relative uplink capacity cost of a user in the active state and not transmitting any data[41]

Thus far, the 3GPP study summarized in Fig. 10, indicates that with Rel-7, the uplink can support the users not transmitting any data in the active state with one third of the capacity cost than in Rel-6. These users see practically no delay when resuming the data transmission. The same studies indicate the potential for VoIP capacity increase in the uplink is in the order of 50% with Rel-7 (see Fig. 11).

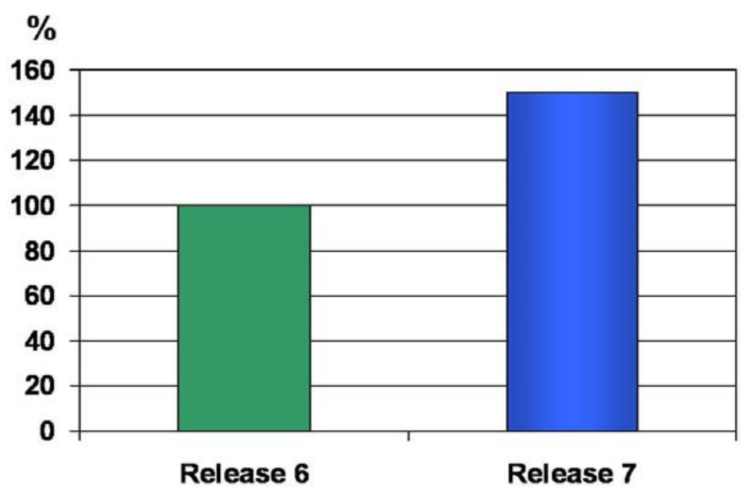


Figure 11. Relative uplink VoIP capacity with Rel-6 and Rel-7[42]

The key technologies studied under the Continuous Connectivity for Packet Data Users for 3GPP Rel-7 are reducing the uplink noise rise caused by the uplink DPCCH transmission of the users not transmitting any data, by either reducing the uplink DPCCH transmission power (SIR_target reduction) or by shutting it down completely for short time durations (UL DPCCH gating). Capacity investigations for the latter are shown in the two figures above.

The benefit of turning the UE's transmitter off is significantly reduced UE power consumption which also enables longer times for the UE to be kept in the active state when the applications require no data transmission.

The benefit of just reducing the uplink DPCCH power to a certain level is that synchronization and power control can be kept stable in all situations together with a less bursty behavior of the channel. In connection with the key technologies further enhancements (e.g., CQI reductions, UL DPCCH slot format modifications) are considered to improve the UL noise rise situation.

[41] 3GPP TR 25.903 v1.0.0 (2006-05), Continuous Connectivity for Packet Data Users
[42] *Ibid.*

Although the main trigger of the work on "continuous connectivity for packet data users" was the bottleneck of UL noise rise which is especially costly for temporarily inactive users, further control channel overhead reduction improvements are also investigated for the downlink (e.g., when looking at UE battery savings or VoIP capacity enhancements).

The downlink HSPA VoIP capacity enhancement is being investigated; the key techniques being optimizing the control signaling of HSDPA to be most efficient for small VoIP-like packets and optimizing the HSDPA scheduler to take the full advantage of knowing that certain traffic is VoIP traffic. To some extent, the scheduler enhancements and control signaling optimizations may be mutually exclusive and thus selecting which method is best requires careful consideration.

Gaming over IP (GoIP)

As part of the IMS realtime services using HSDPA/HSUPA, GoIP may become very important applications for the operator. To ensure the target gaming performance and propose proper improvements of existing standards, it is necessary to investigate and define the performance requirements for gaming traffic.

Existing requirements

The following tables are cited from the current 3GPP standards:

Table 1.
3GPP TS 22.105: requirements for conversational voice, videophone and interactive games

Medium	**Application**	**Degree of symmetry**	**Data rate**	**Key performance parameters and target values**		
				End-to-end One-way Delay	Delay Variation within a call	Information loss
Audio	Conversational voice	Two-way	4-25 kb/s	< 150 msec *preferred* < 400 msec *limit* *	< 1 msec	< 3% FER
Video	Videophone	Two-way	32-384 kb/s	< 150 msec *preferred* < 400 msec *limit* Lip-synch < 100 msec		< 1% FER
Data	Interactive games	Two-way	< 1 KB	< 250 msec	N.A	Zero

**The overall one way delay in the mobile network (from UE to PLMN border) is approximately 100 msec*

If VoIP over HSDPA is intended to become the primary mechanism for providing voice and/or video services, then it can be assumed that the requirements should not be degraded from the existing requirements shown above.

Requirements for interactive games are obviously very dependent on the specific game, but it is clear that demanding applications will require very short delays. Consistent with demanding interactive applications, a maximum 250ms end-to-end (E2E) one-way delay is proposed here and leads to a ping time of 500ms.

Table 2.
3GPP TS 23.107: RAB characteristics for Conversational class

RAB characteristics	
Traffic class	**Conversational class**
Maximum bitrate (kbps)	<= 16 000 (2) (7)
Delivery order	Yes/No
Maximum SDU size (octets)	<=1 500 or 1 502 (4)
SDU format information (1)	(5)
Delivery of erroneous SDUs	Yes/No/-
Residual BER	$5*10^{-2}$, 10^{-2}, $5*10^{-3}$, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}
SDU error ratio	10^{-2}, $7*10^{-3}$, 10^{-3}, 10^{-4}, 10^{-5}
Transfer delay (ms)	80 – maximum value
Guaranteed bit rate (kbps)	<= 16 000 (2) (7)
Traffic handling priority	
Allocation/Retention priority (1)	1,2,3
Source statistic descriptor	Speech/unknown
Signalling Indication	

No specific mention of gaming traffic has been made. The transfer delay characteristic is one way, and measured from CN to UE. This allows for 150ms for internet based delay which is more than feasible.

Gaming over HSDPA
The following three major performance parameters have been identified to be sufficient for defining the gaming performance requirements:

- End-to-end delay
- Jitter
- Application packet loss

Given the wide variety of games available, it is recommended to separate the games into the following four categories in which the corresponding tolerable gaming performance have been described with the use of the above proposed performance parameters:

- **First Person Shooter (FPS)** – fast user response, many online players at once, highly dynamic
  - Up to 150ms end-to-end delay may be acceptable
  - 10ms jitter may be expected to be critical for FPS gaming
  - Up to 5% packet loss is acceptable
- **Real Time Strategy (RTS)** – slightly lower response required, slower gameplay, handful of players in a single game
  - 250ms-500ms end-to-end delay may be acceptable
  - Requirements for jitter are undefined
  - 1% packet loss with 150ms delay may be acceptable
- **Massive Multiplayer Online Role Playing Games (MMORPG) –** Persistent games, highly variable scenarios, many hundreds of players online at once, many tens in a given situation
  - Several packets every ms
  - Latency << 350ms
    - o With 80ms RAB latency no problem
    - o 150ms ping delay cannot be achieved with 80ms RAB
  - Depending on the time and game contents, the required data rate ranges between 8kbps-24kbps

- 10% packet loss may be acceptable if latency is low; 10~15% packet loss with 150ms ping delay is acceptable

- **Non-real Time Games (NRTG)** – e.g., chess, backgammon, cards etc.
  - Zero packet loss, which can be achieved by retransmission methods

It is understood that, within these four gaming categories, the requirements for delay, jitter and packet loss are different depending on the games and on the expectations of the player, but the typical range of the requirement attributes for real time gaming have been observed as following:

- Packet loss 0.1% → 5%
- Latency (e2e) 75ms – 250ms
- Data rate (5kbps- 60kbps)

It is clear from the values above that the definition in TS 22.105 is considerably stricter than necessary in terms of packet loss in most cases.

Jitter has been shown to be problematic, but not in a truly quantifiable way and it is proposed that jitter should be minimized to as little as possible, potentially by algorithms in the application rather than in the network.

However, in terms of latency, the requirements on the RAB delay for best performance are too low since E2E delays >75ms will lead to a perceived drop in performance from the user if the game requires the fastest response.

Activities in 3GPP on defining more appropriate values related to realtime gaming for TS 22.105 are ongoing. Currently, the following requirements are in discussion:

Table 3. 3GPP TS22.105 Values Related to Realtime Gaming

Medium	Application	Degree of symmetry	Data rate	End-to-end One-way Delay	Delay Variation within a call	Information loss
Data	realtime games	two-way	< 60 kb/s	< 75 msec *preferred*	N.A.	< 3% FER *preferred* < 5% FER *limit*

It should be noted that these values are considered the most demanding with respect to delay requirements (e.g., supporting First Person Shooter games). Other types of games may require higher or lower data rates and more or less information loss but can tolerate longer end-to-end delay.

Delay optimization for procedures applicable to PS and CS Connections

In Rel-99, UMTS introduced a dedicated channel (DCH) that can be used for CS and PS connections when UE is in CELL_DCH state. In addition to CELL_DCH state, Rel-99 introduced CELL_FACH state where signaling and data transmission is possible on common channels (RACH and FACH) and CELL_PCH and URA_PCH states, where the transmission of signaling or user data is not possible but enables UE power savings during inactivity periods maintaining the RRC connection between UE and UTRAN and signaling connection between UE and PS CN. The introduction of the CELL_PCH and URA_PCH states, the need of releasing the RRC connection and moving the UE to Idle mode for PS connections was removed and thus the Rel-99 UTRAN can provide long living Iu-connection PS services.

On the other hand, when UE is moved to CELL_PCH or URA_PCH state, the start of data transmission again after inactivity suffers inherent state transition delay before the data transmission can continue in CELL_DCH state. As new packet-oriented features like HSDPA and HSUPA in Rel-5 and Rel-6 UMTS systems respectively provide higher data rates for both downlink and uplink in CELL_DCH state, the state transition delay has been considered to be significant and negatively influencing the end user experience.

In addition to RRC state transition delay, the radio bearer setup delay to activate new PS and CS services has been seen as problematic in UMTS, due to signaling delays on CELL_FACH state where only low data rates are available via RACH and FACH, and due to activation time used to synchronize the reconfiguration of the physical and transport channel in CELL_DCH state.

To secure future competitiveness of UMTS and enhance the end user experience even further, the delay optimization for procedures applicable to PS and CS connections work is targeted to reduce both setup times of new PS and CS services and state transition delays to, but still enable, excellent UE power saving provided by CELL_PCH and URA_PCH states.

During the 3GPP Rel-6 time frame, the work was focused on solutions that can be introduced in a fast manner on top of existing specifications with limited effects to the existing implementations. In addition, the solutions which allow the Rel-6 features to be used in the most efficient manner were considered. The agreed modifications can be summarized as: introduction of enhanced support of default configurations, reduced effects of the activation time, and utilization of HSPA for signaling. Thus, from Rel-6 onwards, the signaling radio bearers (SRBs) can be mapped on HSDPA and HSUPA immediately in RRC connection setup and default configurations can be used in radio bearer setup message and RRC connection setup message in a more flexible manner.

The utilization of default configuration and mapping of the SRBs on HSDPA and HSUPA will reduce message sizes, activation times, and introduce faster transmission channels for the signaling procedures, thereby providing significant enhancement to setup times of PS and CS services compared to Rel-99 performance.

In the 3GPP Rel-7 time frame, the work will study methods of improving the performance even further, especially in the area of state transition delays. As the work for Rel-7 is less limited in scope of possible solutions, significant improvements to both RRC state transition delays and service setups times are expected.

4.3 IMS/Core Network Enhancements

Fixed Broadband Access to IMS (FBI)

It is recognized that several standards organizations are in the process of defining NGN (Next Generation Network) session control using IMS as a platform. Fixed Broadband Access provides a means of extending IMS services to wireline subscribers. The work on Fixed Broadband Access (FBI) will embed IMS as the framework for advanced services for many types of operators. IMS is extended to act as a common core and services platform for fixed and mobile networks.

Under the Fixed Broadband Access (FBI) work, 3GPP is considering requirements from a number of different communities of operators including those based on DSL and cable technology. IMS is now accepted as the de facto basis for session oriented services in next generation telecommunications networks.

A number of features have been introduced primarily in order to extend the IMS towards providing services for fixed broadband access:

- NAT traversal
- Optional use of SIP preconditions for wireline access
- PSTN bridging – the use of IMS as a transit network with PSTN round the edge

One Tunnel for Packet Traffic

The amount of user plane data is assumed to increase significantly during the next few years because of the introduction of HSPA and the IP Multimedia Subsystem. Currently in UMTS, packet data traffic must traverse two nodes in the core network – the SGSN and GGSN. This is independent of the traversal done in the UTRAN.

The discussions in 3GPP have shown that more scalable UMTS system architecture can be achieved by direct tunneling of user plane data between the RNC and the GGSN, which is known as One Tunnel approach (Fig. 12).

In the One Tunnel Approach, the transport and control functionality of the SGSN are separated, resulting in a new distribution of functionality with the GGSN. The new SGSN controller (cSGSN) is performing all control functions of an SGSN while the enhanced GGSN (xGGSN) is responsible for SGSN and GGSN transport functionality for the majority of traffic.

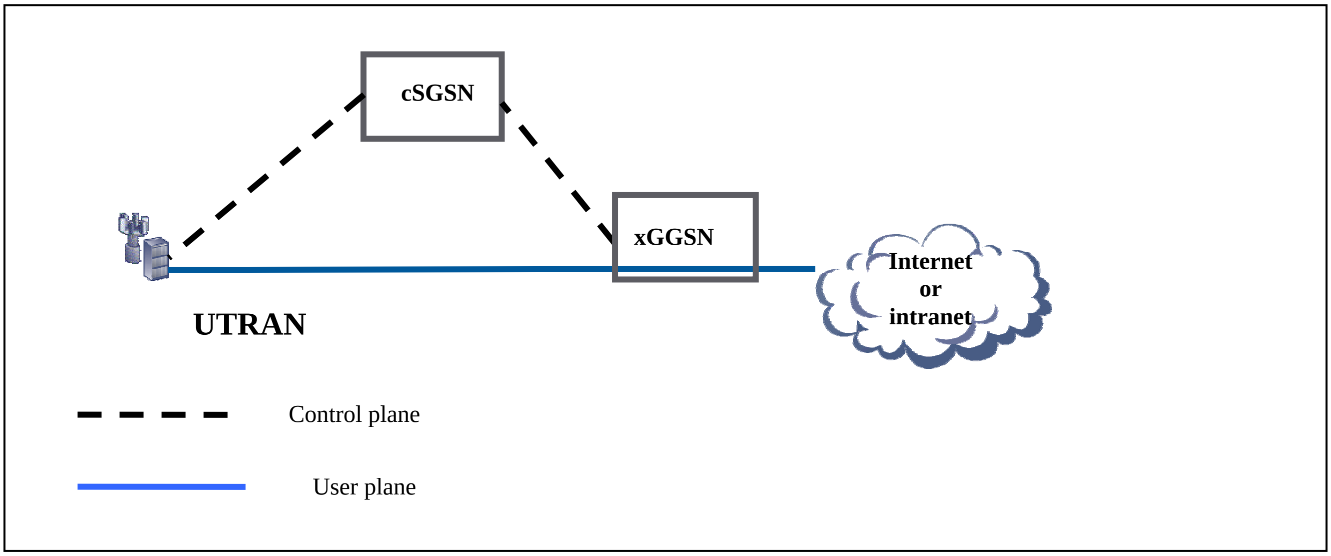


Figure 12. One Tunnel architecture

This architecture has several benefits:

- All bearer resources are shared between cSGSNs resulting in reduction in CAPEX by eliminating the bearer hardware on new cSGSNs
- 3G bearer plane is engineered only at the xGGSN and not tied to geographic distribution of users
- User plane scalability: as 3G bearer throughput grows, bearer resources only added at the xGGSN
- No need to project 3G bearer capacity of individual cSGSN for roamers; only need to project network-wide 3G bearer capacity for roamers

IMS Multimedia Telephony Communication Enabler (MITE) and Supplementary Services
The aim of MITE is to provide specifications for common telephony services over IMS, including well known and well used supplementary services. This builds on the capabilities provided by IMS in Rel-5 and Rel-6. MITE will enable consistent user experience and interoperable implementations. MITE covers voice and multimedia user-to-user sessions that can be enhanced with features like forwarding and conferencing. MITE offers operators a path to evolve telephony services from the CS domain towards IMS without abandoning legacy features.

MITE is aligned with service definitions being generated for Next Generation Networks (NGN) and therefore MITE can be used in conjunction with the FBI work item to provide consistent wireline and wireless services.

Combining CS and IMS (CSI)
CSI provides a means for a mobile station to combine a CS voice call with PS-based IMS services between the same two users. The motivation is to introduce multi-media telephony, without the immediate requirement to upgrade the radio to support VoIP. This is done by using legacy CS voice for the voice component of the multi-media session.

In addition, CSI introduces a SIP-based mechanism for users to exchange terminal capabilities. Capability exchange provides a means by which party A can know which IMS services/media types can be included as part of a multi-media session with party B. Capability exchange can be done independent of CSI and is expected to be used for detecting if a voice call can be successfully upgraded to video.

CSI provides a path to introduce subscribers to IMS services and in particular the concept of rich calls. The main usage scenario is to start each session with a CS voice call then to detect what add-on services are possible and display these available services to the user in order to encourage their use.

By re-using CS calls for the voice, there is no risk of VoIP performance issues impacting IMS launch. CSI also allows operators to manage their investment in rolling out IMS while establishing the level of market demand for new services.

CSI is the basis for video sharing services (adding video to an established voice call in progress) being launched on some networks.

Policy and Charging Convergence (PCC)
PCC provides enhanced and future-proof tools to allow operators to perform advanced dynamic QoS control and charging for IP data bearers. PCC develops the capabilities provided in Rel-5 Service Based Local Policy (SBLP) and Rel-6 Flow Base Charging for IP bearers. PCC will combine the policy control and charging functions into a single architecture which provides consistent signaling and which can support multiple access types.

PCC will enable operators to adjust the QoS being provided to users based on a range of factors including application requirements and user subscription level (gold, silver, bronze). PCC will also provide tools useful to manage the impact of "bandwidth hogging" applications such as peer-to-peer file sharing.

The PCC architecture is built on the Rel-6 Flow Based Charging including evolution of the Rel-6 FBC reference points (Gx, Gy, Rx). Like FBC (Flow Based Charging), the PCC architecture can manage multiple service data flows on one single bearer, allowing more flexibility to configure and optimize the radio interface.

Voice Call Continuity (VCC)
VCC is a home IMS application, which enables seamless continuity of voice services between CS domain and IMS. VCC subscribers' calls are anchored in home IMS when roaming across CS domain and IMS. VCC provides functions for call originations, terminations and call continuity across CS domain and IMS.

The VCC Application is inserted in the control signalling path of VCC subscriber's CS and IMS sessions for employment of a 3pcc (third party call control function) controlling these sessions. Calls established over CS domain are redirected to IMS for insertion of VCC Application in the call control signalling path using standard CS domain techniques available for redirecting calls at call establishment; these calls are then processed according to standard IMS procedures. This allows for voice service continuity across CS domain and IMS.

VCC provides selection of domain for delivery of incoming calls to VCC subscribers simultaneously registered in CS domain and IMS. VCC provides inter-domain mobility while maintaining active session(s), manifested by transfers between CS domain and IMS, with capability to transition multiple times in both directions.

5 Evolution Beyond Rel-7 – SAE/HSPA+/LTE

To ensure the competitiveness of the 3GPP systems in a time frame of the next ten years and beyond, a long term evolution of the 3GPP access technology is specified in 3GPP. The vision of this long term evolution and transition towards a packet switched only system is shown in Fig. 13.

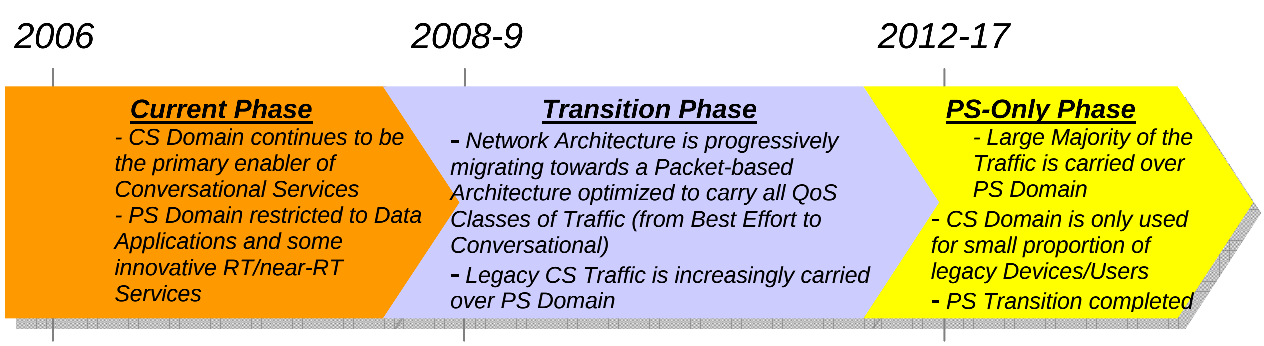


Figure 13. Migration towards full service delivery through the evolved packet core[43]

To enhance the capability of the 3GPP system to cope with the rapid growth in IP data traffic, the packet-switched technology utilized within 3G mobile networks requires further enhancement. Continued evolution and optimization of the system is also necessary in order to maintain a competitive edge in terms of both performance and cost. Important parts of such a long term evolution include reduced

[43] Cingular Wireless

latency, higher user data rates, improved system capacity and coverage, and reduced overall cost for the operator.

Additionally, it is expected that IP-based 3GPP services will be provided through various access technologies. A mechanism to support seamless mobility between heterogeneous access networks is needed for future network evolution.

In order to achieve this, an evolution or migration of the network architecture, as well as an evolution of the radio interface is studied in the System Architecture Evolution (SAE), Long Term Evolution (LTE) and HSPA Evolution (HSPA+) Study Items in 3GPP. From a network deployment point of view it is likely that HSPA enhancements will be introduced first, followed by the evolved packet core (SAE) and then the evolved radio interface (LTE).

5.1 Architecture Evolution (SAE)

SAE or 3GPP System Architecture Evolution is the study item where the 3GPP industry is developing a framework for an evolution and migration of current systems to a higher-data-rate, lower-latency, packet-optimized system that supports multiple radio access technologies. The focus of this work is on the PS domain with the assumption that voice services are supported in this domain.

The main drivers for the network evolution are:

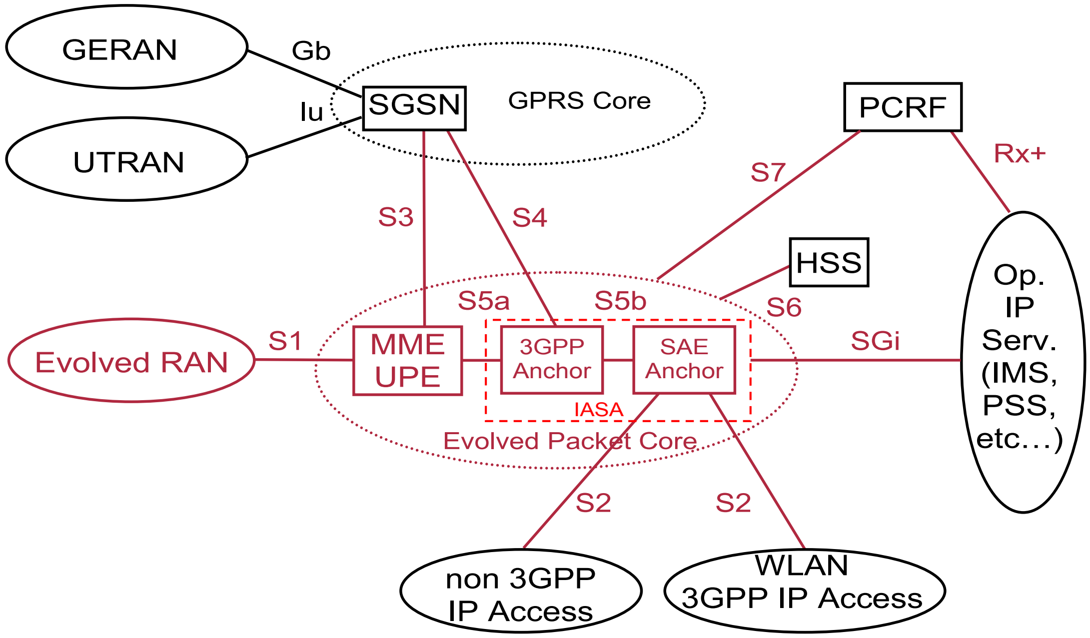
- To be able to meet the targets for the evolution of the radio-interface (a.k.a. LTE)
- To enable the evolution towards an All-IP Network
- To support mobility and service continuity between heterogeneous access networks

The main objectives for the evolved architecture are:

- To get very low latency for the overall network
- To efficiently support a variety of services, especially from the PS domain (e.g., Voice over IP, Presence)
- To support a variety of different access systems (existing and future) and support access selection based on combinations of operator policies, user preferences and access network conditions
- To improve basic system performance e.g., communication delay, communication quality, connection set-up time, etc.
- To be able to maintain negotiated QoS across the whole system; in particular inter-domain and inter-network interworking and QoS on the network link to the Base Station site
- To support service continuity between I-WLAN and the 3GPP PS domain
- To support multiple radio access technologies and terminal mobility between different radio access technologies
- To be able to maintain and support the same capabilities of access control (authentication, authorization), privacy and charging when moving between different radio access technologies

High Level Architecture Overview

Figure 14 shows the current architecture model for the evolved system. It identifies functional entities which may be physically co-located or distributed, according to product development and deployment scenarios. For instance, the Inter-AS anchor may or may not be co-located with the UPE; the MME and UPE may or may not be co-located in the same node.



* Color coding: red indicates new functional element / interface

Figure 14: Logical high level architecture for the evolved system[44]

New functional elements

The architecture model contains the following new functional elements:

- **Mobility Management Entity (MME):** The MME manages and stores UE context (for idle state: UE/user identities, UE mobility state, user security parameters). It generates temporary identities and allocates them to UEs. It checks the authorization whether the UE may camp on the TA or on the PLMN. It also authenticates the user.
- **User Plane Entity (UPE):** The UPE terminates for idle state UEs the downlink data path and triggers/initiates paging when downlink data arrive for the UE. It manages and stores UE contexts, e.g., parameters of the IP bearer service or network internal routing information. It performs replication of the user traffic in case of interception.
- **3GPP Anchor:** The 3GPP Anchor is a functional entity that anchors the user plane for mobility between the 2G/3G access system and the LTE access system.
- **SAE Anchor:** The SAE Anchor is a functional entity that anchors the user plane for mobility between 3GPP access systems and non-3GPP access systems.

New interfaces

The architecture model contains the following new interfaces:

- **S1:** S1 provides access to Evolved RAN radio resources for the transport of user plane and control plane traffic.
- **S2:** S2 provides the user plane with related control and mobility support between WLAN 3GPP IP access or non 3GPP IP access and the SAE Anchor.
- **S3:** S3 enables user and bearer information exchange for inter 3GPP access system mobility in idle and/or active state. It is based on Gn reference point as defined between SGSNs.
- **S4:** S4 provides the user plane with related control and mobility support between GPRS Core and the 3GPP Anchor and is based on Gn reference point as defined between SGSN and GGSN.
- **S5a:** S5a provides the user plane with related control and mobility support between MME/UPE and the 3GPP Anchor.
- **S5b:** S5b provides the user plane with related control and mobility support between the 3GPP anchor and SAE anchor.

[44] 3GPP TR 23.882 v1.2.0

- **S6:** S6 enables transfer of subscription and authentication data for authenticating/authorizing user access to the evolved system (AAA interface).
- **S7:** S7 provides transfer of (QoS) policy and charging rules from PCRF to Policy and Charging Enforcement Point (PCEP).
- **SGi:** SGi is the reference point between the Inter AS Anchor and the packet data network. Packet data network may be an operator's external public or private packet data network or an intra operator packet data network, e.g., for provision of IMS services. This reference point corresponds to Gi and Wi functionalities and supports any 3GPP and non-3GPP access systems.

5.2 Air-interface Evolution or Long Term Evolution (LTE)

The first wave of UMTS-based network rollouts are experiencing data rates up to 384 Kbps both in the uplink and downlink. The High Speed Downlink Packet Access (HSDPA) is being rolled out with 2-3 Mbps practical data rate capabilities and a theoretical peak rate of 14.4 Mbps. With High Speed Uplink Packet Access (HSUPA) to follow during 2007, the theoretical capability up to 5.7 Mbps in the uplink can be achieved.

In order to prepare for the future needs of wireless operators, 3GPP has initiated activity on the long term evolution of UTRAN (Universal Terrestrial Radio Access Network), which is aiming clearly beyond what the UMTS/HSPA can achieve. The UTRAN long term evolution work is looking for the market introduction of Evolved UTRAN (EUTRAN) around 2010, with resulting specification availability planned toward the end of 2007. The fundamental targets of this evolution – to further reduce user and operator costs and to improve service provisioning – will be met through improved coverage and system capacity as well as increased data rates and reduced latency.

The feasibility study is currently ongoing in 3GPP and recently, key decisions have been reached on the multiple accesses and the protocol architecture. Feasibility study finalization is scheduled for the June 2006 time frame when actual detailed specification development will start. The following sections will cover the requirements for the work defined in 3GPP, introduce the physical layer development, cover the network and protocol architecture developments and discuss multi-antenna solutions. The initial findings on performance are covered as well.

Requirements

The latest developments with Rel-5 and Rel-6 UMTS specifications can achieve up to 14.4 Mbps downlink and 5.7 Mbps uplink peak data rates (theoretical rates without channel coding) with HSDPA and HSUPA, respectively. Clearly, for the long term evolution, more ambitious goals were necessary to make it worth the effort. This was also learned from the earlier 3GPP feasibility studies on the adoption of a basic OFDM system in the downlink with 5 MHz bandwidth. Thus the following targets were defined in 3GPP:

- User plane latency below 5 ms with 5 MHz or higher spectrum allocation. With spectrum allocation below 5 MHz, latency below 10 ms should be facilitated
- Reduced control plane latency
- Scalable bandwidth up to 20 MHz, with smaller bandwidths covering 1.25 MHz, 2.5 MHz, 5 MHz, 10 MHz and 15 MHz for narrow allocations. Also 1.6 MHz is considered for specific cases, especially for the unpaired frequency band
- 2 to 3 times capacity over the existing Rel-6 reference scenarios with HSUPA
- 2 to 4 times capacity over the existing Rel-6 reference scenarios with HSDPA
- Improved end user data rates at the cell edge
- Support for packet switched (PS) domain only
- Downlink peak data rates up to 100 Mbps with 20 MHz bandwidth
- Uplink peak data rates up to 50 Mbps with 20 MHz bandwidth

While considerable investments have been made and continue to be made in UMTS and GSM-based networks, inter-working with UMTS and GSM is a key requirement for any new system part of the 3GPP technology family. The requirement for handover between legacy systems and E-UTRAN is a break of 300 ms for services with real time quality and 500 ms for the non-real time services. Further, there is a desire to have a reduced CAPEX/OPEX for lower cost per bit.

Agreed assumptions for evaluation include two receiver antennas in the mobile terminal, which facilitates usage of advanced antenna technologies, such as Multiple Input Multiple Output (MIMO) antenna concepts. Respectively, a typical base station is expected to have two antenna transmit and receive capabilities.

The defined mobility support is aiming for optimized performance for mobile speeds of less than 15km/h and high performance for speeds up to 120km/h. The connection should be maintained with mobile speeds even up to 350 km/h.

Multiple Access Technology

Following the requirements laid down for the multiple access technologies, it has become evident that something other than the use of the current radio interface technology needs to be considered for the radio access supporting up to 100 Mbps and up to 20 MHz bandwidth. The UMTS radio interface technology is very efficient for providing (downlink) peak data rates up to 10 Mbps and is in the same ballpark with OFDM when considering 5 MHz bandwidth in large macro-cell. However, the requirements such as reaching 100 Mbps peak rates cannot be met with UMTS technology with reasonable mobile terminal complexity. As an example, the downlink direction would require either multiple 5 MHz carriers or at least four times higher chip rates, neither of which solutions are very attractive when aiming for very high performance with advanced receivers in the mobile terminal.

Because this was clearly understood in the 3GPP community, the decision was made to adopt Single Carrier FDMA (SC-FDMA) for the uplink direction due to the good performance in general and superior properties in terms of uplink signal Peak-to-Average Ratio (PAR) when compared to the possible use of OFDM technology in the uplink.

In the downlink direction the solution was OFDM, mainly due to the simplicity of the terminal receiver in the case of large bandwidths in a difficult environment. Also, the network side transmission PAR was not considered such a key problem.

Downlink: OFDM with Frequency Domain Adaptation

The evolved radio access is adapting the transmission parameters not only in the time domain, but also in the frequency domain. Frequency domain adaptation is made possible through the use of OFDM and can achieve large performance gains in cases where the channel varies significantly over the system bandwidth. Thus, frequency domain adaptation becomes increasingly important with an increased system bandwidth. Information about the downlink channel quality, obtained through feedback from terminals, is provided to the base station scheduler. The scheduler determines which downlink spectrum blocks to allocate to which user and dynamically selects an appropriate data rates for each spectrum block by varying the output power level, the channel coding rate and/or the modulation scheme. Quadrature phase shift keying (QPSK), 16 quadrature amplitude modulation (16-QAM) and 64-QAM modulation schemes are supported in the downlink.

For downlink, the adoption of OFDMA enabled better support of different bandwidth options. The basic OFDM transmitter chain is shown in Figure 15. For the feasibility studies, several advanced techniques are being considered on top of the basic OFDMA operation including frequency domain scheduling, MIMO antenna technologies and variable coding and modulation.

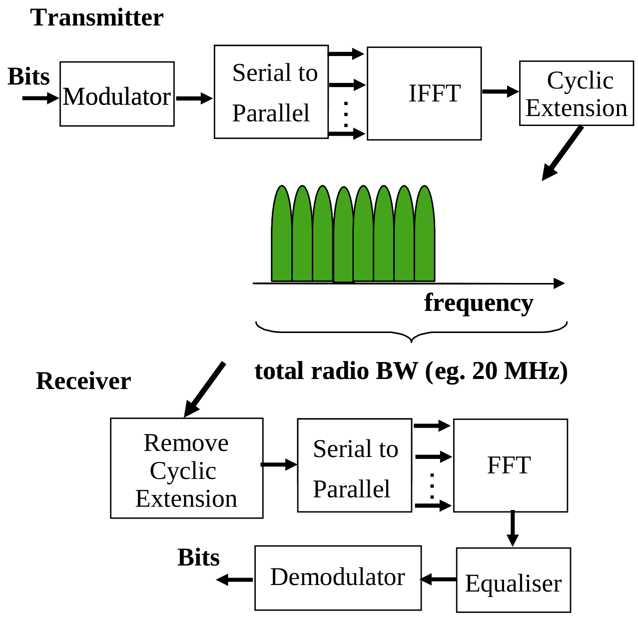


Figure 15. OFDMA principle[45]

Uplink: Single Carrier FDMA with Dynamic Bandwidth

For uplink the focus was on the novel and rather new approach, SC-FDMA, in order to reach Peak to Average Ratio (PAR), which has been identified as a critical issue for use of OFDMA in the uplink where power efficient amplifiers are required. Another important requirement was to maximize coverage. For each time interval, the base station scheduler assigns a unique time-frequency interval to a terminal for the transmission of user data, thereby ensuring intracell orthogonality. The terminal is only assigned with contiguous spectrum blocks in the frequency domain to maintain the single-carrier properties and thereby ensure power-efficient transmission. Frequency domain adaptation is typically not used in the uplink due to lack of channel knowledge, as each terminal cannot continuously transmit a pilot signal covering the whole frequency domain. Slow power control, compensating for path loss and shadow fading, is sufficient as no near-far problem is present due to the orthogonal uplink transmissions. Transmission parameters, coding and modulation are similar to the downlink transmission.

The chosen SC-FDMA solution is based on the use of a cyclic prefix to allow for high performance and low complexity receiver implementation in the base station. With SC-FDMA, the type of modulation applied will impact the PAR, but with OFDMA the large number of parallel sub-carriers typically makes the PAR 2-6 dB higher than SC-FDMA. For the uplink considerations, the importance of the cell edge operation (or uplink range in general) was highlighted due to the operator requirements. A mobile data service that provides high data rates in the majority of the cell area is easier to market and sell compared to a mobile data service that severely limits the high data rate availability to a small fraction of the cell area. Hence improvement in PAR is very essential to achieve high data rate availability close to the cell edge.

[45] UTRAN Long Term Evolution in 3GPP, Antti Toskala, Harri Holma, Esa Tiirola, Kari Pajukoski. PIMRC'2006, The 17th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications. Finlandia-Hall, Helsinki, Finland, September 11-14, 2006

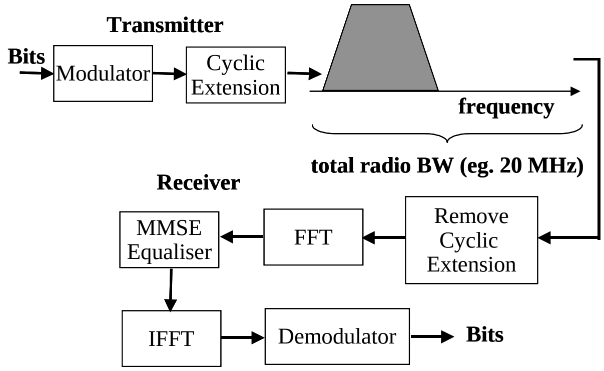


Figure 16. FDMA transmitter and receiver chains[46]

The general FDMA transmitter and receiver concept is illustrated in Figure 16. The OFDMA and SC-FDMA uplink PAR comparison is shown in Figure 17, indicating the difference depending on the modulation being used. With optimised modulation the difference may be up to 6 dB in the favor of SC-FDMA.

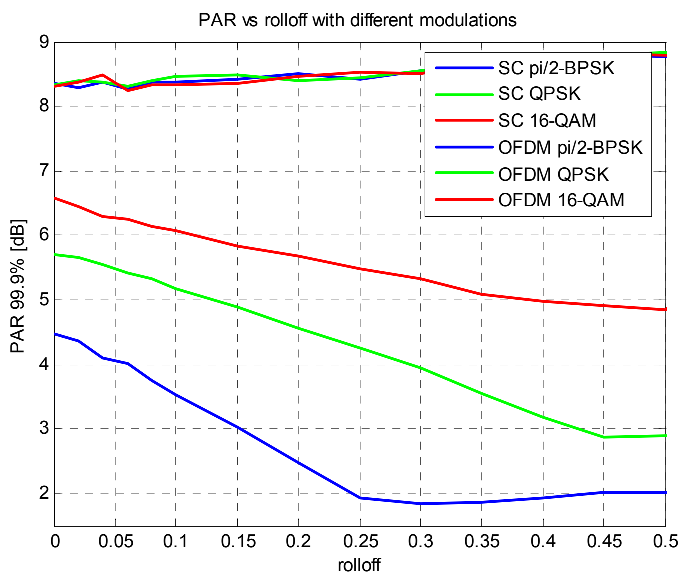


Figure 17. SC-FDMA PAR compared to OFDM PAR in the uplink[47]

Several key physical layer parameters have relationship with the multiple access method, such as the sub-carrier spacing of OFDM. The selection is a compromise between support of high Doppler frequency, overhead from cyclic prefix, implementation imperfections, etc. The sub-carrier spacing used in the feasibility study is 15 kHz. To optimize for different delay spread environments (e.g., ranging from urban pico cells to rural mountain area cells), two cyclic prefix values are to be used.

Doppler will also impact the parameterization, as the physical layer parameterization needs to allow maintaining the connection at 350 km/h. It has been recognized, however, that scenarios above 250 km/h are specific cases, such as the high-speed train environment. The optimization target is clearly the lower mobile terminal speeds, below 15 km/h, and performance degradation is allowed for higher speeds. The parameterization was chosen in such a way that common sampling rates with GSM/EDGE and UMTS can be utilized to reduce complexity and cost and enable easy dual mode / multimode implementation.

[46] H. Holma, A. Toskala, "HSDPA/HSUPA for UMTS", Wiley, 2006
[47] Nokia, "Coverage comparison between UL OFDMA and SC-FDMA", October 10-14, 2005, San Diego, USA, 3GPP TSG RAN WG1 Meeting #42, Tdoc R1-051088

Radio Access Protocol Architecture
The long term evolution protocol and network architecture is characterized by three special requirements:

- Support for PS domain only i.e. there will be no connection to circuit switched (CS) domain nodes, such as the Mobile Switching Center, but speech services need to be handled as Voice over IP (VoIP) calls
- Tight delay targets for small roundtrip delay; the roundtrip delay target is 5 ms for bandwidths of 5 MHz or more. Respective target is 10 ms for the bandwidths of below 5 MHz
- Reduced cost of the system

3GPP defined the functional split between the eNode B and the access gateway (aGW). All the radio related signaling (RRC) as well as all layers of retransmission are located in eNode B. It was natural that MAC layer functionality etc., similar to HSDPA/HSUPA operation, will remain in the eNode B. Ciphering and header compressions were decided to be located in aGW, as shown in Figure 18. The physical layer solution to be chosen for EUTRA was concluded, not requiring uplink or downlink macro-diversity.

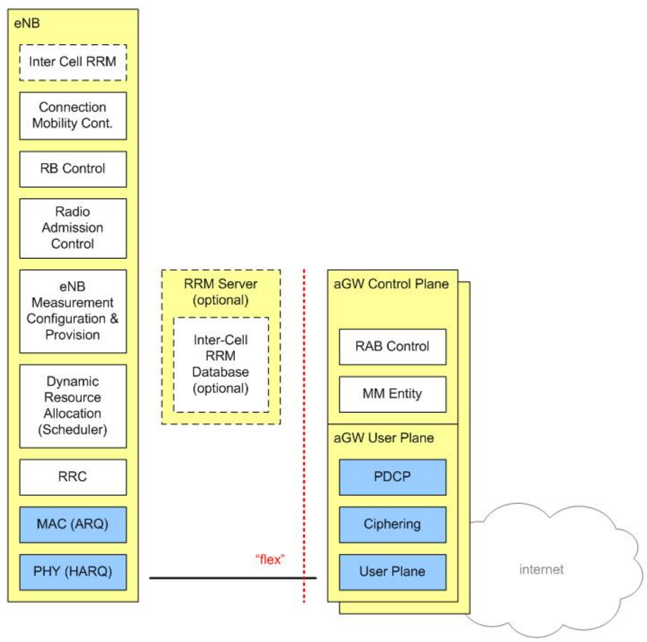


Figure 18. UTRAN LTE Architecture in 3GPP with RRM server for future study[48]

Multi-Antenna Solutions
In order to fulfill the requirements on coverage, capacity and high data rates, various multi-antenna schemes need to be supported as part of the specifications for the long term 3G evolution. For example, beamforming can be used to increase coverage and/or capacity. Spatial multiplexing, sometimes referred to as MIMO, can be used to increase data rates by transmitting multiple parallel streams to a single user. However, conventional multi-antenna diversity techniques, at both the receiver and transmitter, will also play an important role in fulfilling the requirements.

It is necessary to consider multi-antenna technologies as a well-integrated part of the evolved radio access and not as an extension added to the specification at the later stage. The provision of low cost single antenna devices, especially for new emerging markets, should be allowed when multi-antenna solutions are covered in the very first version of specification. The potential of using the spatial domain is large and the development of new and even more efficient multi-antenna algorithms is expected to continue in the future. Hence, to make the evolved radio access future-proof, it should be able to support new and improved multi-antenna algorithms in an efficient manner.

OFDM in the downlink direction can be designed to provide good support for MIMO technologies, as technologies such as frequency domain scheduling allow creating such signal to noise conditions where

[48] Nokia, "Further evaluation results for SC-FDMA", May 8-12, 2006, Shanghai, China, 3GPP TSG RAN WG1 Meeting #45, Tdoc R1-061239

MIMO technology works better compared to the more uniform interference conditions. Also, the received solutions with OFDM fit well together with MIMO and allow implementation with a reasonable impact to baseband complexity. Different multi-antenna algorithms require measurements with different resolutions in the time, frequency, space and stream domains. The Doppler spread of the radio channel and the velocity of the UE will also affect which resolutions are appropriate. By using a set of adjustable preprocessing rules for the receiver, it is possible to adapt the measurement resolution to the current conditions.

For a large group of multi-antenna schemes, such as various open-loop beamforming schemes, open loop transmit diversity and basic spatial multiplexing techniques, a required data rate is a sufficient measurement result format. For other multi-antenna schemes, more feedback information about the radio channel is needed. By letting the transmitter specify how many bits should be used to represent the phase and amplitude, respectively, various multi-antenna schemes that require knowledge of the radio channel will be supported (e.g., closed loop transmit diversity and eigenvalue-based MIMO).

Performance

It can be seen that, especially in the macro-cell environment (and 5 MHz bandwidth), HSDPA is setting a rather high bar of the baseline reference performance that is not easily beaten with a classic OFDM approach, as has been discussed in 3GPP previously. When one starts to look for higher bandwidths and also environments where multiple antenna solutions could be applied together with advanced methods, like frequency domain scheduling, there are opportunities to have a better performance level. In the uplink direction the use of SC-FDMA offers possibility, especially for the cell edge performance, as one can create orthogonal uplink which helps the link budget for the users at cell edge. An example reference case is shown in Figure 19, which shows the uplink performance when compared to the reference HSUPA reference case from 3GPP. With the smaller cells, with the inter-site distance of 500 meters, there is a bit more gain, as shown in Figure 20.

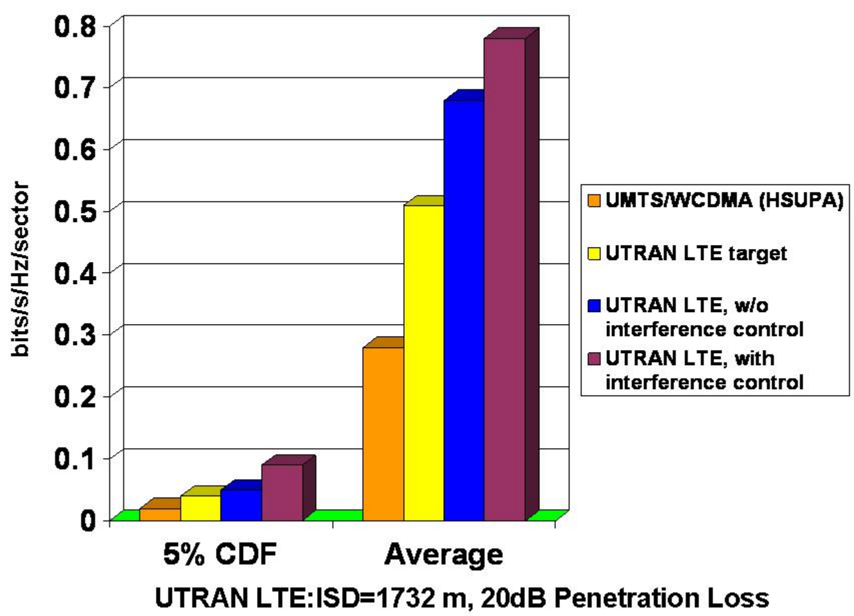


Figure 19. Comparison of SC-FDMA vs. UMTS/WCDMA

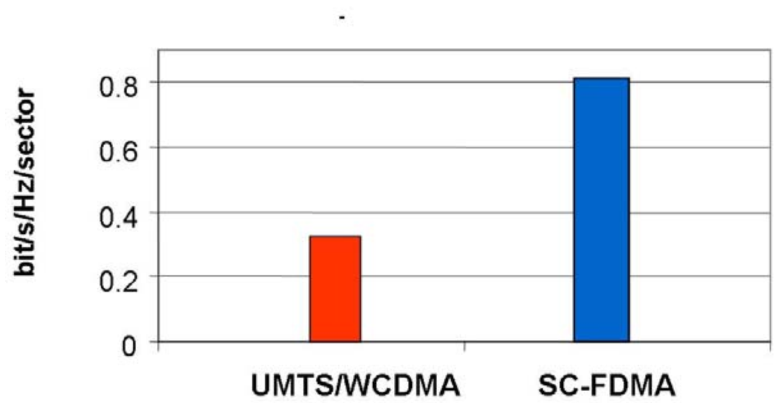


Figure 20. UMTS/WCDMA (HSUPA) and SC-FDMA performance for 500 meter cell radius[49]

Remaining Work in 3GPP
In 3GPP, the following key milestones have been reached thus far:

- December 2005: Decision on the multiple access principles and macro-diversity support
- March 2006: Radio protocol architecture agreed
- June 2006: Work Item opened, and Study Item continues in selected areas to cover more performance results as per operators' request

It should be noted that the standardization of 3G LTE is currently ongoing. It is therefore uncertain to what extent the technical solutions will be included in the standard. The aim of the Study Item was to develop solutions and evaluate their potential for the evolution of the 3GPP radio-access technology towards a high-data-rate, low-latency and packet-optimized radio-access technology. The evaluation results presented so far indicate that system concepts can meet most of requirements and no significant issue was identified in terms of feasibility. In some areas further results are to be provided to improve the coverage of the results in this study. In the June 2006 RAN#32 plenary meeting the feature Work Item Description was approved and therefore moved to Work Item phase according to study results. The actual specification work will continue in order to produce the specifications during 2007 to meet, on a timely basis, the need for wider bandwidth as part of the 3GPP technology family evolution.

5.3 HSPA Evolution (HSPA+)

HSPA Evolution, also known as HSPA+, is an effort by 3GPP to enable operators to capitalize on existing RAN infrastructure investments by further improving the radio performance of HSPA as well as leveraging the use of the SAE core with the current radio interface in 2 x 5 MHz spectrum. HSDPA is being deployed now, and HSUPA (E-DCH) will be deployed by 2006-2007. Both will continue to be enhanced in the 3GPP standards as well as products for quite some time as the HSPA technologies represent considerable recent and future business investments for the 3GPP operators. LTE is being developed to address a significantly higher level of performance than provided by Rel-6 HSPA and products will not be available until 2009-2010. Mass deployment of LTE could take several years after introduction. SAE is being developed to rationalize the System Architecture in the scope of a full service delivery within the PS Domain.

Although it is expected that most GSM/UMTS operators will deploy HSPA, when LTE becomes available on the market, LTE will be the natural choice for operators that have not deployed HSPA. This could be green-fielders or existing GSM/EDGE operators. For existing HSPA operators that have the additional spectrum, LTE will co-exist with HSPA and enhance the network in densely populated areas and hot-

[49] Nokia, "Further evaluation results for SC-FDMA", May 8-12, 2006, Shanghai, China, 3GPP TSG RAN WG1 Meeting #45, Tdoc R1-061239

spots, in the same way as HSDPA is used today to enhance the offering of existing GSM/UMTS operators.

HSPA+ is, from a terminology perspective, a nomenclature for further developments encompassing both directions of transmission of information - the downlink direction (HSDPA) and the uplink direction (HSUPA). HSPA+ is a plan that addresses the PS domain and the positioning of HSDPA and HSUPA further enhancements and evolutions towards LTE performance targets. HSPA+ plans to take a simple approach, use sensible technology, and incorporate these facts to synthesize a smart business process for HSPA evolution to LTE. HSPA+ addresses, in as simple a way as possible, the system evolution of UMTS/HSPA to raise the overall performance of existing HSPA.

HSPA+ Goals and Objectives

The goal of HSPA+ is not to replace LTE nor slow down LTE's progress in 3GPP. HSPA+ seeks to enhance HSDPA/HSUPA. HSPA+ provides an incremental technology developmental path for both RAN and Core aspects to meet the stated 3GPP and industry commitment to balance the work and developments between HSPA and LTE.

HSPA+ is therefore an enhancement, where simplifications and rationalizations agreed for LTE/SAE are partially applied to the HSPA system, providing enhanced performances and leveraging the existing infrastructure. The HSPA+ system vision is positioned towards providing full service delivery through the PS Domain.

Since HSPA networks will form an integral part of future 3G systems, there is a need to enhance the capabilities and performance of HSPA-based radio networks as well as enable co-existence with LTE and provide a smooth migration path towards LTE and SAE. HSPA operators are just as interested in the potential performance and cost savings which may be achieved through HSPA Evolution in a 5 MHz bandwidth as they are in the future LTE / SAE system.

In March 2006, a new Study Item was approved in 3GPP to look at the evolution of HSPA using the following guiding principles:

- HSPA spectrum efficiency, peak data rate and latency should continue to evolve. The tradeoffs necessary to achieve performance comparable to LTE in 5 MHz should be analyzed
- The interworking between HSPA Evolution and LTE should be as smooth as possible from one technology to the next and should facilitate joint technology operation
- Evolved HSPA should be able to operate as a packet-only network based on utilization of Shared Channels only
- HSPA Evolution shall be backward compatible in the sense that legacy terminals (R99-DCH and HSPA mobiles) are able to share the same carrier with terminals implementing the latest features of the HSPA Evolution track without any performance degradation
- Ideally, existing infrastructure should only need a simple upgrade to support the features defined as part of the HSPA Evolution

The objectives for the HSPA+ study are:

1. Define a broad framework for HSPA evolution, without introducing any unnecessary delay to existing work in 3GPP
2. Define a set of requirements for HSPA evolution which covers the following aspects:
    - Targets for improvements in latency, throughput and spectrum efficiency utilizing the existing 5 MHz bandwidth
    - Define constraints in terms of acceptable hardware and software changes to current elements (UE, NodeB, RNC, SGSN and GGSN)
    - Define constraints in terms of acceptable network architecture changes
3. Determine what performance benefit is achieved by already ongoing work in 3GPP (to a large extent mentioned in section 4 of this document)
4. HSPA Evolution shall be backward compatible in the sense that legacy terminals (R99-DCH and HSPA mobiles) are able to share the same carrier with terminals implementing the latest features of the HSPA Evolution track without any performance degradation

5. Identify potential solutions to improve HSPA performance towards the agreed targets within the defined constraints

In order to accomplish these objectives, 3GPP will have to make recommendations for future HSPA Evolution Work Items and possible revisions to ongoing Work Items related to HSPA.

Current Progress with HSPA+

The HSPA+ work is in its early stages, as the initial Technical Report (TR) for HSPA+ was just introduced into TSG-RAN #32 by a group of operators[50] in June 2006. Continuing work on the TR will continue and is expected to be concluded at TSG-RAN #34 in December 2006. It is expected that many architectural options to meet the HPSA+ goals discussed above will be explored.

3GPP has a number of open Rel-7 Work Items targeting focused areas of improvement (CS/PS Set Up Procedures, Continuous Connectivity, MIMO, Gaming, Advanced Receivers of all kinds, Single GTP Tunnel), but no way forward to look at an optimized PS-only operation mode based on usage of fast shared channels only (HS-DSCH + E-DCH). 3GPP must also consider the possibility of adapting the LTE Solutions to HSPA Evolution. "LTE Solutions" should be understood as LTE approaches of what is happening in each state, what is preserved and where, the functional split, and how the reduction in Latency is achieved.

In summary, HSPA+ is expected to provide the operator with enhancements towards a packet core, while making a transition to LTE easier. It is expected to provide performance benefits via architectural enhancements, while being fully backwards compatible with the current UTRAN radio interface.

6 Conclusions

In 1991, a typical user of wireline data used only one megabyte per month. In 1999, that figure grew dramatically -- to nearly 200 megabytes per month. Wireless data services are starting to follow a growth curve similar 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. Analysts report the cost advantages of 3G over 2G are immense, with the cost per megabyte falling from several dollars to under $0.10 per megabyte. As the cost falls for operators and consumers alike, more compelling services will be deliverable at reasonable prices, and critical mass can be reached. It is expected that HSDPA Rel-5 will provide a 50 percent reduction in cost per megabit versus Rel-99, and HSDPA Rel-6 will increase that even further.

UMTS has arrived to meet these growing wireless data demands, delivering the opportunity for high-speed wireless data services to nearly 75 million customers as of June 2006. It is forecast to reach 100 million customers by the end of the year, and half a billion in late 2009 or early 2010. UMTS customers already outnumber all other 3G technologies by a ratio of nearly 3:1.[51]

The networks are in place. Currently, UMTS is commercially launched by 107 operators in 50 countries[52] with 79 more networks planned or in deployment. In the U.S. marketplace, Cingular Wireless launched the world's first wide scale UMTS/HSDPA network in sixteen markets in December 2005, providing several HSDPA-capable PC cards to their customers. Furthermore, the operator plans to introduce HSDPA terminals in 1Q 2006 and cover most major U.S. markets with UMTS/HSDPA by the end of 2006. Now, six months after the first network launch, HSDPA is commercially deployed in 41 networks, and 62 additional operators have networks planned, in deployment, or in trial. In total, 103 operators have announced their HSDPA deployment plans. It is expected that nearly all UMTS operators will deploy HSDPA, essentially a simple upgrade to the existing system, resulting in a significant increase in data capacity and offering operators a much-reduced network cost for data services. This scope of UMTS/HSDPA networks across the world ensures the continuation of benefits offered by the GSM family of technologies, including vast economies of scale as well as the opportunity for global roaming. Additionally, commitments by leading terminal manufacturers are being satisfied with more than 300 UMTS devices available for various spectrum bands, and a wide variety of bandwidth-hungry applications in the offering. Today's customer is beginning to utilize the functionality, speed, and variety offered by mobile wireless enterprise solutions and entertainment options.

[50] 3GPP RP-060296, "HSPA Evolution beyond Release 7", China Mobile, Cingular, DoCoMo, o2, Orange, 3, Telecom Italia, Telefonica, Telia-Sonera, T-Mobile, Vodafone

[51] 3G customers worldwide pass the 100 million mark at mid June 2006, UMTS Forum press release, June 13, 2006

[52] Appendix A: Global UMTS Network Status, December 2005

The growing commercialization of UMTS includes 41 network introductions of Rel-5 with HSDPA. With the standards completion of Rel-6 demos and trials of features like HSUPA and advanced receivers are currently ongoing. Thus, UMTS evolution is focused in two main areas: 1) Rel-7 enhancements to the HSPA RAN and core network to enable even greater speeds, capacity improvements and improved support of real-time services like VoIP, gaming and PTT, and 2) future evolution defining a flatter IP system architecture and new OFDMA based air-interface. Rel-7 enhancements include features such as MIMO on HSPA, continuous connectivity improvements, setup latency improvements, support of voice call continuity and IMS Multi-media Telephony. Future evolution to a flatter IP network is being defined through the System Architecture Evolution (SAE) work item in the SA working groups while the new OFDMA based air-interface is being defined through the Long Term Evolution (LTE) work item in the RAN working groups. The RAN working groups are also studying the migration of the HSPA system to the new SAE/LTE system through the HSPA+ work item.

UMTS is rapidly gaining momentum, not only in deployment progress and the availability of terminals, applications and services for Rel-99, but also through the recently deployed Rel-5 improvements to provide significant data capacity, performance and feature functionality benefits. Rel-6 and Rel-7 continue this momentum by further improving both uplink and downlink capacity/throughput performance and efficiency for all types of services (including broadcast/multicast and real-time services like VoIP, gaming and PTT). The SAE/LTE work in 3GPP is defining the future evolution beyond Rel-7. The 3GPP standards continue to deliver the indisputable merits and benefits of the GSM family of technologies -- GSM, GPRS, EDGE and UMTS/HSDPA -- to more than 2 billion wireless customers throughout the world today.

Appendix A: Detailed Vendor Progress on Rel-99/Rel-5/Rel-6

The following sections were contributed by companies represented in the working group for this 3G Americas' white paper. This is not a comprehensive document of all the progress made to date by the vendor community, but is representative of some of the activities at leading members of the UMTS/HSPA eco-system.

Andrew Corporation delivers products and solutions that address all areas of the UMTS RF path and coverage requirements, including a suite of UMTS tools for planning, implementation, geo-coded traffic, and performance data management.

Andrew's solutions specifically address the unique needs of wireless operators facing UMTS deployments, including:

- *Rapid development of a focused outdoor UMTS footprint* — Andrew accelerates dense urban builds with small footprint rooftop deployments; supplements macro coverage with microcell-based capacity for outdoor hotspots; simplifies greenfield site builds with kits and bundles; broadens effective cell coverage with tower-mounted amplifiers, multi-carrier power amplifiers, and Node M interference cancellation repeaters; and provides turnkey coverage and distributed capacity for outdoor venues such as urban streets, urban canyons, road tunnels, and railways. Andrew's cable and connector products have best in class RF performance, coupled with ease of deployment. Andrew's broadband, multiband basestation antennas, with available Remote Electrical Tilt, facilitate site optimization and simplify configuration, lowering rental costs. Andrew Insitute provides world renowned training for personnel involved with RF system installation and maintenance.
- *Cost-effective indoor capacity and coverage* — Andrew helps operators and OEMs evolve beyond voice and move indoors aggressively with Pico Node B, a fully functional Node B product that supports 40 and 80 user configurations and supports microcell applications. They offer balanced coverage and capacity in a phased, modular manner through active and/or passive distributed antenna systems, along with Pico Node B, and distribute coverage and capacity creatively, granularly and cost-effectively with ION-B and ION-M.
- *Real-time network monitoring and optimization* — Andrew makes regular, systemic drive testing, and service benchmarking fast and effective with Invex3G, scanners that were among the first to support UMTS and other technologies in the same instrument. Our patented remote electrical tilt base station antennas accelerate post-deployment optimization by responding quickly to changing traffic patterns and reducing interference and coverage "holes." Andrew's SmartBeam antennas with 2 and 3 way pattern remote adjustment provide capacity increases through load balancing and interference management. In addition, Andrew's network management software helps manage repeaters and minimize maintenance trips.
- *Effective network planning and rollout* — Andrew's network planning tools such as Odyssey, Optum, Omnix, and Q.link help operators design and plan networks, accurately predict coverage needs, efficiently expand and deploy networks, optimize data, analyze and monitor performance, and improve efficiency.

Andrew's RF solutions enable operators to synchronize investments with revenue using scalable deployment strategies and technologies, accelerate payback by expanding macro coverage effectively while concentrating on balancing coverage, capacity and interference management in key areas such as urban settings, indoors, and along transportation corridors.

Ericsson is a primary supplier to the world's UMTS and HSPDA networks. In May 2006, Ericsson equipment powered more than 10 commercially launched HSDPA networks, starting with Cingular Wireless in December 2005 followed by, among others, 3 Italy, Vodafone Germany and Vodafone Portugal. Ericsson products supports more than 50 commercially launched UMTS networks in all parts of the world and upgrade to HSDPA is ongoing in more than 30 networks.

One of the key merits of the Ericsson HSDPA equipment is the superior support for mixing Rel-99 voice and data traffic with HSDPA traffic on the same carrier. The flexible solution allows for simultaneously high Rel-99 load and significant HSDPA data rates which defers the need for the operator to add an additional carrier. The Ericsson HSDPA equipment today supports peak rates of 3.6 Mbps downlink and 384 kbps uplink while support for 14.4 Mbps as well as HSUPA can be added with a software upgrade.

During the CTIA Wireless 2006 show in Las Vegas, Ericsson performed the world's first HSDPA demonstration with Multiple Input Multiple Output (MIMO) technology using a commercial radio base station. In the demonstration, data rates were doubled from 10 to 20 Mbps.

Ericsson's new generation of radio base stations allows for 30 percent fewer sites, increases capacity by 50-150 percent and is optimized for cost efficiency at every site. It also enhances power efficiency, with power consumption cut by a further 35-55 percent and the size is half that of previous models. It includes distributed, carry-to-site, multi-access GSM/UMTS and mega-capacity products for both indoor and outdoor use. To support 3G evolution, the new generation of base stations is also prepared for LTE. The base stations are already available for the 850, 1900 and 2100MHz frequency bands and will fully support all forthcoming frequency bands, including 900, 1700, 1800, 1700/2100 and 2500MHz.

As of May 2006, Ericsson has signed 28 IMS system agreements for commercial launch or trial, all based on the IP Multimedia Subsystem standard, including both mobile operators such as Telecom Italia Mobile (TIM) and fixed operators such as Telefónica. The contracts are distributed over the Americas, Europe, Asia and Africa and include GSM/GPRS, UMTS, CDMA2000 and fixed network implementations. The various contracts include a mix of applications such as push-to-talk, weShare (combinational services, CSI), IP Telephony (Voice over IP) and IP Centrex.

Ericsson has successfully trialed Multimedia Broadcast Multicast Service (MBMS) for distribution of multimedia services, such as mobile TV, over 3G networks. The trial, performed in Stockholm, Sweden, was the first live use of MBMS. In April 2006 Ericsson showcased its enhanced program guide for mobile TV that integrates TV and on-demand mobile TV services in one location in one device. It also allows users to easily access stored content for playback, making the mobile TV service even more attractive and personal. By the end of 2005, more than 40 operators had commercially launched mobile TV over cellular networks. Of these, 16 operators had mobile TV solutions delivered by Ericsson.

Ericsson Mobile Platforms (EMP), a Business Unit within the Ericsson, is a leading platform supplier for UMTS with, as of February 2006, more than 15 million of the world's UMTS handsets based on EMP technology. EMP was the first platform provider in the world to have commercially launched handsets containing its UMTS, EDGE and GPRS technologies. During 2006 EMP started deliveries of HSDPA platforms for true mass-market deployment that are designed to facilitate true mass-market HSDPA volumes with a strong focus on size, cost and performance. The HSDPA platforms also incorporate advanced receiver technology to provide enhanced data rates over wider cell coverage areas or enhance cell capacity.

Gemalto *(the resulting company from the merger of Axalto and Gemplus)* already delivers USIMs to 3G operators around the world including: 3, Amena, Cingular, Cytamobile-Vodafone, FarEasTone, HK Danmark, KTF, Maxis, NTT DoCoMo, O2, Orange, SmarTone, SK Telecom, Sunrise, T-Mobile, Telefonica MoviStar, Telekom Srbija, Telecom Italia, Vodafone, Vodafone K.K. (JPhone), and Wind. By the end of 2005, Gemalto had supplied tens of millions of USIM cards with more than 100,000 of these going to device and infrastructure manufacturers for test purposes to ensure product interoperability. Gemalto monitors the implementation of USIM features in devices, particularly helping device manufacturers implement the 3GPP phonebook, higher communication speeds to the USIM, as well as the ISIM for IMS provisioning and authentication.

All USIMs are based on a multi-application platform and run Java Card™ operating systems in a tamper-resistant environment. They can support access to 2G and 3G networks and inter-mode roaming. USIMs and SIMs are combined to enable various migration paths to 3G services. Some operators launched the USIM to provide higher security and a richer and portable phonebook to their 2G subscribers.

As multi-application platforms, USIMs also enable non-telecom smart card applications in mobile devices. They are compatible with smart card payment and Pay-TV security standards and protocols:

- SK Telecom deployed USIMs co-branded with VISA International. The (U)SIM cards support the VSDC (VISA Smart Debit Credit) application for the world's first mobile proximity payment service on a USIM;
- 3 Italy, a UMTS operator, is using Gemalto's USIMs to secure access to its DVB-H service with a Pay TV Conditional Access applet.

USIMs support over-the-air remote updates for applet download, roaming list updates, and other subscription maintenance services. Gemalto provides two thirds of 3G OTA platforms and recently announced its selection by Telefonica for an OTA platform to remotely manage SIMs and USIMs over SMS and packet data. In 2005, H3G Hong Kong downloaded 5 KB applets to USIMs in 20 seconds using UMTS packet data.

The Gemalto USIM support mutual authentication, full device provisioning for wireless data, a Java Card API including J2ME integration, faster speeds to devices up to 460 Kbps, IMS provisioning with ISIM, support of 1.8 V, and a richer phonebook. The latest Gemalto USIMs feature a 3GPP Rel-6-compliant operating system, which can be enhanced to include R7 features.

The USIM is also offering large and secure storage suitable for protected content and associated rights, enabling easy portability of acquired content from phone to phone. With up to 1 GB of storage, the latest Gemalto USIMs can also store multimedia content accessible at 52 Mbps. In November 2005, Orange successfully launched a 128 MB version with pre-loaded content (MP3 and MP4 files) to promote multimedia services on its network.

Overall the 3GPP R7 smart card platform adopted several requirements addressed by the ETSI-SCP that will be specified overtime, such as:

- New protocols to communicate between the smart card and the device (high speed protocol and direct interface for contactless transactions like mass transit and payment);
- Trusted link between the card and the device (a.k.a. secure channel);
- Delivery of IP packets directly to the card;
- Enablers for the OMA Smart Card Web Server (HTTP server in the card for offline pages, tutorials, and service teasers).

Hewlett-Packard provides revenue generating solutions for service providers that incorporate HP carrier-grade platforms, industry standard IMS core network elements, management software, extensible service delivery framework, and partner assets.

The HP Service Delivery Platform (SDP) is a strategic blueprint for helping service providers develop, deploy and manage standards-based end-user services and migrate from today's legacy networks to the next generation IMS architecture. The SDP does this by focusing on the key areas that service providers must address in making the transition to IMS; service creation and composition, service delivery infrastructure, service management, transport, signaling and end user devices. The SDP allows service providers to deliver services (web and real-time) across multiple network types (fixed, mobile, and broadband) and generations (2G/2.5G/3G/IMS) -- essentially bridging the networks of today and tomorrow by evolving the existing network model to a Services Oriented Architecture (SOA).

The HP OpenCall portfolio of software solutions powers the real-time service delivery infrastructure of the HP SDP and consists of the following:

- HP OpenCall Software signaling portfolio – provides for the development of 3G solutions and evolution of applications from 2G to 3G network environments. Consisting of both a signaling platform and gateway component, the environment supports access to SS7, SIGTRAN, SIP and Diameter protocols in both a highly-scalable and cost-effective manner.
- HP OpenCall Home Location Register (HLR) – providing support for Rel-5 and 3G Authentication. The HLR has been in production operation for over 15 years and currently services over 150 million subscribers worldwide. The HP HLR can be co-located with the OpenCall Home Subscriber Server, offering a transition path from a 2G to a 3G setting.
- HP OpenCall Home Subscriber Server (HSS) – providing authentication, authorization, and auditing capabilities in compliance with 3GPP standards. The HSS manages and maintains customer profile data for IMS services and provides a point where application, subscriber and service data may be defined, provisioned, maintained, and retrieved.
- HP OpenCall XML Document Management Server (XDMS) – performs standards-based functions necessary for storing and managing group membership information. This OMA-compliant network element supports XML Configuration Access Protocol (XCAP) Directory, Push-to-talk Over Cellular (POC), Resource List Server (RLS) rules and shared XML Document Management System (XDMS) model. Through the XDMS, group function capabilities include multicasting of instant and multi-

media messages, filtration of incoming communications, sharing of status information, and creation of dynamic virtual communities.

- HP OpenCall Media Platform (OCMP) – supplying the IMS Media Resource Function (MRF) that supports video streaming, video-mail, and other interactive multi-media solutions. OCMP fully supports SIP interaction and extends the capabilities of standard MRF solutions by providing support for advanced functions such as VoiceXML (VxML) and Voice+Video XML (V^2xML). With this, the MRF delivers a concurrent service to subscribers connected through diverse network-types (wireless, fixed, broadband). The MRF can combine video, audio, text-to-speech, and auto-speech-recognition within one service.

HP OpenView is a broad suite of management products spanning telecom-specific tools including TeMIP, Service Quality Manager, Identity and Application management, and broader IT capabilities based upon the Service-Oriented Architecture (SOA) model. HP OpenView is delivered to service providers in the context of the HP Integrated Service Management (ISM) blueprint covering fulfillment, assurance and billing. It is used by service providers to improve service availability and allow these operators to more readily meet Service Level Agreements (SLAs) necessary for day to day operations.

HP offers products and solutions running on a range of carrier grade telecommunications platforms and a variety of hardware and operating system variants including ATCA-based Linux, carrier-grade high-availability UNIX, and fault-tolerant Nonstop Servers.

Lucent Technologies first demonstrated HSDPA in March 2003 at the CTIA Wireless 2003 trade show in New Orleans and has since played a significant role in the commercialization of the technology. Lucent's UMTS/HSDPA solutions powered the first two commercial HSDPA network launches in the world – Cingular in the United States and Manx Telecom (a wholly owned subsidiary of O2) on the Isle of Man, respectively.

Lucent helped Cingular launch the world's first commercial HSDPA network with Lucent-supplied equipment in the Phoenix and Seattle markets on Oct. 18, 2005. Cingular has since launched many more Lucent-supplied markets. In fact, in February 2006, Cingular expanded the market coverage of Lucent's existing agreement to supply 3G UMTS/HSDPA network equipment - including radio access network and core switching, and software and services - to support Cingular's nationwide 3G service.

O2, Manx Telecom and Lucent announced the first commercial HSDPA network service in Europe on the Isle of Man on November 1, 2005. This marked a significant milestone in the deployment of a super-fast, mobile network based on Lucent's end-to-end, 3G UMTS/HSDPA and IMS solutions for Manx Telecom.

Lucent also announced an extension to the network analysis and optimization service it has been delivering for T-Mobile International, focused on improving the end-to-end performance of the customer's UMTS networks in Germany, Austria, the Netherlands and the United Kingdom. These services also will include T-Mobile's 3G HSDPA networks when they become operational.

Additionally, Lucent is engaged in an ongoing UMTS collaboration with China Netcom, having completed a successful UMTS trial in Shanghai and the first successful field trial of HSDPA technology in China. The two companies conducted a series of data calls -- including demonstrations of live TV and video-on-demand services -- on a 3G UMTS trial network deployed by China Netcom in Shanghai. These achievements serve as a follow up to Lucent's successful completion of the UMTS testing regime coordinated by China's Ministry of Information Industries (MII).

On the hardware side, Lucent's HSDPA solution requires software-only upgrades, which can be downloaded remotely to its UMTS RNC and Node B. Lucent also unveiled the Lucent Base Station Router (BSR), a Bell Labs innovation that integrates key components of 3G mobile networks into a single network element optimized to support UMTS/HSDPA data services, and "flattens" what is typically a more complex architecture. O2 is currently conducting laboratory trials of the Lucent BSR in Germany. The BSR was selected as the first place winner of a CTIA WIRELESS 2006 Wireless Emerging Technologies (E-tech) Award in the category of *"Most Innovative In-Building Solution."*

Lucent also is pioneering the introduction of HSUPA technology, having completed live demonstrations of the technology at several major wireless trade shows including 3GSM World Congress 2006 in Barcelona, Spain and CTIA Wireless 2006 in Las Vegas.

Lucent has established itself as an industry leader in the introduction of commercial IMS networks announcing commercial IMS agreements with Cingular, SBC, Bell South, Netia (Poland), Sprint, Manx Telecom, PAETEC and an initial deployment in China. Lucent also is conducting more than 77 trials of various IMS network elements with more than 16 operators globally. Lucent's IMS-based solution is a service delivery architecture that serves as the cornerstone of Lucent's vision for next-generation blended lifestyle services, and Lucent is continuously evolving its IMS solution, such as the integration of Bell Labs-developed software technologies into its portfolio to enable wireless, wireline, and converged network operators to create and deliver simple, seamless, secure, portable, and personal multimedia services to their subscribers. These software technologies are part of a "Service Enhancement Layer" that gives Lucent's IMS solution distinct competitive advantages.

Motorola has been contributing to the 3GPP standardization of HSDPA -- Mobile Broadband for Rel- 5 since 2000. This culminated in extensive simulation capabilities and the early ability to demonstrate HSDPA over the air on commercial infrastructure. Motorola regularly demonstrates its HSDPA devices and solutions and is currently in the process of deploying HSDPA into its customer's networks [2006].

In November 2003, Motorola became the first vendor to demonstrate HSDPA on a commercially available UMTS base station at its Swindon, UK facility. Shortly thereafter Motorola publicly demonstrated HSDPA at the 3GSM World Congress 2004 event, with more than 70 presentations in three days.

October 2004 saw the extensive testing of HSDPA using a suite of consumer and corporate applications in multi-cell, multi-user environments to assess key performance criteria compared with UMTS, WiFi and with Motorola's own simulation results. These trials were conducted with five major operators who independently witnessed all or the majority of the impressive results obtained. Motorola has since tested HSDPA and UMTS combined on a single carrier to enable field characterization in this configuration that is most suited to initial HSDPA deployments.

3GSM World Congress 2005 was equally successful, demonstrating a multi-user HSDPA scenario that secured much industry attention; throughout 2005 numerous customer demonstrations were delivered both at Motorola Swindon and elsewhere around the world including 3GSM Asia (Hong Kong).

In January 2006 Motorola launched its Motorola AXPT product: a UMTS and HSDPA access point solution that enables rapid and effective indoor wireless broadband coverage. This revolutionary new device features a "collapsed architecture" design and uses IP backhaul; a real alternative to WiFi that provides the end user with a "One Device, One Operator" solution for voice as well as high-speed data. Understandably this generated significant interest at 3GSM World Congress Barcelona, with almost 100 private demonstrations taking place.

Also at 3GSM 2006 Motorola demonstrated HSUPA on a modified commercial platform. This natural compliment to HSDPA was demonstrated peaking at over 4Mbps, enabling the ready use of many more applications.

Motorola is now in the final stages of validating its HSDPA Mobile Device solution for the 3GSM Marketplace. The company has completed or is nearing the completion of all relevant test cases in conjunction with its lead Interoperability Test (IOT) Partners. In addition, Motorola is actively participating in field and lab trials with a number of key carriers. The first sealed terminal testing of 16QAM and 384 Kbps uplink was part of this field testing. Motorola's leadership position in Category 6 and 12 HSDPA in a sealed terminal form factor has been confirmed by a number of key carriers.

Enabling HSDPA in Motorola's extensive UMTS network product portfolio requires only a straightforward upgrade with minimal operator capital outlay; this provides the opportunity for rapid return on investment via simplified infrastructure deployment (pre-optimization of system parameters), rapid introduction of end user devices (Motorola was one of first vendors to be awarded an HSDPA handset contract by NTT DoCoMo) and the efficient enablement of revenue-generating applications and services.

Beyond HSDPA, Motorola has been actively developing and testing its IMS device implementation across key vendor labs. This work has led to Motorola being selected by a number of IOT partners to participate in the GSMA's IMS (Videoshare) Interoperability Test Sessions. These sessions have yielded important early successes in demonstrating IMS functionality, as well as ensuring interoperable solutions that will increase the take-up of this next step in the GSM/UMTS evolution. Motorola's participation (across multiple frequency bands, carriers and regions) has given it a strong position in the development and deployment of such services.

Motorola has a two-fold approach to delivering valuable applications and services:

1. For fixed operators serving enterprise and residential markets, Motorola offers advanced services like Seamless Mobility on IMS
2. For mobile operators, Motorola offers advanced VoIP, IP-based services like Push-to-talk over Cellular.

To these ends, Motorola has more than 60 contracts with mobile operators worldwide for IMS-based deployments, including PTX and MSS, supporting more than 2.5 million subscribers. This activity is in addition to ongoing IMS trials of seamless mobility with cable, fixed and mobile operators.

IMS is the key control point as part of Motorola's Seamless Mobility vision -- enabling seamless experience at home, work, out in the world and in autos. Motorola has assets in all the segments and hence there is significant commitment to all programs and technologies.

Nokia has introduced network infrastructure optimized for the 1700/2100 MHz band to support operators bidding in the 2006 3G spectrum auction in the US. The Nokia Flexi Base Station enables easy deployment of cellular and/or broadband wireless access networks, such as UMTS, HSPA, and WiMAX with up to 70 percent lower base station site expenditures because of its small footprint, light weight and reduced power consumption. The Flexi Base Station will be available for UMTS and HSPA for the IMT-2000 frequencies 2100 MHz, 1700 MHz, 1800 MHz and 1700/2100 MHz in the second half of 2006. Other frequencies like 1900 MHz and 850 MHz will be introduced during the first half of 2007. The 700 MHz frequency variant will be introduced in time to support rollouts when the 700 MHz band has been auctioned and cleared by the FCC. Meanwhile the field proven Nokia UltraSite site solution, including both GSM/EDGE and UMTS variants, already support the 800/900/1800/1900/2100 MHz frequencies.

Nokia was the first company to introduce Internet-High-Speed Packet Access (I-HSPA), an innovative, cost effective flat network architecture solution that enables high-speed mobile access with wide area coverage for data intensive business and consumer applications. The flat network architecture will enable significant cost savings making UMTS with I-HSPA a cost-effective broadband wireless option for high data volumes. I-HSPA architecture is based on the current HSPA standards for uplink and downlink and therefore all current HSPA capable terminals and data cards will be fully interoperable with this unique solution. Flexi Base Station and I-HSPA solutions were demonstrated live at CTIA Wireless in Las Vegas in April 2006, at CeBIT in Germany in March 2006 and at 3GSM in Barcelona in February 2006.

Nokia has launched two HSDPA networks commercially, one of these being T-Mobile Germany. T-Mobile and Nokia provided HSDPA to CeBIT 2006 visitors in Hanover and simultaneously activated HSDPA in Germany and later in the Netherlands and the United Kingdom. Prior to the launch, Nokia and T-Mobile successfully trialed HSDPA in live networks. Nokia is expecting the majority of its UMTS customers, 58 UMTS Rel-99 reference customers of which 49 are commercially launched, to update their UMTS networks to HSDPA during this year. With Nokia, HSPA is available as a simple upgrade to existing UMTS networks through a remote software upgrade. HSUPA for enhanced uplink data speeds is planned to be available during the second half of 2007 now that it has been ratified in 3GPP Rel-6. Meanwhile the Nokia Rel-99 UMTS RAN currently supports up to 384 kbps uplink throughput ensuring incomparable uploading times already today for high speed data users.

At 2006 3GSM in Barcelona, Nokia launched its 3GPP Rel-6 based Unlicensed Mobile Access (UMA) network solution. UMA technology enables the use of broadband and unlicensed access technologies, such as WLAN, to offer and expand mobility to users of voice and data services as well as extending GSM indoor coverage. Nokia's offering combines network equipment and UMA capable handset to create a complete end-to-end solution. Nokia also launched its newest UMA capable phone, the Nokia 6136, and gave a live demonstration of UMA calls. The Nokia UMA solution has already been commercially launched successfully with Saunalahti in Finland and with an operator in the Middle East. In addition Nokia has trialed the solution in Latin America and with three operators in the US and Europe as of today.

Nokia launched a new release of the Nokia IP Multimedia Subsystem (IMS), building on successful deployments of Nokia IMS applications such as Push-to-talk over Cellular and Video Sharing. Nokia IMS Release 2.0 now brings VoIP and real-time multimedia not only for mobile networks, but for fixed networks. Nokia also supports a broad IMS application development community through Forum Nokia.

Nokia IMS 2.0 release is compliant with 3GPP IMS specifications and the Next Generation Network architecture defined by ETSI TISPAN, and becomes available in the second half of 2006. Nokia is a leader in deliveries of IMS for fixed and mobile networks, with over 70 references for IMS solutions commercially launched, for example, by TMN Portugal, CSL Hong Kong and TIM Italy. Nokia was also selected on February 2006 by Vodafone Group as a preferred supplier, with a contract to begin deploying the Nokia IMS solution to Vodafone affiliates worldwide, with first deployments commencing during 2006. With over 80 customers, Nokia has also delivered the majority of the world's commercial 3GPP compliant mobile soft switches.

Nokia provides a full range of services to help operators differentiate and innovate their mobile offerings based on Nokia's end to end capability from networks to devices. As an example of such a service, Nokia launched its Mobility Hosting Solution at CTIA Wireless 2006 that will offer the mobile service providers a chance to quickly roll out new, exciting services for subscribers while ensuring that an operators' investment in such new services is utilized as efficiently as possible. Further strengthening Nokia's end to end capability, Nokia is able to deliver a portfolio of leading convergence devices with more than 15 announced UMTS/GSM phones to date world wide. At the end of 2005, Nokia held the global market share leader position for 3G devices with 24 percent, and was leading EMEA at 35 percent market share. 50 percent of the new Nokia devices to be launched in 2006 globally will support UMTS, with shipments of Nokia 3G devices likely to reach upwards of 40 million units during 2006.

Nortel has a complete set of solutions like Omni Transmit Sector Receive (OTSR) and Variable Bit Rate (VBR) for transmissions and a complete portfolio with the new compact RCN 1500, the unique GSM-UMTS dual mode Macro BTS 18000 (Indoor and Outdoor), the new BTS 6000 compact macro BTS, and the Optical Remote Radio Head based on Common Public Radio Interface (CPRI) architecture. Other Nortel solutions include the new UMTS Micro BTS 1120, a small "zero footprint" BTS and UMTS Pico BTS 1010, a lightweight and compact indoor solution planned for cost effective coverage.

Nortel recently demonstrated a number of industry milestones including:

- At the 3GSM World Congress in February 2006, Nortel demonstrated the industry's first simultaneous HSUPA and HSDPA calls.
- Also at the 3GSM World Congress in February 2006, Vodafone and Nortel demonstrated HSDPA at 3.6 Mbit/s on a live commercial network. Reports from the field confirmed the high stability of the network and typical/average speeds per user around 1 Mbit/s.
- In March 2006, the first HSDPA commercial services launched by Orange were based on Nortel equipment with confirmed performance and stability.
- In March 2006, Nortel and Qualcomm demonstrated the industry-first HSDPA category 8 call at 7.2 Mbit/s, based on Nortel commercial infrastructure, and a Qualcomm Form Factor handset
- In January 2005 Nortel, QUALCOMM and Orange successfully completed UMTS and HSDPA calls in the 900 Mhz band, becoming the world's first companies to showcase UMTS and HSDPA services in the 900 MHz band, for the improved delivery of broadband services to rural areas and in-building penetration.
- In April at CTIA 2006, Nortel's HSUPA performance was demonstrated real time on the physical layers L1 and L2 with a Nortel Node B - BTS and mobile emulators.

HSUPA for enhanced uplink data speeds is planned to be introduced during the first half of 2007. HSUPA is the complement of HSDPA and together provides for an evolution towards HSPA.

Nortel is also delivering fully compliant 3GPP Rel-4 and Rel-5 solutions in the core network. In February 2006, Nortel was selected to deploy North America's largest 2G/3G 3GPP Rel-4 compliant network including MSC (Mobile Switching Center) Server and Media Gateway products. According to Nortel's estimate, the company's Rel-4 technology will help provide up to a 300 percent increase in call handling capacity.

Nortel's IMS solution supports 3GPP (IMS), 3GPP2 (MMD), Packet Cable 2.0 and TISPAN standards. Nortel's 2^{nd} generation ATCA-compliant hardware is the platform for Nortel's Call Session Control and Home Subscriber Server functions in the IMS architecture. Nortel's IMS solution is based upon open protocols and interfaces so it gives operators a smooth evolution to future technology delivery and interoperates with a wide range of legacy equipment.

Nortel's IMS solution is one of the most open IMS implementations in the market as evidenced by the collaboration with many developers, partners and applications providers in its seven SIP Interoperability labs, six IMS Live Experience Centers and two Joint Customer Innovation Centers. In addition, Nortel is enhancing its IMS solution through work with IBM in the IBM Telecommunications Solutions Labe (TSL) in Montpellier, France.

Long Term Evolution (LTE) - Nortel has a clear strategy in place to deliver next generation wireless networks with a significant time to market advantage and a smooth evolution path. Nortel views two key technologies - OFDM and MIMO - as the fundamental blocks for all next generation access technologies and is leveraging its R&D investment across 3GPP LTE, 3GPP2 EVDO Rev C and WiMAX, enabling maximum synergies across these product lines. Nortel has invested in developing OFDM and MIMO since 1998, demonstrating its commercial benefits and feasibility to more than 100 customers worldwide.

At the 3GSM World Congress 2005, Nortel publicly promoted the advantages of HSOPA – High Speed OFDM Packet Access - to the 3GPP operators and the introduction of OFDM MIMO into the 3GPP standards. HSOPA/LTE has the potential to increase ten-fold the number of users that can be served by an operator's network. In 2006, Nortel expects to deliver an HSOPA/LTE laboratory prototype solution that can provide up to 25 Megabits per second uplink in the 5MHz spectrum – at least 15 times faster than today's fastest mobile connectivity. Nortel's original OFDM-MIMO laboratory prototype, demonstrated in 2004, delivered 37 Mbit/s in downlink in the same bandwidth. Nortel anticipates beginning customer HSOPA/LTE trials in 2007. Nortel aims to demonstrate that UMTS operators can evolve to HSOPA/LTE with minimal additional investment. On the radio access side, Nortel's Base Transceiver Station (BTS) platforms enable a smooth evolution to HSOPA as well as supporting GSM, UMTS, HSDPA, HSUPA and HSOPA/LTE.

Siemens and NEC won, on average, one UTRAN contract per month since the beginning of 2005 and maintain one of the strongest UMTS positions in the market. As of May 2006, Siemens and NEC delivered their solution to about 30 countries and more than 40 operating companies. More than 80 percent of all UMTS subscribers in commercial networks are using Siemens/NEC technology. The HSDPA end-to-end solution was available for commercial use since the second half of 2005 and nearly 10 HSDPA contracts followed. All NodeBs shipped since 2002 can support HSDPA via a simple software upgrade. Siemens' HSDPA data cards support different UMTS frequency bands and can be used in both the U.S. and Europe. Siemens wireless modules are expected to introduce more UMTS/HSDPA data capabilities in 2006 through enabling the machine-to-machine (M2M) market and further improving the diversity of possible applications. At 3GSM World Congress 2006 in Barcelona, Siemens demonstrated live HSDPA data downloading at a speed of 3.6 Mbps. HSDPA on-air tests have shown 950kbps at 80mph in a live UMTS network. With the delivery of HSUPA in 1Q2007, Siemens' UMTS will be compliant to Rel-6.

Starting in 2005, Siemens has introduced a distributed RAN architecture by separating the NodeB into Radio Server (RS) and Remote Radio Head (RRH). With this distributed architecture concept, the total size, weight and power consumption can be significantly reduced compared to the conventional NodeBs. In April 2006, Siemens announced the Multi-standard Base Station (MBS) solution by using a single modular platform to support both 2G/GSM and 3G/UMTS. Operators can upgrade their 2G/GSM BTS by adding a small slide-in Radio Server Unit (RSU) into the existing 2G/GSM rack. Because the RSU can fit into any standard 19-inch shelf space, this solution has provided operators more flexible ways to perform a vendor independent 3G/UMTS upgrade on their existing 2G/GSM sites. The new Rel-6 compliant and ATCA based RN-880 RNC will be available this year. The RN-880 will not only offer unique performance density and granular scalability, but also provide a migration path to IP.

Siemens is one of the few vendors that offers both IMS infrastructure and IMS services. ***Siemens IMS@vantage*** has already been installed by more than 35 carriers as a secure and powerful convergence platform for IP-based multimedia applications. It is built around the session initiation protocol (SIP), a protocol for multimedia services (via many IP access networks) such as Push-to-talk over Cellular, Call & Share, instant messaging and chat applications, as well as for conference calls and VoIP telephony. In 2005, Siemens started the industry's first IMS Developer Program with the first projects in Germany, USA, China (Nanning) and Singapore with the following major targets: creating a developer community, leveraging the development of new applications, and delivering new applications to operators.

GSM Association's tests in 2006 examined the interworking of IMS platforms from different vendors and the interoperability of IMS carrier networks under real-world conditions. The IP Multimedia Subsystem from Siemens passed the GSM Association test series without a hitch – the Siemens system interoperates seamlessly with the IMS systems of other key vendors. Siemens also took part in trials testing the delivery of new applications. These tests are designed to ensure that new multimedia services, such as video sharing, can be used smoothly by wireless users across network boundaries.

In April 2006, Cingular Wireless, Siemens and Georgia Institute of Technology announced a program to encourage the creation of advanced IMS applications and services. The program includes developing an IMS Laboratory at Georgia Tech co-sponsored by the Georgia Electronic Design Center and the Office of Information Technology. The IMS Lab will be used by students and researchers. A public demonstration of the IMS Lab is scheduled for October 2006.

In this context, Siemens also actively contributes to the convergence of cellular networks and alternative access technologies like WiFi. Using IMS, Siemens and Time Warner Cable demonstrated several ways in which cellular networks and IP-based broadband or WiFi networks could be set up to provide seamless access for users. To complement this evolution, wide area meshed WLAN network solutions are available and capable to carry real-time services at a high capacity. The first traction of municipal scale deployment using Siemens equipment was recently announced, for example, in Toronto.

Appendix B: Global UMTS Operator Status

GLOBAL UMTS OPERATOR STATUS ***Informa Telecoms & Media, WCIS*** **Updated: July 7, 2006** **Source: Informa Telecoms & Media** **World Cellular Information Service**		
	OPERATORS IN SERVICE	**107**
	PRE-COMMERCIAL	**4**
	PLANNED/IN DEPLOYMENT	**74**
	LICENSE AWARDED	**11**
	TRIAL	**19**
	POTENTIAL LICENSE	**95**
	LICENSE REVOKED/SOLD	**11**

	Country	**Operator**	**Status**	**Start Date**	**Opening**
1	Andorra	STA	Planned/In Deployment		Dec-05
2	Australia	Hutchison 3G (3)	In Service	Apr-03	
3	Australia	Optus	In Service	Oct-05	
4	Australia	Telstra	In Service	Sep-05	
5	Australia	Vodafone	In Service	Oct-05	
6	Austria	Connect Austria (ONE)	In Service	Dec-03	
7	Austria	Hutchison 3G (3)	In Service	May-03	
8	Austria	mobilkom	In Service	Apr-03	
9	Austria	tele.ring	In Service	Dec-03	
10	Austria	T-Mobile Austria	In Service	Dec-03	
11	Bahrain	MTC Vodafone Bahrain	In Service	Dec-03	
12	Belgium	BASE (Orange)	Planned/In Deployment		Q1 2007
13	Belgium	Belgacom Mobile (Proximus)	In Service	Sep-05	
14	Belgium	Mobistar	Planned/In Deployment		Q3 2006
15	Brunei	B-Mobile	In Service	Sep-05	
16	Brunei	DST	Planned/In Deployment		Q1 2007
17	Bulgaria	BTC (Vivatel)	Planned/In Deployment		Q3 2006
18	Bulgaria	Cosmo Bulgaria Mobile	Planned/In Deployment		Q3 2006
19	Bulgaria	MobilTel (M-TEL)	In Service	Mar-06	
20	Cambodia	CamGSM (Mobitel)	Planned/In Deployment		1H 2006
21	Canada	Rogers Wireless	Planned/In Deployment		3Q 2006
22	Croatia	Tele2	Planned/In Deployment		Q2 2006
23	Croatia	T-Mobile	Planned/In Deployment		Q1 2006
24	Croatia	VIPNet	In Service	Nov-05	
25	Cyprus	Areeba	In Service	Oct-05	
26	Cyprus	CYTA	Planned/In Deployment		Q1 2006
27	Czech Republic	Eurotel Praha	In Service	Dec-05	
28	Czech Republic	Vodafone (Oskar Mobil)	Planned/In Deployment		Q3 2007
29	Czech Republic	T-Mobile	Planned/In Deployment		Q1 2007
30	Denmark	HI3G Denmark (3)	In Service	Oct-03	
31	Denmark	Sonofon	Planned/In Deployment		Q4 2006
32	Denmark	TDC Mobil	In Service	Nov-05	
33	Denmark	Telia	Planned/In Deployment		2H 2006
34	Denmark	T-Mobile	Planned/In Deployment		Q1 2006
35	Estonia	Elisa	Planned/In Deployment		Q4 2006
36	Estonia	EMT	In Service	Oct-05	
37	Estonia	Tele2	Planned/In Deployment		Q4 2006
38	Fiji	Vodafone Fiji	Planned/In Deployment		Q1 2007
39	Finland	Alands Mobiltelefon	Planned/In Deployment		Q2 2006
40	Finland	DNA Finland	In Service	Dec-05	
41	Finland	Elisa	In Service	Nov-04	

	Country	Operator	Status	Start Date	Opening
42	Finland	Song Networks	Planned/In Deployment		Q2 2006
43	Finland	TeliaSonera	In Service	Oct-04	
44	France	Bouygues Telecom	Planned/In Deployment		Q2 2006
45	France	Orange France	In Service	Dec-04	
46	France	SFR	In Service	Nov-04	
47	Georgia	Argotex	Planned/In Deployment		Q1 2007
48	Georgia	Magticom	Planned/In Deployment		Q4 2009
49	Germany	E-Plus	In Service	Aug-04	
50	Germany	O2	In Service	Jul-04	
51	Germany	T-Mobile	In Service	May-04	
52	Germany	Vodafone D2	In Service	May-04	
53	Greece	Cosmote	In Service	May-04	
54	Greece	Panafon (Vodafone)	In Service	Aug-04	
55	Greece	STET Hellas (TIM)	In Service	Jan-04	
56	Guernsey	Wave Telecom	In Service	Jul-04	
57	Guernsey	Cable & Wireless Guernsey	Planned/In Deployment		Dec-06
58	Hong Kong	Hong Kong CSL	In Service	Dec-04	
59	Hong Kong	Hutchison	In Service	Jan-04	
60	Hong Kong	SmarTone	In Service	Dec-04	
61	Hong Kong	Sunday	In Service	Jun-05	
62	Hungary	Pannon GSM	In Service	Oct-05	
63	Hungary	T-Mobile	In Service	Aug-05	
64	Hungary	Vodafone	Pre-commercial		Q3 2006
65	India	Reliance	Planned/In Deployment		Mar-08
66	India	Tata Teleservices	Planned/In Deployment		Mar-08
67	India	Spice Telecom	Planned/In Deployment		Jun-08
68	Indonesia	Excelcomindo Pratama ProXL	License Awarded		Q1 2007
69	Indonesia	Hutchison Telecom Indonesia	Planned/In Deployment		Q4 2006
70	Indonesia	Indonesian Satellite	License Awarded		Q1 2007
71	Indonesia	Natrinto Telepon Selular Lippo	Planned/In Deployment		Q4 2006
72	Indonesia	Telkomsel	License Awarded		Q1 2007
73	Ireland	Hutchison Whampoa	In Service	Jul-05	
74	Ireland	O2	In Service	Mar-05	
75	Ireland	Vodafone Ireland	In Service	Nov-04	
76	Isle of Man	Manx Telecom	In Service	Nov-05	
77	Israel	Cellcom Israel	In Service	Jun-04	
78	Israel	Partner Comm. (Orange)	In Service	Nov-04	
79	Italy	H3G (3)	In Service	Mar-03	
80	Italy	Ipse 2000	License Awarded		
81	Italy	TIM	In Service	May-04	
82	Italy	Vodafone Omnitel	In Service	May-04	
83	Italy	Wind	In Service	Oct-04	
84	Japan	eAccess	Planned/In Deployment		Mar-07
85	Japan	Softbank	Planned/In Deployment		Apr-07
86	Japan	NTT DoCoMo (FOMA)	In Service	Oct-01	
87	Japan	Vodafone	In Service	Dec-02	
88	Jersey	Cable & Wireless Guernsey	Planned/In Deployment		2007

	Country	Operator	Status	Start Date	Opening
89	Jersey	Jersey Telecoms	Planned/In Deployment		Jun-06
90	Kenya	Safaraicom	Planned/In Deployment		Q4 2007
91	Korea	KTF	In Service	Dec-03	
92	Korea	SK Telecom	In Service	Dec-03	
93	Kuwait	MTC	Planned/In Deployment		
94	Kuwait	Wataniya Telecom	In Service	Mar-06	
95	Latvia	Bité	Planned/In Deployment		Q2 2006
96	Latvia	LMT	In Service	Dec-04	
97	Latvia	Tele2	Pre-commercial		Q2 2006
98	Libya	El Madar Tel. Company	Planned/In Deployment		Q1 2006
99	Libya	Libyana	Planned/In Deployment		Q1 2006
100	Liechtenstein	Orange	Planned/In Deployment		Q1 2006
101	Liechtenstein	Tele2 (Tango)	Planned/In Deployment		Q1 2006
102	Lithuania	Bité	In Service	Jun-06	
103	Lithuania	Omnitel	Planned/In Deployment		Q4 2006
104	Lithuania	Tele2	Planned/In Deployment		Q2 2007
105	Luxembourg	LUX Communications (VOX)	In Service	May-05	
106	Luxembourg	P&T Luxembourg (LUXGSM)	In Service	Jun-03	
107	Luxembourg	Tele2 (Tango)	In Service	Jul-04	
108	Malaysia	Maxis	In Service	Jul-05	
109	Malaysia	Telekom Malaysia	In Service	May-05	
110	Malaysia	MiTV	Planned/In Deployment		Q2 2007
111	Malaysia	TT docCom	Planned/In Deployment		Q1 2007
112	Maldives	Wataniya	Planned/In Deployment		Q4 2006
113	Malta	MobIsle Comm. (go mobile)	Planned/In Deployment		Q4 2006
114	Malta	Vodafone	Planned/In Deployment		Q1 2006
115	Mauritius	Cellplus Mobile Comm.	Planned/In Deployment		Mar-06
116	Mauritius	Emtel	In Service	Nov-04	
117	Monaco	Monaco Telecom	Pre-commercial		Q2 2006
118	Netherlands	KPN Mobile (Telfort)	In Service	Oct-04	
119	Netherlands	Orange	Planned/In Deployment		Q2 2006
120	Netherlands	T-Mobile Netherlands	In Service	Jan-06	
121	Netherlands	Vodafone Libertel	In Service	Jun-04	
122	New Zealand	Econet Wireless	Planned/In Deployment		Dec-06
123	New Zealand	TelstraClear	Planned/In Deployment		Q2 2007
124	New Zealand	Vodafone	In Service	Aug-05	
125	Norway	Hi3G Access	Planned/In Deployment		Q1 2006
126	Norway	Netcom	In Service	Jun-05	
127	Norway	Telenor Mobil	In Service	Dec-04	
128	Oman	Nawras Telecom	Planned/In Deployment		Q3 2006
129	Philippines	CURE	Planned/In Deployment		Q3 2007
130	Philippines	Digitel Mobile	Planned/In Deployment		Q4 2006
131	Philippines	Globe Telecom	In Service	May-06	Q4 2006
132	Philippines	SMART	In Service	May-06	Q4 2006
133	Poland	Centertel (Orange)	Planned/In Deployment		Q4 2005
134	Poland	P4	Planned/In Deployment		Q4 2006
135	Poland	Polkomtel	In Service	Sep 204	
136	Poland	Polska Telefonia Cyfrowa (Era)	Pre-commercial		Q4 2006
137	Portugal	Optimus	In Service	Jun-04	

	Country	Operator	Status	Start Date	Opening
138	Portugal	TMN	In Service	Apr-04	
139	Portugal	Vodafone Telecel	In Service	May-04	
140	Qatar	Q-TEL	Planned/In Deployment		Q2 2006
141	Romania	MobiFon	In Service	Apr-05	
142	Romania	Orange Romania	In Service	Jun-06	
143	Saudi Arabia	Etisalat	Planned/In Deployment		Q1 2006
144	Saudi Arabia	Saudi Telecom Company	In Service	Jun-06	
145	Seychelles	Telecom Seyshelles (AIRTEL)	Planned/In Deployment		Q1 2006
146	Singapore	MobileOne	In Service	Feb-05	
147	Singapore	SingTel Mobile (3loGy Live)	In Service	Feb-05	
148	Singapore	StarHub	In Service	Apr-05	
149	Slovak Republic	Orange	In Service	Mar-06	
150	Slovak Republic	T-Mobile	In Service	Jan-06	
151	Slovenia	Mobitel	In Service	Dec-03	
152	South Africa	3C Telecom.	Planned/In Deployment		Q2 2006
153	South Africa	MTN	In Service	Jun-05	
154	South Africa	Vodacom	In Service	Dec-04	
155	Spain	Amena	In Service	Oct-04	
156	Spain	Telefónica Móviles (Movistar)	In Service	May-04	
157	Spain	Vodafone España	In Service	May-04	
158	Spain	Xfera	Planned/In Deployment		Dec-06
159	Sudan	Bashair Telecom	Planned/In Deployment		Q2 2006
160	Sudan	Mobitel Sudan	Planned/In Deployment		Q4 2006
161	Sweden	HI3G (3)	In Service	May-03	
162	Sweden	TeliaSonera	In Service	Mar-04	
163	Sweden	Svenska UMTS-Nät (Tele2)	In Service	Mar-04	
164	Sweden	Vodafone Sweden	In Service	Jul-04	
165	Switzerland	Orange	In Service	Sep-05	
166	Switzerland	Swisscom Mobile	In Service	Dec-04	
167	Switzerland	TDC Switzerland (sunrise)	In Service	Dec-05	
168	Switzerland	Team 3G	License Awarded		
169	Syria	Spacetel Syria	Planned/In Deployment		Q4 2006
170	Syria	SyriaTel	Planned/In Deployment		Q4 2006
171	Tadjikistan	Babilon Mobile OAO	In Service	Jun-05	
172	Tadjikistan	Indigo Tadjikistan	Planned/In Deployment		Q4 2006
173	Tadjikistan	TaCom	Planned/In Deployment		Q4 2006
174	Tadjikistan	TT Mobile	In Service	Jun-05	
175	Taiwan	Chunghwa Telecom	In Service	Jul-05	
176	Taiwan	FarEasTone	In Service	Jul-05	
177	Taiwan	Taiwan Mobile Co.	In Service	Oct-05	
178	Taiwan	VIBO	In Service	Dec-05	
179	Tajikistan	Indigo/MCT Russia	Planned/In Deployment		Q1 2006
180	Tanzania	Vodacom	Planned/In Deployment		Q3 2006
181	Thailand	CAT	License Awarded		Q4 2006
182	Thailand	TOT	License Awarded		Q4 2006
183	UAE	Etisalat	In Service	Jan-04	
184	UAE	Du	Planned/In Deployment		Q4 2006
185	UK	Hutchison 3G (3)	In Service	Mar-03	

	Country	Operator	Status	Start Date	Opening
186	UK	O2	In Service	Mar-05	
187	UK	Orange	In Service	Dec-04	
188	UK	T-Mobile	In Service	Oct-05	
189	UK	Vodafone	In Service	Nov-04	
190	Ukraine	Ukrtelecom	Planned/In Deployment		Q1 2007
191	Uruguay	Ancel	Planned/In Deployment		Q4 2006
192	USA	Cingular	In Service	Jun-06	

Networks in Trial					
1	Algeria	Algérie Télécom	Trial		
2	China - Beijing	Beijing Mobile	Trial		
3	China - Beijing	Beijing Netcom	Trial		
4	China - Beijing	CATT	Trial	Dec-00	
5	China - Beijing	China Tietong	Trial		
6	China - Guangdong	Guangdong Mobile	Trial		
7	China - Guangdong	Guangdong Telecom	Trial		
8	China - Guangdong	Guangdong Unicom	Trial		
9	China - Shanghai	China Tietong	Trial		
10	China - Shanghai	Shanghai Netcom	Trial		
11	China - Shanghai	Shanghai Telecom	Trial		
12	China - Shanghai	Shanghai Unicom	Trial		
13	French Polynesia	Tikiphone	Trial	Sep-05	
14	Indonesia	Indosat	Trial	Dec-06	
15	Indonesia	Telkomsel	Trial		Jun-06
16	Thailand	AIS	Trial		Dec-06
17	USA	Edge Wireless	Trial		
18	Vietnam	MobiFone	Trial		
19	Vietnam	VinaPhone	Trial		

Potential Licenses					
1	Argentina	CTI Movil	Potential License		Q1 2008
2	Argentina	Telecom Personal	Potential License		Q1 2008
3	Argentina	Telefonica Moviles	Potential License		Q1 2008
4	Bangladesh	BTTB	Potential License		Dec-10
5	Bangladesh	GrameenPhone	Potential License		Mar-10
6	Bangladesh	PBTL	Potential License		Jun-10
7	Bangladesh	Sheba Telecom	Potential License		Jun-10
8	Bangladesh	TM International	Potential License		Jun-10
9	Bangladesh	Warid Telecom	Potential License		Dec-10
10	Belgium	-tba-1	Potential License		Q4 2008
11	Bhutan	Bhutan Telecom	Potential License		Dec 2013
12	Brazil	CTBC	Potential License		Q1 2008
13	Brazil	Telemar PCS (Oi)	Potential License		Q1 2008
14	Brazil	Algar Telecom Leste (Claro)	Potential License		Q1 2008
15	Brazil	Telemig Cellular	Potential License		Q1 2008
16	Brazil	Amazonia Celular	Potential License		Q1 2008
17	Brazil	TIM Celular	Potential License		Q1 2008

18	Brazil	Sercomtel Celular	Potential License		Q1 2008
19	Brazil	Brasil Telecom	Potential License		Q1 2008
20	Bulgaria	-tba-1	Potential License		Q4 2009
21	Chile	Entel PCS	Potential License		Q1 2008
22	Chile	SmartCom	Potential License		Q1 2008
23	Chile	Telefonica Moviles	Potential License		Q1 2008
24	Colombia	Comcel	Potential License		Q1 2008
25	Colombia	Telefonica Moviles (Movistar)	Potential License		Q1 2008
26	Costa Rica	ICE Telefonia Celular	Potential License		Q1 2008
27	Ecuador	Conecel (Porta)	Potential License		Q1 2008
28	Ecuador	Otecel (Movistar)	Potential License		Q1 2008
29	Egypt	-tba-1	Potential License		Q4 2007
30	Egypt	ECMS	Potential License		Q4 2007
31	Egypt	Vodafone Egypt	Potential License		Q4 2007
32	Estonia	-tba-	Potential License		Q4 2008
33	France	-tba-	Potential License		Q4 2008
34	Hungary	-tba-	Potential License		Q1 2007
35	Iceland	-tba-(1)	Potential License		Q2 2007
36	Iceland	-tba-(2)	Potential License		Q2 2007
37	India	Aircel	Potential License		Mar 2007
38	India	Bharti Televentures	Potential License		Mar 2007
39	India	BPL Cellular	Potential License		Mar 2007
40	India	BSNL	Potential License		Mar 2007
41	India	Dishnet Wireless	Potential License		Jun 2007
42	India	Essar Spacetel	Potential License		Sep 2007
43	India	Idea Cellular	Potential License		Mar 2007
44	India	MTNL	Potential License		Mar 2007
45	Ireland	-tba-(1)	Potential License		Q2 2007
46	Lithuania	Bité	Potential License		Q3 2007
47	Lithuania	Tele2	Potential License		Q3 2007
48	Macedonia	Cosmofon	Potential License		Q4 2009
49	Macedonia	Mobimak	Potential License		Q4 2009
50	Malaysia	DiGi	Potential License		Q1 2007
51	Malta	-tba-	Potential License		Q4 2006
52	Mexico	Radiomovil Dipsa	Potential License		Q1 2008
53	Mexico	Telefonica Moviles	Potential License		Q1 2008
54	Mongolia	Mobicom	Potential License		Dec 2009
55	Mongolia	Skytel	Potential License		Dec 2009
56	Montenegro	-tba-1	Potential License		Q 2007
57	Montenegro	Monet	Potential License		Q4 2007
58	Montenegro	ProMonte	Potential License		Q1 2007
59	Morocco	-tba-1	Potential License		Q4 2007
60	Morocco	-tba-2	Potential License		Q4 2007
61	Nepal	Nepal Telecom Corp	Potential License		Mar 2012
62	Nepal	Spice Nepal	Potential License		Sep 2012
63	Pakistan	Paktel	Potential License		Dec 2007
64	Pakistan	PMCL	Potential License		Dec 2007

65	Pakistan	PTML	Potential License		Dec 2007
66	Pakistan	Telenor	Potential License		Dec 2007
67	Pakistan	Warid Telecom	Potential License		Dec 2007
68	Peru	America Movil - Claro	Potential License		Q1 2008
69	Philippines	-tba-	Potential License		Mar 2007
70	Philippines	Digitel	Potential License		Jun 2007
71	Philippines	Globe Telecom	Potential License		Mar 2007
72	Philippines	Smart Communications	Potential License		Mar 2007
73	Romania	-tba-1	Potential License		Q3 2007
74	Romania	-tba-2	Potential License		Q3 2007
75	Russia	-tba-1	Potential License		Q1 2007
76	Russia	-tba-2	Potential License		Q1 2007
77	Russia	-tba-3	Potential License		Q1 2007
78	Saudi Arabia	-tba-1	Potential License		Q2 2007
79	Serbia	-tba-1	Potential License		Q4 2006
80	Singapore	-tba-1	Potential License		Q1 2009
81	Slovak Republic	-tba-(2)	Potential License		Q1 2008
82	Slovenia	-tba-1	Potential License		Q2 2007
83	Slovenia	-tba-2	Potential License		Q2 2007
84	Sri Lanka	Celltel Lanka	Potential License		Apr 2008
85	Sri Lanka	Dialog Telekom	Potential License		Jan 2008
86	Sri Lanka	Hutchison	Potential License		Sep 2008
87	Sri Lanka	Mobitel	Potential License		Mar 2008
88	Turkey	-tba-1	Potential License		Q4 2006
89	Turkey	-tba-2	Potential License		Q4 2006
90	Turkey	-tba-3	Potential License		Q4 2006
91	Turkey	Turkcell	Potential License		Q2 2007
92	Ukraine	-tba-	Potential License		Q4 2008
93	Uruguay	CTI Movil	Potential License		Dec-07
94	Uruguay	Telefonica Moviles	Potential License		Q1 2008
95	USA	T-Mobile	Potential License		Dec-07
License Revoked/Sold					
1	Austria	3G Mobile	License Revoked/Sold		Q4 2003
2	Denmark	Telia Denmark	License Revoked/Sold		Q4 2004
3	Finland	Finnish 3G	License Revoked/Sold		Q3 2005
4	Germany	Group 3G	License Revoked/Sold		
5	Germany	MobilCom Multimedia	License Revoked/Sold		
6	Luxembourg	Orange	License Revoked/Sold		Q1 2005
7	Norway	Broadband Mobile	License Revoked/Sold		
8	Norway	Tele2 Norway	License Revoked/Sold		
9	Portugal	OniWay	License Revoked/Sold		
10	Slovakia	Profinet	License Revoked/Sold		
11	Sweden	Orange Sweden	License Revoked/Sold		Dec 2004

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.
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.
Potential License: Small level of speculation. Government policy or privatization process indicates that licensing opportunity may become available

Appendix C: Global EDGE-UMTS Operator Status & Devices

	Country	Operator	EDGE Launch	UMTS Launch
1	Australia	Telstra	June 2006	09/2005
2	Austria	Mobilkom Austria	06/2005	04/2003
3	Bahrain	MTC Vodafone	01/2004	12/2003
4	Belgium	Mobistar	12/2005	Q3/2006
5	Belgium	BASE (Orange)	Q2/2006	Q1/2006
6	Belgium	Belgacom Mobile (Proximus)	12/2005	09/2005
7	Brunei	DST	12/2004	Q1/2007
8	Bulgaria	MobilTel	03/2005	09/ 05
9	Cambodia	CamGSM (Mobitel)	Q4 2006	1H 2006
10	Canada	Rogers Wireless	06/2004	2006
11	Croatia	T-Mobile Croatia	06/2004	Q1 2006
12	Croatia	VIPNet	04/2004	11/2005
13	Cyprus	Areeba / Scancom	2006	10/2005
14	Czech Republic	EuroTel Praha	03/2005	12/2005
15	Czech Republic	Oskar Mobil	03/2005	Q3 2007
16	Czech Republic	T-Mobile	11/2004	Q1 2007
17	Denmark	Sonofon	EDGE-Capable	Q4 2006
18	Denmark	Telia Denmark	12/2005	01/2006
19	Estonia	EMT	06/2004	10/2005
20	Finland	Alands Mobiltelefon	03/2005	Q2 2006
21	Finland	DNA Finland	12/2005	12/2005
22	Finland	Elisa	11/2004	11/2004
23	Finland	TeliaSonera	12/2003	10/2004
24	France	Bouygues Telecom	05/2005	Q1/2007
25	France	Orange	04/2005	12/2004
26	France	SFR	11/2005	11/2004
27	Germany	T-Mobile	Mar 2006	May 2004
28	Greece	STET Hellas (TIM)	2006	01/2004
29	Hong Kong	CSL	09/2003	12/2004
30	Hong Kong	Sunday	Trial	06/2005
31	Hungary	Pannon GSM	02/2005	10/2005
32	Hungary	T-Mobile	10/2003	08/2005
33	India	BSNL	09/2005	Mar 2007
34	India	Dishnet Wireless	12/2005	Jun 2007
35	India	Hutchison Max	07/2004	Mar 2007
36	India	Idea Cellular	07/2004	Mar 2007
37	Indonesia	Telkomsel	02/2004	Jun 2006
38	Israel	Cellcom	06/2004	06/2004
39	Italy	TIM	05/2004	05/2004
40	Italy	Wind	Jun 2006	10/2004
41	Kuwait	Wataniya	08/2005	03/2006
42	Latvia	Bité	10/2005	Q2 2006
43	Latvia	LMT	06/2005	12/2004
44	Libya	El Madar Telephone Company	Planned	Q1 2006
45	Libya	GPTC	Q1 2006	Q1 2006
46	Lithuania	Bité	Dec 2003	Q3 2006
47	Lithuania	Omnitel	Aug 2004	Q4 2006
48	Malaysia	Maxis	EDGE-Capable	07/2005
49	Netherlands	Telfort	04/2005	Q4 2005
50	Norway	Netcom	12/2004	06/2005
51	Norway	Telenor Mobile	09/2004	12/2004
52	Oman	Nawras	06/2005	Q3/2006
53	Philippines	GLOBE	03/2004	05/2006
54	Philippines	SMART	02/2004	05/2006
55	Poland	Polkomtel/Plus GSM	01/2005	11/2004

	Country	Operator	EDGE Launch	UMTS Launch
56	Poland	Era	03/2004	Q4 2006
57	Poland	Orange (Centertel)	10/2004	Q1 2006
58	Romania	Orange Romania	10/2004	Q2 2006
59	Saudi Arabia	Mobily (etihad Etisalat Company)	04/2005	Q1 2006
60	Slovak Republic	T-Mobile Slovensko	04/2005	Q4 2006
61	Slovak Republic	Orange Slovensko	01/2005	Q1 2005
62	South Africa	MTN	04/2005	06/2005
63	South Africa	Vodacom	11/2004	12/2004
64	Sweden	TeliaSonera	01/2005	03/2004
65	Switzerland	Swisscom Mobile	03/2005	12/2004
66	Switzerland	TDC (Sunrise)	12/2005	12/2005
67	Thailand	AIS	10/2003	Dec 2006
68	UK	Orange	01/2006	12/2004
69	USA	Cingular	06/2003	06/2004
70	USA	T-Mobile	09/2005	2007
71	Vietnam	Mobifone	June 2006	Trial

Appendix D: Global HSDPA Operator Status & Devices

HSDPA Deployments

Informa Telecoms & Media *World Cellular Information Service* *July 7, 2006*			IN SERVICE	41 in 31 countries
			COMMITMENTS	103
Networks in service (in red)	(* = data cards only)			
	Country	Operator	Status	Start date
1	Australia	3 Australia/Hutchison 3G	In Deployment	2007
2	Australia	Optus	Planned	2007
3	Australia	Telstra	In Deployment	Sep 2006
4	Australia	Vodafone	Planned	Dec 2006
5	Austria	3 Austria/ Hutchison 3G	Planned	Dec 2006
6	Austria	Connect Austria (ONE)	Planned	Dec 2006
7	Austria	Mobilkom Austria *	In Service	Jan 2006
8	Austria	T-Mobile *	In Service	Mar 2006
9	Austria	Tele.ring	In Deployment	Dec 2006
10	Bahrain	MTC Vodofone	In Service	May 2006
11	Belgium	Mobistar	In Deployment	Sept 2006
12	Belgium	Proximus	In Service	June 2006
13	Bulgaria	Mobiltel	In Service	Mar 2006
14	Canada	Rogers	In Deployment	Q4 2006
15	China	China Mobile	In Trial	2007
16	Croatia	VIPNET	In Service	Apr 2006
17	Czech Republic	Eurotel Praha	In Service	Apr 2006
18	Czech Republic	T-Mobile	Planned	2007
19	Czech Republic	Vodafone Czech (Oskar)	Planned	2007
20	Denmark	3 Denmark	In Deployment	2006
21	Estonia	Elisa	In Trial	Q4 2006
22	Estonia	EMT	In Service	April 2006
23	Finland	Elisa	In Service	April 2006
24	Finland	Finnet/ Finnish 2G	In Deployment	Mar 2007
25	France	Bouygues	Planned	1H 2007
26	France	Orange	In Trial	Mid-2006
27	France	SFR	In Service	May 2006
28	Germany	E-Plus	Planned	Dec 2006
29	Germany	O2	In Deployment	Dec 2006
30	Germany	T-Mobile *	In Service	Mar 2006
31	Germany	Vodafone *	In Service	Mar 2006
32	Greece	Cosmote (data card)	In Service	Jun 2006
33	Guernsey	Cable & Wireless	In Deployment	2007
34	Hong Kong	CSL	In Deployment	2H 2006
35	Hong Kong	3HK	In Deployment	Q3 2006
36	Hong Kong	Smartone/Vodafone	In Service	June 2006
37	Hong Kong	Sunday	In Deployment	Jun 2006
38	Hungary	Pannon	In Deployment	Mar 2007
39	Hungary	T-Mobile (Budapest)	In Service	May 2006
40	Hungary	Vodafone	In Trial	2007
41	Ireland	O2	In Deployment	Sep 2006
42	Ireland	Vodafone	In Deployment	Dec 2006

	Country	Operator	Status	Start Date
43	Isle of Man	Manx Telecom	In Service	Nov 2005
44	Israel	Cellcom Israel	Planned	1H 2006
45	Israel	Partner Comm. (Orange)	In Service	Apr 2006
46	Italy	H3G (data cards only)	In Service	June 2006
47	Italy	TIM	In Service	May 2006
48	Italy	Vodafone Omnitel	In Service	Jun 2006
49	Japan	BB Mobile	In Deployment	2007
50	Japan	eMobile	Planned	Mar 2007
51	Japan	NTT DoCoMo	In Deployment	Q3 2006
52	Japan	Vodafone	Planned	2H 2006
53	Jersey	Cable & Wireless	In Deployment	2007
54	Korea	KTF	In Service	Jun 2006
55	Korea	SK Telecom 3G+ (1st commercial network with HSDPA handheld devices)	In Service	May 2006
56	Kuwait	Wataniya Telecom	In Service	Feb 2006
57	Latvia	Bité	In Deployment	Dec 2006
58	Lithuania	Bité	In Service	Jun 2006
59	Lithuania	Omnitel	In Trial	Dec 2007
60	Malaysia	Celcom	In Service	Jun 2006
61	Malaysia	Maxis Communications	In Deployment	2006
62	Malaysia	Time dotCom Bhd	In Trial	2007
63	Mexico	Telcel	In Deployment	2007
64	Netherlands	KPN	In Deployment	Dec 2006
65	Netherlands	Telfort	In Deployment	Dec 2006
66	Netherlands	T-Mobile	In Service	Apr 2006
67	New Zealand	Vodafone	In Deployment	2006
68	Philippines	GLOBE Telecom	In Service	Mar 2006
69	Philippines	SMART Communications	In Service	April 2006
70	Poland	Polkomtel	Planned	2006
71	Poland	Polska Telefonia Cyfrowa	In Deployment	2006
72	Portugal	Optimus *	In Service	Mar 2006
73	Portugal	TMN	In Service	Apr 2006
74	Portugal	Vodafone Telecel	In Service	Mar 2006
75	Qatar	Q-Tel	Planned	Mar 2007
76	Romania	Vodafone (Connex)	In Service	May 2006
77	Romania	Orange Romania	In Deployment	2007
78	Saudia Arabia	Mobily	In Service	Jun 2006
79	Saudi Arabia	STC / Al Jawwal	In Service	May 2006
80	Singapore	MobileOne	Planned	Dec 2006
81	Slovak Republic	Orange	In Trial	2006
82	Slovenia	Mobitel	In Deployment	Jun 2007
83	South Africa	MTN	In Service	Mar 2006
84	South Africa	Vodacom	In Service	Apr 2006
85	Spain	Amena/ Orange	In Service	Jun 2006
86	Spain	Vodafone España	Pilot network	Dec 2006
87	Spain	Telefonica Moviles	Planned	Dec 2006
88	Sweden	H3G	In Deployment	Dec 2006
89	Sweden	Svenska UMTS-Nät	Planned	Dec 2006
90	Switzerland	Orange	Planned	Dec 2006
91	Switzerland	Sunrise	In Trial	Q2 2006

	Country	Operator	Status	Start Date
92	Switzerland	Swisscom Mobile	In Service	Mar 2006
93	Taiwan	Taiwan Mobile	Planned	Dec 2006
94	Taiwan	VIBO	Planned	Mar 2007
95	Tanzania	Vodacom	Planned	Dec 2006
96	UAE	Etilisat	In Service	April 2006
97	UK	3 UK / Hutchison	In Deployment	Sep 2006
98	UK	O2	In Deployment	Sep 2006
99	UK	Orange	Planned	Dec 2006
100	UK	T-Mobile	In Deployment	Aug 2006
101	UK	Vodafone	In Deployment	Sep 2006
102	USA	Cingular Wireless	In Service	Nov 2005
103	USA	EDGE Wireless	In Trial	2007

Source: Informa Telecoms & Media, World Cellular Information Service and public announcements

HSDPA Devices

PC DATA CARDS:
Huawei: HSDPA E620 PC card GSM/EDGE 900/1800/1900 UMTS/HSDPA
Motorola: D1100 PC card GSM/GPRS/UMTS/HSDPA
Novatel Wireless: PC card devices backward compatible with 850/900/1800/1900 MHz GSM/GPRS/EDGE: - Merlin U730: 850/1900 MHz UMTS/HSDPA (North America) – - Merlin U740: 2100 MHz UMTS/HSDPA (Asia, Africa, Europe, Middle East) - Merlin U870: 850/900/2100 MHz (North America & Europe) PCI Express Mini Card modems for laptops and wireless broadband devices, backward compatible with 850/900/1800/1900 MHz GSM/GPRS/EDGE – in development phase, availability pending: - Expedite EU730: 850/1900 MHz UMTS/HSDPA (North America) - Expedite EU740: 2100 MHz UMTS/HSDPA (Asia, Africa, Europe, Middle East) - Dell Wireless 5510 ExpressCard for Cingular networks (available August 06) - Panasonic® Toughbook® Convertible Tablet PC with embedded Novatel Wireless Expedite EU730 Module
Option: PC cards - Globetrotter GT MAX: 850/1900/2100 Multi-mode HSDPA/UMTS/EDGE/GPRS/GSM - GlobeTrotter HSDPA: 850/900/1800/1900/2100 MHz EDGE-UMTS-HSDPA for North America and EMEA; shipping now - GlobeTrotter 3G EDGE: 850/900/1800/1900/2100 MHz EDGE-UMTS-HSDPA-ready, available now - GlobeTrotter FUSION+: HSDPA-ready-850/900/1800/1900/2100 MHz EDGE-UMTS-Wi-Fi 802.11G-; available now - GlobeTrotter FUSION+ HSDPA: Multimode WLAN/HSDPA/UMTS/EDGE/GPRS/GSM 850/900/1800/1900 - GTM351E PCI Express Mini Card module for laptops: 850/900/1800/1900 EDGE-UMTS-HSDPA-WWAN; to ship in H1 2006
Siemens: - DC10: GSM/EDGE 850/900/1800/1900/UMTS/HSDPA 2100 Available H2 2005 - CD16 GSM/EDGE 850/900/1800/1900/UMTS/HSDPA 850/1900 Available H2 2005
Sierra Wireless: both PC cards available now - AirCard 850: 850/900/1800/1900/2100 EDGE-UMTS-HSDPA (Europe) - AirCard 860: 850/900/1800/1900 EDGE-UMTS-HSDPA (North America) - AirCard 875: 850/900/1800/1900/GPRS/EDGE 800/1900/2100 UMTS/HSDPA (Global) - MC8755 PCI Express Mini Cards 2100 MHz for use on HSDPA capable networks (Europe and Asia) - MC8765 PCI Express Mini Card 850/1900 MHz (North America) Available 2006

- MC8775 PCI Express Mini Card HSDPA/UMTS 850/1900/2100 and EDGE/GPRS quad-band - MC8775V PCI Express mini Card – same as above but supports simultaneous voice & data
ZTE Corporation: (China) MF330 data card scheduled for commercial availability 2006
HANDSETS
BenQ-Siemens Mobile: **-** EF91 –GSM 900/1800/1900 UMTS HSDPA 2100 slated for commercial availability around June 2006
Fujitsu Ltd/Motorola/NEC Corp: - Developed for NTT CoDoMo Inc. -prototypes shown at 3GSM World Congreso Feb 06
LG Electronics: **-** GSM/ UMTS/ HSDPA device slated for commercial availability in 2006 - LG KU730 GSM/EDGE 900/1800/1900/UMTS HSDPA 2100 - LG SH100 and LGKH1000 (SK Telecom and KFT only) handset for video calls - LG CU500 GSM/EDGE 850/900/1800/1900 UMTS – HSDPA 850 Cingular Wireless
NTT DoCoMo: N902iX
Qtek: - Qtek S300 GSM EDGE 850 900/1800/1900 UMTS HSDPA 850 1900 2100 - Qtek 9600 GSM/EDGE/850/900/1800/1900 UMTS HSDPA 210 / WLAN Available July 2006
Samsung Electronics: - SGH-zx20: Quad-band GSM 850/1900/2100 for global and Cingular networks –Available now **-** SGH-Z560**:** GSM/EDGE 900/1800/1900 UMTS HSDPA 2100 Available 2Q 2006 - ZX20 850/900/1800/1900 MHz handset, planned availability in Q2 2006 - SCH-W200 and SPH-W2100 terrestrial DMB (digital multimedia broadcasting) HSDPA handset through KTF.
MODEMS, ROUTERS and other access devices
- Huawei E220 USB modem: GPRS/EDGE/UMTS/HSDPA external mini USB interface - GlobeSurfer /CON : quad band GSM/EDGE/UMTS/HSDPA 2100 – USB connector - GlobeSurfer 3G HSDPA Wireless Broadband Router: EDGE/UMTS/HSDPA 802.11 & Ethernet - Novamedia: launch2net® for Mac OS X - mobile data connecting software - ZadaCOM 3G+ (www.zadako.com): GSM/GPRS/EDGE/UMTS/HSDPA (EMEA+North America) available now
INTEGRATED LAPTOPS
Acer: TravelMate 4260, Aspire 5650 upgradeable to HSDPA
Dell: Dell Wireless 5505 Mobile Broadband 3G HSDPA card available in the U.K. June 2006
Fujitsu Siemens Computers: Lifebook Q2010 notebook equipped with 3G, HSDPA and WLAN (for T-Mobile networks)
HP: April 06 announced global wireless for notebook PCs (UMTS/HSDPA for Cingular networks)
Lenovo: ThinkPad Z60, T60, X60 laptops to incorporate HSDPA
Panasonic: -Panasonic® Toughbook® Convertible Tablet PC with embedded Novatel Wireless Expedite EU730 Module (Available on Cingular BroadbandConnect and Compatible Global Networks – June 2006)

Vendors

A growing number of manufacturers and software providers support HSDPA.

Acer	Lucent Technologies
Aeroflex	Motorola
Agere Systems	NEC
Agilent Technologies	Nokia
Alcatel	Nortel Networks

Analog Devices	Novatel Wireless
Andrew Corporation	Option
Anritsu Solution	Panasonic
Argogroup	picoChip
BenQ	Qualcomm
Broadcom	Radioplan
Cellular3G	Rohde & Schwarz
Dell	Samsung
Dovado	Sanyo
Elan Digital Systems	Sharp
Ericsson	Siemens
Fairchild Seminconductor	Sierra Wireless
Freescale Semiconductor	Sirific Wireless
Fujitsu	Spirent Technologies
HP	Sony Ericsson
Huawei	Texas Instruments
Icera	TriQuint SemiConductor
Infineon Technologies	TTPCom
InterDigital Communications	UbiNetics
IPWireless	ZADAKO
Lenovo	ZTE Corporation
LG Electronics	

N.B.: This list is representative of some of the many companies that are supporting HSDPA, and may not be a fully comprehensive listing of HSDPA vendors. Should you wish to add your company to the list, please send an email to info@3gamericas.org.

Acknowledgments

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