A White Paper from
the UMTS Forum

Recognising the Promise of Mobile Broadband

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UMTS
Forum

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1 The Mobile Broadband Promise

The promise of mobile broadband has long been understood by the mobile industry. Predictions of subscriber numbers, network traffic and spectrum requirements have always assumed that the promise will eventually be fulfilled. Mobile technologies and standards have pursued a decades-long evolutionary path to realise the potential of mobile broadband by delivering ever increasing performance from networks and devices.

Progress has not been consistently smooth. The deployment and acceptance of mobile broadband has been regularly interrupted by adverse economic conditions and negatively affected by technologies that did not match up to continually increasing user expectations.

But now it seems that a threshold has been crossed. The congruence of smart endpoints plus always on broadband plus cloud computing has been described as providing the building blocks for revolution.[1] The widespread deployment of high performance mobile broadband access networks, the availability of many capable networks of "resources for rent", and the current generation of intelligent endpoints with extensive capabilities and standard environments together enable new ways to build services and allow new competitive models.

The widespread availability of bandwidth together with the availability of smart user devices has changed the game. The turning point has been the simultaneous availability of networks and devices both capable of delivering a compelling user experience – usability plus accessibility is a winning combination. The overall user experience has suddenly become satisfying rather than irritating, similar to the transformative impact of DSL broadband access compared with dial-up in the fixed environment.

A similar milestone has now been reached in the mobile environment. According to Rysavy Research: "With typical 3G speeds of 1 Mbps and latency of 100 to 200 milliseconds, small screens can now update in five seconds or less compared with 10 seconds or more on 2G networks".[2] Five seconds may be slow compared with the sub-second screen updates achieved with local native applications in offline operation, but it's still usable. The deployment of HSDPA/HSUPA (and now HSPA+) has increased throughput and reduced latency cutting typical screen update times even further. The introduction of LTE will result in blisteringly fast screen updates, transforming the entire user experience on the mobile internet.

End users, as well as the mobile industry, now understand and recognise the promise of mobile broadband.

"Mobile operators are spending huge sums to upgrade their networks for high-speed access", wrote The Economist in 2007, "and are looking for new sources of traffic for them".[3] Three years later the search for new sources of traffic is no longer an issue; some operators are already finding their network capacities stretched.

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1 Warren Montgomery, ICIN 2009 – Beyond the Bit Pipes, http://home.att.net/~wamontgomery/communications/ICIN2009_notes.htm

2 *The Mobile Web Imperative*, Peter Rysavy, Information Week, Dec 7, 2009

3 *Marconi's brainwave*, The Economist, April 26 2007

Mobile broadband subscribers and revenues in the top five European markets are forecast to nearly double by 2011.[4] Subscriber numbers are predicted to rise from about 22 million at the end of 2009 to over 43 million in 2011 and revenues to rise from less than €6 billion in 2009 to more than €11 billion in 2011.

But this is just the start. Massive waves of video traffic are about to hit the mobile internet and will require yet further upgrades to network performance. Those upgrades will have to deliver mobile data capability at reduced costs to enable new business models that will replace the now broken business model based around the single service of voice connectivity.

[4] *Mobile Broadband in Europe*, 4Q09, CCS Insight, January 2010

2 Discovering the Benefits

Mobile traffic is, and will remain, a small proportion of global traffic volumes (Figure 1). But that does not mean mobile traffic volumes will stay relatively static. On the contrary, mobile traffic volumes are set to explode under the impact of a tsunami of bandwidth-hungry video traffic consumed by devices such as smartphones, netbooks and smartbooks that incorporate computer and internet capability and can run a wide range of data applications.

Figure 1: Growth in fixed and mobile traffic
Source: NSN

Cisco has predicted that three waves of video, driven by changing user behaviour and social networking phenomena, will result in massive volumes of traffic on the networks.[5] The first wave is generated by end users consuming video over the internet on their PCs. This first wave has already arrived and has had a huge impact on fixed network traffic. It's been noted that the website YouTube now streams around 6 petabytes every month. That's an amazing amount given that the entire internet backbone traffic in 2000 was just 25 petabytes.

The second wave – end users consuming video over the internet on their TVs – is now putting many fixed networks under stress. The third wave – internet video consumption on mobile devices – is not far behind and, according to some observers,[6] will far outsize any previous waves on other media access devices.

Mobile data, video in particular, can be a ravenous consumer of bandwidth. Downloading a 5 Mbyte PowerPoint file to a phone or laptop consumes as much data on the downlink as speaking on a phone for over an hour. A single laptop can generate as much traffic as 1,300 basic feature phones. One smartphone typically generates some 10 times the traffic of a basic phone. iPhones, with their heavy signalling traffic requirements, can generate as much traffic as 30 basic feature phones.[7]

Watching a YouTube video on a mobile phone or wireless-enabled laptop consumes almost one hundred times the data bandwidth of a mobile voice call. And whereas a mobile voice call typically consumes 6-12 kbps, enhanced high-speed mobile internet access consumes up to 5 Mbps on today's deployed networks.[8] In terms of network impact, according to the CTO of O2 in the UK, watching a YouTube video on a smartphone can be equivalent to sending 500,000 text messages simultaneously.

Mobile uploads to websites such as YouTube are a rapidly increasing recent driver of mobile broadband usage. Mobile uploads to YouTube in the USA increased 1,700 per cent in the first six months of 2009 and increased more than 400 per cent per day in the week following the launch of the iPhone 3GS.[9]

2.1 The rise of the mobile internet

Early applications for mobile phones largely consisted of ringtones and basic arcade-style games. For many years mobile phones lacked the processing capacity, display capability, memory, and connectivity necessary to match user expectations conditioned by their home or office computer experience. But the huge innovation and investment in smartphones has transformed the applications space in mobile over the past two years. Since the launch of the iPhone and iPod Touch the take-up of the mobile internet by subscribers has far exceeded the equivalent adoption rate of the fixed internet on the desktop (Figure 2).[10]

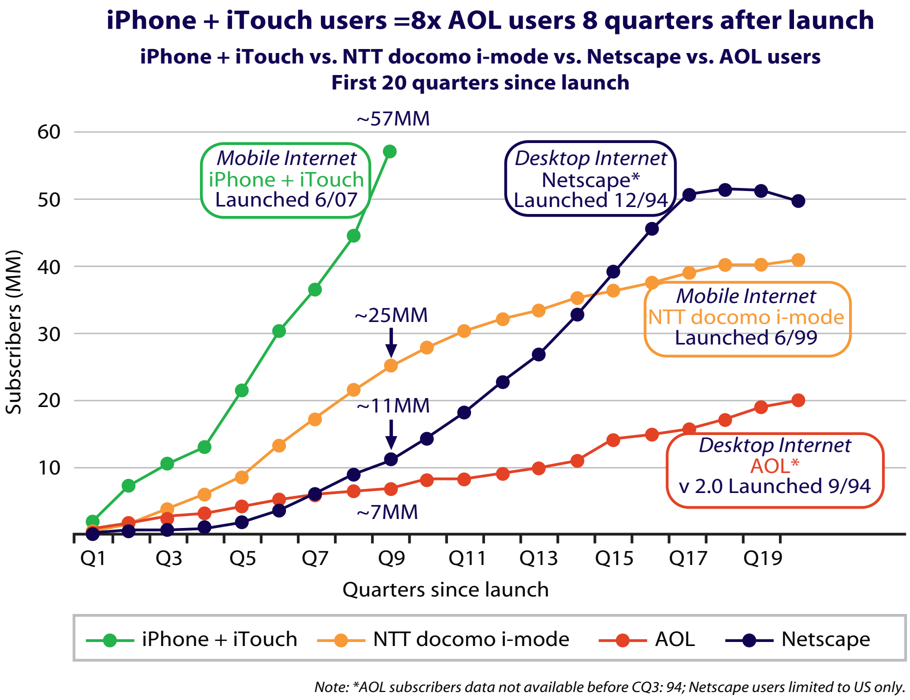

Figure 2: Mobile internet outpaces desktop internet adoption
Source: Morgan Stanley

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9 *Ex Parte* Letter from Christopher Guttman-McCabe, V.P., Regulatory Affairs, CTIA – The Wireless Ass'n, to Chairman Julius Genachowski, and Commissioners Copps, McDowell, Clyburn, and Baker, Federal Communications Commission, GN Docket No. 09-51 (filed Sept. 29, 2009)

10 *Economy + Internet Trends*, Mary Meeker, Morgan Stanley, Web 2.0 Summit, October 2009

In 2005 mobile data traffic was 1 petabyte (1,000 terabytes or 1,000,000 gigabytes) per month globally. By 2012, according to Cisco, global mobile data traffic will exceed 1000 petabytes (1 exabyte) per month, a thousand-fold increase in seven years. The internet took twice as long, taking 14 years to grow from 1 petabyte to 1,000 petabytes per month.

One thousand petabytes is an awful lot of data. Accenture estimates that all the music ever made accounts for about 1.5 petabytes and all the movies ever produced account for between 4 and 5 petabytes. One year of TV broadcasts in the USA represents 12-15 petabytes. Everything that has been written since the beginning of recorded history, in all languages that have ever existed, would amount to just 50 petabytes of data.[13]

User generated content is dwarfing these figures. The daily upload of photos in the USA is now some 40-45 petabytes. That's per day, not per year. And it's upload, not download.

2.2 The impact of smartphones

Mobile traffic will reach over 2,000 petabytes per month by 2013 and mobile video, driven by smartphones, netbooks and smartbooks, will be responsible for the majority of the traffic growth. Further growth will be fuelled by an increasing number of consumer electronic devices utilising mobile broadband networks. By 2015, the mobile data traffic footprint of a single subscriber could be 450 times what it was 10 years earlier in 2005.

The impact of connected laptops, netbooks and smartphones on mobile data usage has already been dramatic. The NGMN Alliance reports that smartphone users in Europe on platforms such as the iPhone and Android currently generate over 15 times more data usage than basic feature phone subscribers.[14]

Data usage is strongly influenced by the availability of applications. The App Store concept introduced by Apple in July 2008 allows iPhone users to browse and directly download applications developed with the iPhone software development kit and published exclusively through Apple. At the start of 2010 there were 115,000 applications in the iPhone App Store with more than three billion downloads.

According to AdMob, 50% of iPhone users are willing to purchase one or more apps and iPhone users typically spend over $9 per month on apps. The iPhone App Store only covers one operating system. Other app stores, often hosted by device manufacturers, focus on other operating systems such as Symbian, Android, RIM, Windows Mobile and Palm (Figure 4). As these other app stores become established in specific regions they are already generating similar volumes of traffic as the iPhone.

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13 Wikipedia, petabyte entry

14 *Next Generation Mobile Networks - Opportunities and Challenges*, Peter Meissner, NGMN Alliance, ICC 2009, Dresden, June 2009

The last quarter of 2009 was notable for the continued growth of the smartphone segment which ended the year at some 170 million units, 14% of total mobile device shipments worldwide.[15] Mobile broadband access devices, another important driver of growth, shipped 32.2m datacards, USB modems and embedded laptops in 2009.

Users of these mobile broadband access devices generate about five times more data traffic than the 30 million iPhone users, according to Morgan Stanley, and iPhone users generate about 10 times more traffic than other smartphone users. There could be over a billion subscribers in these three categories of heavy mobile data users by 2013 (Figure 5).

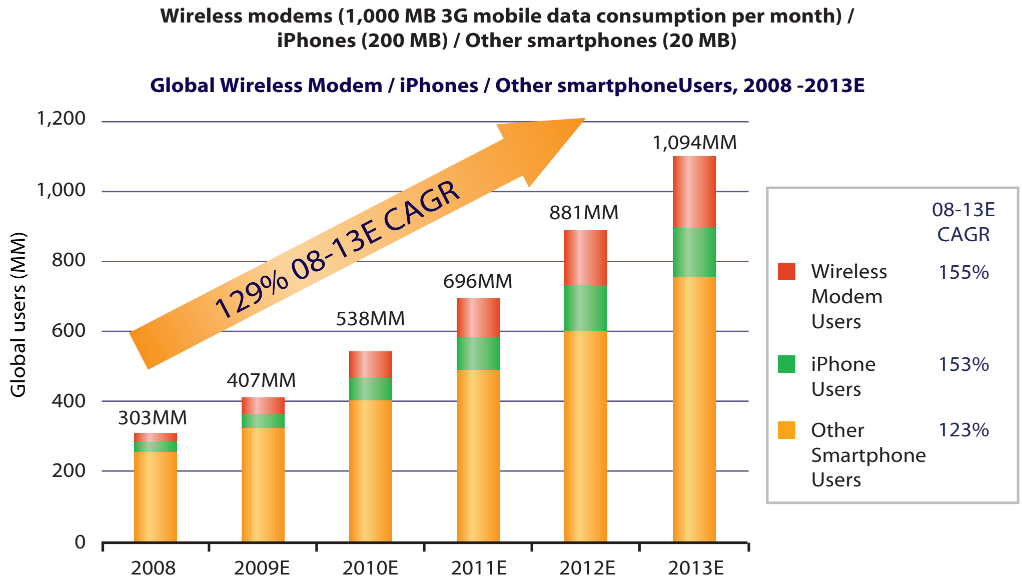

Figure 5: Growth in heavy mobile data users
Source: Morgan Stanley

A billion heavy mobile data users will represent quite a challenge for network operators. Mobile video, the dominant component of mobile internet traffic, is uncompromising in its demands on network data rates, throughput and latency. Network performance will have to satisfy those demands if operators are to remain competitive – the selection and timing of appropriate network infrastructure will be critical.

2.3 The need for new business models

Remaining competitive depends on more than acceptable service delivery. Watching a YouTube video on a smartphone may be equivalent to sending 500,000 text messages simultaneously but it cannot command an equivalent revenue stream. Radically new business models are required and redefining business priorities will also impact the selection of network infrastructure.

15 Gartner, Forecast Analysis: Mobile Devices, Worldwide, 2003-2013, 4Q09 Update

Voice and SMS traffic still generate around 80% of mobile operator average revenues but this revenue stream is at risk not only from commoditisation but also from OTT VoIP and IM services. However, operators now have the opportunity to expand their core business of providing communication beyond classic voice and SMS. Features such as Hi-Fi speech, presence, visual ring-back, chat and telepresence are currently being worked on and could be introduced as soon as operators go back to co-operation around communication services. RCS is the first step in this direction and is described later in this white paper. In addition, operators can now enter new value chains such as advertising and TV and can also open up their networks for others to deliver services based on telecom enablers such as identity, SMS payments and M2M communications. Mobile advertising can compensate for only a small proportion of the lost revenue, however, the most promising areas of potential growth lie in mobile commerce and brokerage services.

Social networking sites such as QQ in China and Mixi in Japan have demonstrated just how strong this growth potential can be. At the end of 2006, a quarter of the 6,000 monthly page views on Mixi, Japan's leading social networking site with over 23 million users, were from mobile devices and three-quarters from PCs. At the beginning of 2009 the situation had reversed with three-quarters of the over 14,000 page views each month coming from mobile devices.

The combination of mobile devices and social networking sites has created an entirely new mode of communicating. And that new communications platform provides a vehicle for mobile commerce and brokerage services within which mobile usage can be monetised through a range of personalisation and premium services. Mobile network operators are, in principle, well positioned to play a pivotal role in that process as they are capable of providing robust levels of personalisation and security that are unthinkable in the web environment.

Morgan Stanley points to the experience of Mixi in Japan to highlight the growth potential of the mobile internet. The potential can of course only be realised if network infrastructure with adequate performance is deployed at the right time. That time could be sooner rather than later. The complex and multi-dimensional nature of devices, applications and business models is about to accelerate the growth and impact of the mobile internet.

3 Realising the Potential

Ubiquitous mobile broadband access combined with the current generation of intelligent endpoints with extensive capabilities is an immensely powerful mixture. Factoring in network-based resources from telcos such as location, presence, identity management, authentication, authorisation, registration and charging would add significant strength to that mixture, enabling levels of personalisation, security and QoS that cannot be provided by over-the-top services from webcos. Complex services now being developed, some of which are described below, could well become building blocks for a revolutionary new era in mobile centred on e-commerce and social networking. Such services will impose increasing demands on access network performance, requiring higher throughput and lower latency at dramatically reduced costs.

3.1 Service provision options

Two radically different approaches to service provision over fixed IP networks have evolved over the past few years. Telcos have focused on "all-IP" architectures based on the IMS standard and programmable service delivery platforms (SDPs). These are intended to enable rapid service development so that telcos can compete with web 2.0 service providers in terms of service portfolio and reusable capabilities. Webcos such as Google and Facebook have relied more on open but proprietary interfaces to create and integrate new services and applications intended to give them a competitive edge over telcos.

Telcos need to find new revenue streams to compensate for the decline of their traditional voice market. Their strategy has been to move from the large centralised systems strongly governed and built around "voice service" to a more complex computing environment oriented towards an internet approach and supporting a multitude of different services.[16]

The webcos' approach on the other hand epitomises client-server architectures and the end-to-end principle.[17] Interfaces are often open but proprietary for technical and business reasons: they are instrumental in the creation of new technologies and *de-facto* standards controlled and governed by the specific webco. Major webcos have deployed large data centres at the edge of the network to support their service proposition to the vast internet market.

Different web 2.0 technologies such as SOAP (used largely in the telco environment) and REST (favoured by webco developers) can be used for service creation in telecom networks. The simple object access protocol (SOAP) is a protocol specification for exchanging structured information in the implementation of web services. Despite its name it is no longer simple, it grew in complexity as developers of applications and services tackled ever more complicated scenarios.

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[16] A. Manzalini et al., "*If the Web is the platform, then what is the SDP?*" in 2009 13th Int. Conf. Intelligence in Next Generation Networks: Beyond the Bit Pipes (ICIN 2009), Bordeaux, France, 2009 © IEEE

[17] "mechanisms should not be enforced in the network if they can be deployed at end nodes, and that the core of the network should provide general services, not those tailored to specific applications". Saltzer, J., Reed, D., and Clark, D. D. "*End-to-end arguments in system design*". ACM Transactions on Computer Systems 2, 4 (Nov. 1984)

Seen by many as a reaction against SOAP, Representational State Transfer (REST) is an architectural style consisting of clients and servers that characterises the web. REST is – and will remain – stateless and does not address many areas.

Amazon was a pioneer in both SOAP and REST, opening up APIs in both technologies. They found that 89% of developers used REST, implying that the majority of current applications in the fixed network are relatively simple. Yahoo! had the same experience – they put out REST and SOAP APIs and 90% of the developers used REST.

Now the focus is on mobile. Web developers are stampeding into mobile applications urged on by the iPhone App Store. The social networking site Facebook is seeing huge growth in mobile users – from five million in August 2008 to 100 million users in February 2010. Many new users of Facebook never see the web version, entirely using the iPhone version.

Although there are hundreds of thousands of items now available in app stores the vast majority are standalone applications that either function natively within a mobile device or utilise information delivered over a basic connection to a remote server. Few applications today make use of network-based resources that can provide location, presence, identity management, authentication, authorisation, registration, charging and routing. Even fewer applications operate across multiple devices and operating systems. Hardly any operate over multiple networks. Most applications available today are pretty one-dimensional.

There are significant revenue opportunities for these simple applications and for web-based applications that can connect, communicate and benefit from understanding the status of mobile users. But the real benefits of the mobile internet could come with multi-modal applications that connect multiple endpoints across a wide range of access networks and make full use of the capabilities and information resources available within devices and networks. Such multi-dimensional applications are now being developed and typically involve a combination of web and telecom technologies and services.

The approach to standardisation neatly illustrates a major difference between the web and telecom worlds. The web contains thousands of proprietary APIs that are ubiquitously available. These proprietary APIs differentiate the offerings of each single webco, all of which have potentially global reach. In the telecom world, on the other hand, there are hundreds of APIs differentiating the offerings of individual telcos, which each have national or regional rather than global coverage. In the telecom world standards are more about enabling interoperability. Standardisation initiatives are pushing for the specification and consolidation of standards, such as Parlay/OSA APIs and Parlay X Web Services. Projects such as GSMA OneAPI – now strengthened by the Wholesale Applications Community launched at the Mobile World Congress in February 2010 – are creating a set of standard telecom web services that provide secure, high level access to telecom functions, hiding the complexity of telecom for developers.

This situation has been termed the Standardisation Paradox.[18] It states that: "Operators use standards for guaranteeing the operation and interworking of their networks and services, while webcos use standards as a means to impose their technical solutions and services on the market".

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[18] A. Manzalini et al., "*If the Web is the platform, then what is the SDP?*" in 2009 13th Int. Conf. Intelligence in Next Generation Networks: Beyond the Bit Pipes (ICIN 2009), Bordeaux, France, 2009 © IEEE

In the mobile environment the separation between the telco and webco approaches to service provision could well become blurred as the construction of compelling services requires combinations and mashups of different technologies. Telcos are inevitably country based and, even when there is an operator group, are never able to provide a service to a third party developer that allows ubiquitous access to all consumers in a country without interoperability being in place across many different operators. Co-operation between telcos and webcos may well be necessary to create the immensely complex applications that will take mobile services to new dimensions. A threshold will have been crossed with such a marriage of telco and webco capabilities, allowing new ways to build services and create new competitive business models.

3.2 Grocery Gadget

At one stage, the grocery list application Grocery Gadget was the top iPhone App paid download.[19] It cost $4.99 and made it easy to create and manage shopping lists by organising information in user friendly ways with good graphics. The application contains lists that are easy to check and uncheck and shows pricing based on past purchases.

But the user has to do everything. The user has to update the list in response to messages, set reminders, find a store with the items, find the best price and discounts for everything on the list, pick up and check off all items.

The shopping experience will change with the mobile internet and web 3.0. Whereas web 2.0 was all about social networking, web 3.0 is all about personalisation, turning the unstructured web into a structured source of information, products and services. Grocery shopping with the mobile internet and web 3.0 will not just be a shopping list app – it will be a personalised service. The application will run at all times and be customisable, the user will be in control, allowing or denying it the opportunity to autonomously connect to the network, buy things automatically, communicate with other applications, etc.

Future services and applications will be more interconnected and automated, communicating with each other and with internet-based counterparts. They will be able to use each others' services and share semantic annotated data.

Shopping services could be location sensitive to alert users of nearby stores, sales, discounts, coupons or promotions. They could be configured to use their owner's mobile wallet to pay and ship items.

The future shopping service will become a fully Personalised Assistant. Such future services will place stringent demands on access network performance.

3.3 Visual Search

Usability has a significant impact on the adoption of the mobile internet. Google's Nexus One smartphone, for example, incorporates single click video uploads to YouTube. But text input on these devices is still a limitation and the difficulty of inputting lengthy URLs is a barrier for many potentially powerful mobile internet services.

However, most smartphones incorporate cameras and these can provide an elegant solution to this problem.

T-Systems Enterprise and Deutsche Telekom Laboratories have developed a comprehensive mobile application framework called Visual Search which uses the built-in camera of the mobile device as a visual input channel.[20] Visual Search

[19] Pankaj Shroff, Tellabs, http://www.icin.biz/files/slides2009/Shroff.pdf

[20] T. Huynh et al., "*Visual Search: Advancing Mobile Internet Services with Visual Interaction*", in 2009 13th Int. Conf. Intelligence in Next Generation Networks: Beyond the Bit Pipes (ICIN 2009), Bordeaux, France, 2009 © IEEE

provides users with a multi-modal interface for exploring mobile internet services. Simply snap a picture of an object of interest and the system downloads and displays information and services related to the object.

Visual Search is an enabling technology that can complement and enhance existing services of telecom operators. It combines a lightweight mobile client with a modular back-end architecture that allows the delivery of different service and content sources depending on the envisioned usage, recognition technologies and business models.

Visual Search integrates three different recognition technologies in a single and intuitive user interface. Barcode scanning is performed locally on the client and simply involves pointing the phone at a barcode. Image recognition involves taking a picture of an object with the mobile device. Images captured by the mobile client are sent to a server for analysis by an image recognition component and results are returned to the client for display in a browser window. The page scanning module allows users to inspect items printed on catalogue pages in real time. The camera phone acts as a "magic lens", which augments the information on the page with additional information as the user moves across the page.

As with all search applications, low latency is crucial for user satisfaction. Using a 3G link between client and server, the average response time of the Visual Search system is currently between three and 10 seconds, aided by various caching mechanisms. The main bottleneck is the querying of third party services and not, as might be expected, the image recognition.

Visual Search is an example of a service enabled by high throughput, low latency network infrastructures such as HSPA+ or LTE which allows for a range of different business models and revenue streams.

3.4 Rich Communication Suite

The Rich Communication Suite (RCS) is a collaborative effort within the GSM Association (GSMA) intended to accelerate the deployment of IMS-based services. It is currently supported by over 80 companies including 28 operators representing approximately 1.8 billion global connections. A current RCS initiative, chaired by Orange, is working to ensure worldwide end-to-end interoperability of rich multimedia communication services – services that use more than just voice for communication. Operator members of this initiative commit to deploy IMS and launch the same set of IMS-based rich communication services.[21]

Without end-to-end interoperability between operators, devices and networks, the deployment of rich multimedia communication services makes little sense. Services that only work on specific clients or devices have a limited appeal. Services that only work on particular network technologies or brands experience low take-up rates.

Genuinely interoperable services, on the other hand, can achieve huge success. When SMS was being developed it was regarded primarily as a machine-to-person service, alerting subscribers that voice mails had been received. Although person-to-person messaging was possible and was universally enabled in GSM handsets, few envisaged it as a potential commercial service. But it was adopted avidly by the consumer market. Following the eventual introduction of interoperability, SMS today generates around $100 billion annually for mobile network operators.

21 K. Henry et al., "*Rich Communication Suite: A convergent multimedia communication service over IMS*", in 2009 13th Int. Conf. Intelligence in Next Generation Networks: Beyond the Bit Pipes (ICIN 2009), Bordeaux, France, 2009 © IEEE

Interoperability should be seen as a prerequisite for the commercial introduction of a new convergent communication suite such as RCS for the mass market. The IMS core network provides a powerful infrastructure for the deployment of such an innovative suite as it addresses both mobile and internet access. As the underlying service platform, IMS takes care of issues such as authentication, authorisation, registration, charging and routing.

RCS is built around a phonebook with easy sharing of content without the need for log in or passwords and enables communication capabilities such as instant messaging, video sharing and buddy lists. Main features include:
- Enhanced Phonebook, with service capabilities and presence-enhanced contact information
- Enhanced Messaging, which enables a large variety of messaging options including group communication in chat mode, messaging history and file transfer
- Enriched Call, which enables multimedia content sharing during a voice call

The enriched call feature allows users to share pre-recorded or live videos or images during a circuit-switched voice call.

The commercial deployment of RCS by several operators all over the world has the potential to repeat the success of SMS. This is supported by the recent experience of SKT in Korea who responded to SMS market saturation by introducing a number of innovative IM-based services with (eventually) some 60% of phones having the application embedded. When interoperability between the three Korean operators was introduced the take-up of services was astonishing.

Given the potential traffic volumes that RCS could generate it seems clear that assessing the impact of technology platforms such as HSPA and LTE should be a priority for the RCS initiative.

On top of this the voice service will evolve to Hi-Fi speech, high definition video communication services for enterprise and residential markets will be launched, and the general telephony service will evolve to include visual and interactive call-back as well as visual calling line identification.

3.5 Quality of Service

Interactive real-time applications such as streaming media and online gaming are predicted to be both a significant generator of traffic and a meaningful source of revenue. But these applications demand high QoS which is notoriously difficult to guarantee across interconnected networks and almost impossible over the best effort architecture of the internet.

IMS networks provide a solution for guaranteeing QoS on networks where the transport layer is controlled by the operator. But in the case of the nomadic user community typically found with online games, the transport layer is the internet and providing QoS remains a challenging task.

Orange Labs together with the University of California, Irvine have developed a mechanism which allows extending IMS service delivery to the internet using a distributed and scalable overlay network that does not require dedicated hardware for system resource management.[22]

Dubbed Advanced Quality of Service (AQoS), the solution aims at dynamically providing alternate high-bandwidth routes on the internet using overlay network measurements to improve connection QoS. AQoS uses latency and bandwidth information gathered by participating nodes and selects routes that exhibit better

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[22] E. Cauich et al., "*Advanced Quality of Service (AQoS): An Overlay Network Mechanism to Improve Service Delivery*", in 2009 13th Int. Conf. Intelligence in Next Generation Networks: Beyond the Bit Pipes (ICIN 2009), Bordeaux, France, 2009 © IEEE

QoS than the default routes provided by the internet backbone. The knowledge of the internet acquired through AQoS makes it possible for the participating nodes to estimate the achievable QoS and adapt IMS services accordingly through SDP negotiation.

Nomadic users can benefit from this routing mechanism which will make it possible to offer IMS-based bandwidth-sensitive multimedia applications on the internet with prior negotiations of the achievable QoS. Operators deploying IMS will benefit from the ability to extend the reach of interactive real-time applications beyond the boundaries of their own networks.

But connection QoS is only part of the picture. The industry is moving beyond traditional QoS and adopting a more holistic understanding of quality as perceived by end users – the ultimate judges of service quality. Such a shift towards Quality of Experience (QoE) raises fundamental questions concerning which QoS parameters are truly relevant to users of a given service class, how these parameters can be measured and which quality levels actually define a satisfying user experience. The link between technical network parameters and the customer's QoE is an active area of research.[23]

3.6 Connected devices

Today, in 2010, mobile internet is a fact. Over 25% of the world's population – about two billion people – are using the internet. Over 60% of the world's population – about five billion people – are mobile subscribers.

And the variety of mobile-enabled devices is exploding, making the mobile internet opportunity broader than just smartphones, netbooks and laptops bundled with embedded mobile connectivity. By 2013 there could be over ten billion devices with mobile internet connectivity, including wireless home appliances, e-books, connected digital photo frames, home monitoring products, and car electronics.[24]

But the really big numbers are associated with much smaller items. There are predictions of one billion mobile wallets by 2015, accounting for 90% of mobile transactions for goods and services and hundreds of billions of RFID-tagged objects, at approximately five cents per tag.[25] By 2020 the so-called internet-of-things could entail 50-70 billion 'machines' with 250 embedded wireless devices/user.

Ericsson has stated that whereas laptops and advanced handsets are connected today, in the future everything that will benefit from being connected will be connected. They are predicting 50 billion connections by 2020 (Figure 6). These connected devices and the signalling traffic they will generate will be a challenge for all-IP networks such as LTE.

23 http://www.ftw.at/research-innovation/projects/ace

24 *Economy + Internet Trends*, Mary Meeker, Morgan Stanley, Web 2.0 Summit, October 2009

25 L. Trappeniers et al., "*Towards Abundant DiY Service Creativity*", in 2009 13th Int. Conf. Intelligence in Next Generation Networks: Beyond the Bit Pipes (ICIN 2009), Bordeaux, France, 2009 © IEEE

These mechanisms focus on operational cost reductions and include managed network services, network sharing, and consolidation. They acknowledge that the spectral efficiency gains provided by new wireless technologies may be unable to bridge the growing gap between costs and revenues as mobile data volumes continue to increase.

Managed network services and infrastructure outsourcing has recently been adopted by major operators such as Vodafone, Telefónica, and T-Mobile. While the commercial imperative to adopt such measures depends heavily on local market conditions, operators in some regions no longer regard owning and operating networks as being among their core competencies. Instead they are increasingly focused on developing and selling services and content, while outsourcing their infrastructures to vendors such as Alcatel-Lucent, Ericsson, and Nokia Siemens Networks.

Network sharing at the passive infrastructure level has become increasingly common and RAN sharing at the active infrastructure level is fast becoming a major trend in 3G networks worldwide. Regulatory antipathy towards network sharing has softened and multi-operator RAN sharing could result in capex and opex savings of as much as $60 billion worldwide over the next five years according to ABI Research.[30] Active RAN sharing can produce cost savings for operators of at least 40% in addition to those available from passive site sharing.

Consolidation is not restricted to vendors but is also increasingly taking place amongst mobile network operators, the joint venture between T-Mobile and Orange in the UK being a recent example. Mergers and acquisitions are dramatically changing the structure and dynamics of the mobile industry.

But these mechanisms do not preclude the three traditional routes that operators have taken to expand network capacity: adding more cell sites, increasing spectral efficiency, and deployment of additional spectrum.

4.2 Cell splitting

Adding more cell sites to keep pace with an increase in traffic has been a commonly used technique that plays to the essence of cellular – the efficient reuse of spectrum. The smaller the cell, the greater the capacity per unit area. As network traffic has grown, operators have frequently deployed microcells and picocells to augment coverage in localised areas and offload capacity from macrocells. But there are practical limits to this process: adding more base stations can be time consuming and costly particularly if new sites have to be acquired. Upgrading technologies to enhance spectral efficiency can be a viable alternative, especially if existing cell sites can be used.

Femtocells can be seen as a variation on the spectrum reuse theme, not only providing highly localised indoor coverage but also offloading traffic onto the fixed networks through subscribers' broadband connections. Femtocell solutions have to manage interference issues as well as macro/femto and inter-technology handovers. A few commercial systems are currently being trialled.

Dual mode phones using the UMA standard are another way of offloading traffic. Smartphones increasingly include WiFi capabilities and are capable of diverting significant volumes of traffic away from cellular networks. Of more than 2,300 HSPA devices on the market in April 2010, the proportion incorporating WiFi connectivity had grown by 44% since October 2009.[31]

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30 *Active Sharing versus Passive Sharing, Deployment Challenges and Market Activity*, ABI Research, 2009

31 GSA press release, April 2010

4.3 New technologies for spectral efficiency

Increasing spectral efficiency involves either phased upgrades to existing systems or the deployment of new wireless technologies. The options available are commonly assessed by comparing peak data rates, as illustrated in Figure 7.

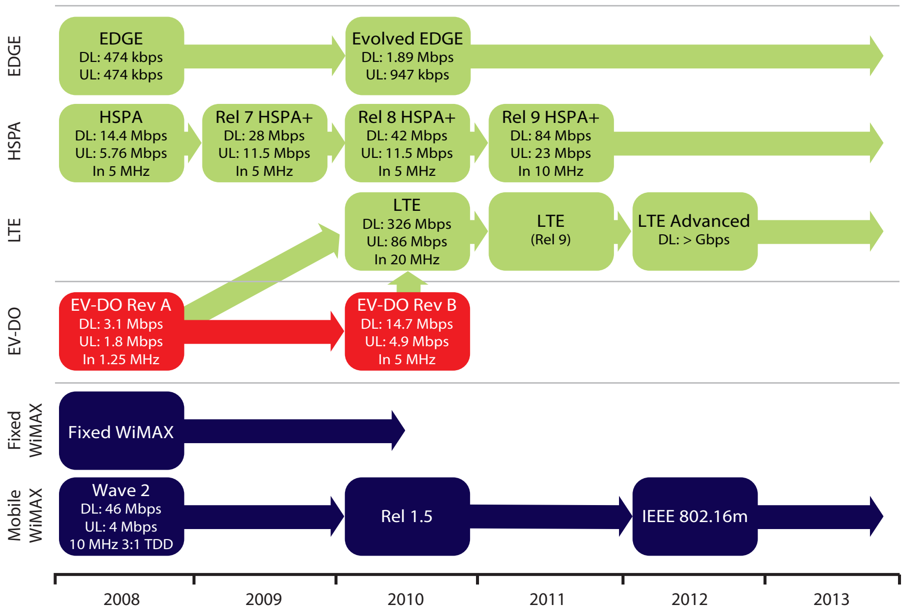

Figure 7: Evolution of TDMA, CDMA and OFDMA systems
Source: Rysavy Research

Most 3GPP standards evolve through a set of phased releases to deliver enhanced capabilities that take advantage of the continual evolution of technology. The HSPA standard delivers peak data rates of between 3.6 and 14.4 Mbps according to which release of the standard has been implemented, corresponding to typical user download data throughputs of between 0.8 and 5.0 Mbps depending on network and user device capabilities.

HSPA+ refers to the set of HSPA enhancements that are defined in 3GPP beyond Release 6. HSPA+ doubles the data capacity over HSPA with up to 28 Mbps theoretical downlink data rates on a 5 MHz carrier in Release 7 and up to 42 Mbps in Release 8.

HSPA+ R9 and beyond involves enhancements such as expanding HSPA+ multicarrier beyond 10 MHz deployments combined with MIMO to provide peak rates of 84 Mbps and more.[32]

LTE is designed to deliver significantly higher levels of capability and performance and will co-exist with the WCDMA and HSPA networks that will also continue to evolve within 3GPP. LTE is scalable to allow operation in a wide range of spectrum bandwidths from 1.4 to 20 MHz and introduces a new radio interface technology based on OFDM (Orthogonal Frequency Division Multiplexing) and a flatter access network designed to deliver over 320 Mbps throughput and fast connection times. The LTE/SAE Trial Initiative has already demonstrated that LTE data rate and latency performance meets or exceeds the requirements established by 3GPP and the NGMN Alliance.[33]

32 *HSPA+ for Enhanced Mobile Broadband*, Qualcomm, February 2009

33 *Update from the LTE/SAE Trial Initiative*, Martin Ljungberg, LTE Forum, Lisbon, October 2009

Commercial deployments of LTE networks have started and will accelerate through 2010. LTE and its continuous enhancements will be capable of delivering the compelling user experience demanded by mobile broadband applications and services for many years to come. The LTE decade has begun.

Planning has already started for the next generation. LTE Release 10 and beyond (LTE-Advanced) is one of the candidates for the future IMT-Advanced system that is targeting peak data rates of 100 Mbps for high mobility and 1 Gbps for low mobility.[34] The ITU's ongoing evaluation process will ultimately result in recommendations for this next generation of networks that could be commercially available towards the end of the decade. Such networks will be able to deliver both fixed and mobile broadband with capabilities for spectrum aggregation and improved performance at all levels including QoS. LTE networks will support LTE-Advanced through software upgrades similar to the multicarrier enhancements through which HSPA evolved into HSPA+.

Peak data rates by themselves are not a reliable measure of performance for an operator or an adequate indicator of service quality for end users. When comparing technology options operators need to consider average sector throughput, latency, spectral efficiency and cost per megabit. These are the factors that most impact the all-important measure: the user experience.

The essential figure that defines the user experience is the average sector throughput – the data rate that can be realistically achieved in serving all subscribers in a typical sector – which varies significantly with available bandwidth (Figure 8).

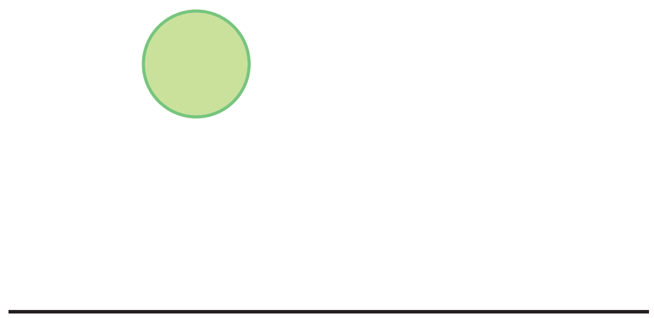

Figure 8: Average sector throughput for HSPA, HSPA+ and LTE
Source: Motorola

With LTE, in addition to increased throughput, lower latency will provide a noticeable improvement in the user experience. According to Motorola, with HSPA networks, a user can expect a two second or longer delay to set up the first

[34] Systems that meet all of the ITU's IMT-Advanced requirements are regarded by the ITU as the successor to 3G systems and so could be nominated as 4G systems. No such systems exist today and none are likely to be in commercial operation until near the end of the decade.

Device availability for LTE has been expected to be dominated by PC cards and modems initially, followed by smartphones and then volume availability of handsets (Figure 9). This may well change if the current massive surge of video traffic from smartphones continues.

Figure 9: LTE devices roadmap
Source: IDATE

Other issues arise with the deployment of LTE as a data-only network. Over-the-top VoIP services could well challenge the mobile network operator's own voice services as they have done to network operators in the fixed environment. Users of LTE data connections, including VoIP applications on smartphones, will expect the same global roaming capabilities that they enjoy today over 2G and 3G networks. VoIP over LTE roaming is a user expectation that cannot be ignored and is now being addressed by the VoLTE initiative to assure a smooth migration to LTE voice services with global roaming.

LTE will initially be deployed in dense urban areas and hot spots and then rolled out further as demand requires. Upgrading networks to the next phase progressively is possible with 3GPP standards because of their backward compatibility. Most deployment scenarios involve multiple technologies in different combinations across different geographies in a single network. Multiple standards are therefore in operation for a significant period ensuring continuity of service and coverage.

LTE is incredibly flexible in this respect. Most previous technologies only included interoperability with their predecessors. LTE, in contrast, is able to co-exist with at least 15 other networks (Figure 10).

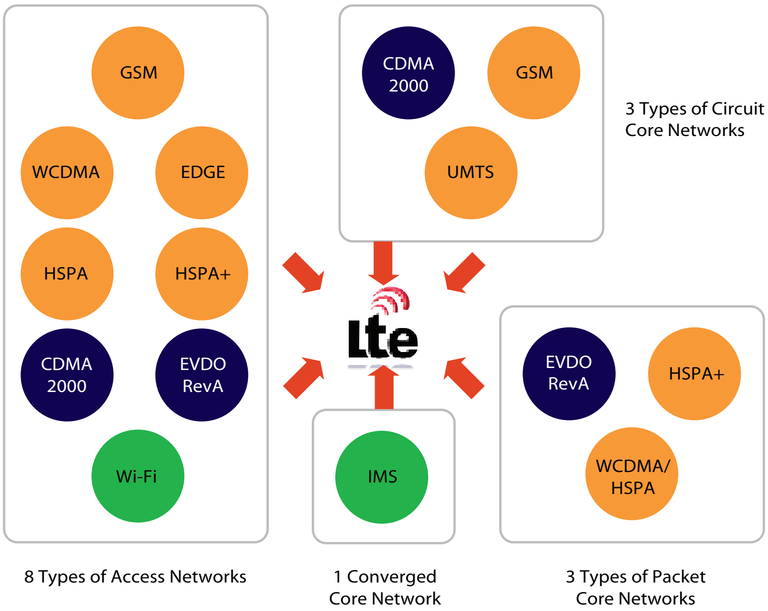

Figure 10: LTE network interoperability
Source: Aricent

LTE spans multiple networks that were never really designed to work together, not only increasing flexibility but also the complexity of end-to-end functionality testing.[38]

Improving spectral efficiency through deployment of new technologies is an important tool for creating greater network capacity but it is not a magic solution. There is no longer much room to manoeuvre as systems such as LTE are approaching both theoretical and practical limits to spectral efficiency. Improving spectral efficiency by itself will not be sufficient to address the magnitude of the expected demand for more bandwidth.[39]

4.5 Spectrum requirements

Exploiting new femtocell architectures and deploying enhanced or new technologies to engineer greater spectral efficiency will increase capacity and reduce costs. But that can only be an interim and partial solution given that we are nearing the technological limits of capacity in existing spectrum allocations. More licensed spectrum will soon be required to enable operators to satisfy the consumer appetite for mobile broadband.

The need to add incremental spectrum over time has long been recognised and quantified. A major exercise conducted by ITU-R Study Group 8 in 2006 – in which the UMTS Forum played a significant role – collated a range of detailed forecasts of mobile broadband traffic across all service categories to estimate spectrum requirements over the next decade.

For the theoretical case of a single network per country the ITU estimated that, for a country that had developed mobile capabilities early, a total of 840 MHz of spectrum would be required by 2010, 1300 MHz by 2015, and 1720 MHz by 2020.[40] These bandwidth requirements are minimum values – more spectrum is required in real world situations where countries have multiple networks. Subsequent review of the ITU projections by the Next Generation Mobile Networks Alliance led to estimates that an additional 500 MHz to 1 GHz of spectrum beyond current allocations would be required, depending on region.[41]

38 *LTE: Beyond the Numbers*, Aricent, 2009

39 *Mobile Broadband Spectrum Demand*, Rysavy Research, December 2008

40 *Estimated Spectrum Bandwidth Requirements for the Future Development of IMT-2000 and IMT-Advanced*, International Telecommunication Union, Report ITU-R M.2079, 2006

41 *Spectrum Requirements for the Next Generation of Mobile Networks*, Next Generation Mobile Networks Alliance, 2007

The amount of additional spectrum that has actually been identified to date for licensed commercial use falls well below these recommendations and varies significantly from country to country (Figure 11).[42]

Figure 11: Spectrum pipeline
Source: CTIA estimates

In the USA, this situation has led the Chairman of the FCC to state "the biggest threat to the future of mobile in America is the looming spectrum crisis".[43] The CTIA is asking US policymakers to launch a process to bring at least 800 MHz of additional spectrum to market for licensed commercial wireless services. The FCC has responded positively and its national broadband plan (April 2010) has called for freeing up 500 MHz of spectrum over the next decade for broadband use. Of this, 300 MHz between the 225 MHz and 3.7 GHz bands should be made available for mobile within five years.

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42 *Ex Parte* Letter from Christopher Guttman-McCabe, V.P., Regulatory Affairs, CTIA – The Wireless Ass'n, to Chairman Julius Genachowski, and Commissioners Copps, McDowell, Clyburn, and Baker, Federal Communications Commission, GN Docket No. 09-51 (filed Sept. 29, 2009)

43 http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-293891A1.pdf

44 Often referred to as the 2.5 GHz band in the Americas

The 2.6 GHz band is of particular interest. The ITU's World Radiocommunication Conference in 2007 (WRC-07) placed limits on satellite systems using this band, allocating it on a primary basis for terrestrial mobile communications in all three ITU regions. The 2.6 GHz band contains a substantial amount of spectrum and is in a unique position to be exploited as a common band for commercial mobile broadband access services on a global basis.[45]

The 2.6 GHz band offers operators the opportunity of obtaining the highest spectral efficiency and highest throughputs from LTE by deploying large bandwidth channels in 20 MHz of contiguous spectrum.

The 2.6 GHz band in the USA was licensed for terrestrial applications other than mobile communications before its international WRC allocation. A large part of the band (120 MHz) is now being used for mobile communications by Sprint Nextel and Clearwire who are deploying mobile WiMAX.

Other operators in the USA such as Verizon Wireless and AT&T Mobility will deploy LTE at 700 MHz in digital dividend spectrum and in the Advanced Wireless Services (AWS) band (1710-1755 MHz paired with 2110-2155 MHz) where they have significant nationwide allocations.

In Europe, licences have already been awarded in the 2.6 GHz band in Norway, Sweden, Belgium, Finland and Germany but licensing in other European countries has been delayed by legal actions from operators and uncertainties over the band plan.

The legal actions reflect the difficulties of designing an equitable and acceptable licensing process when existing operators have markedly different spectrum holdings acquired at varying times under differing market conditions.

The ITU has not yet decided how the 190 MHz available in the 2.6 GHz band plan should be distributed between paired spectrum for FDD operation and unpaired spectrum suited for TDD modes. However the 2 x 70 MHz FDD + 50 MHz TDD scheme currently attracts the most interest.

The LTE ecosystem supports FDD and TDD operation. Fifteen paired and eight unpaired spectrum bands have already been identified by 3GPP for LTE.[46] Yet deployment of TDD systems and usage of existing licensed TDD spectrum in 3G networks has been minimal and recent prices paid for TDD spectrum have been far below those paid for FDD.

But there is renewed interest in TDD following China Mobile's current deployment of TD-SCDMA with plans to eventually migrate to the TDD version of LTE. The decision has now been made to combine FDD and TDD modes to create a unified LTE standard.

The convergence of FDD and TDD in a single chip will enhance the possibilities of seamless global roaming using a single LTE terminal. About 200 MHz of TDD spectrum could be available globally: 100 MHz in the 2.3 GHz band identified at WRC-07, about 40 MHz in the 1900 MHz 3G core band, and potentially 50 MHz in the 2.6 GHz band, depending on the eventual band plan.

Below 1 GHz, spectrum released by the switch from analogue TV broadcasting to more spectrally-efficient digital TV transmission – the so-called digital dividend – is of particular interest because of its superior coverage and in-building penetration. Some digital dividend spectrum has already been auctioned in the

45 *The 2.6 GHz Spectrum Band*, Global View Partners, December 2009

46 *3GPP TDD for LTE Spectrum in the Americas*, 3G Americas, November 2009

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6 Acronyms

3GPP	Third Generation Partnership Project
3GPP2	Third Generation Partnership Project 2
API	Application Programming Interface
AWS	Advanced Wireless Services
CDMA	Code Division Multiple Access
CS	Circuit-Switched
DiY	Do it Yourself
DSL	Digital Subscriber Line
EDGE	Enhanced Data Rates for Global Evolution
EV-DO	Evolution, Data Optimised
FCC	Federal Communications Commission
FDD	Frequency Division Duplex
FTTH	Fibre to the Home
GDP	Gross Domestic Product
GSA	Global mobile Suppliers Association
GSM	Global System for Mobile communication
GSMA	GSM Association
HSPA	High Speed Packet Access
HSPA+	HSPA Evolution
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
IEEE	Institute of Electrical and Electronic Engineers
IM	Instant Messaging
IMS	IP Multimedia Subsystem
IMT	International Mobile Telecommunications
IP	Internet Protocol
ITU	International Telecommunication Union
LTE	Long Term Evolution
MIMO	Multiple Input, Multiple Output
NGMN	Next Generation Mobile Networks
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
OTT	Over the Top
PC	Personal Computer
PS	Packet-Switched
QoS	Quality of Service
RAN	Radio Access Network
RCS	Rich Communication Suite
REST	Representational State Transfer
RFID	Radio Frequency Identification
SAE	System Architecture Evolution
SDK	Software Development Kit
SDP	Service Delivery Platform
SMS	Short Message Service
SOAP	Simple Object Access Protocol
SON	Self-Organising Network
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
TV	Television
UMA	Unlicensed Mobile Access
UMTS	Universal Mobile Telecommunications System
URL	Uniform Resource Locator
USB	Universal Serial Bus
VoIP	Voice over IP
VoLGA	Voice over LTE via Generic Access
WCDMA	Wideband CDMA
WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WRC-07	World Radiocommunication Conference 2007

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