Market Outlook for LTE

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Abstract

With true wireless broadband uptake, ٣GPP is working on the evolution of mobile radio access networks which target capacity and data rate enhancements beyond HSPA to meet the future demand of the traffic growth and services.

The purpose of this paper is to provide a clear understanding of the potential for Long Term Evolution (LTE) technology. This includes an assessment of the technology issues involved, subscriber forecasts, likely deployment scenarios and finally provides some remarks to be considered by the operators when addressing the LTE opportunity.

Introduction

Generally, a ٤G technology is one that is expected to meet the requirements of the International Telecommunications Union Radio Sector's (ITU-R) IMT-Advanced. Technologies seek to fulfill the ITU requirements so that they are legitimate contenders for spectrum. Those technologies that are ٣G technologies meet the requirements of the IMT-٢٠٠٠.

In ٢٠٠٧, it was believed that IMT-Advanced would essentially require technologies to have an all-IP architecture, be OFDM-based, and also provide for ١٠٠Mbps while in motion and ١Gbps while stationary. The three technologies of ٨٠٢.١٦m WiMAX, LTE, and UMB fit the bill for these requirements. As ٢٠٠٧ ended and ٢٠٠٨ has progressed, the following major changes in this ٤G landscape have occurred:

- UMB has essentially disappeared from the running, mainly due to Verizon Wireless, one of CDMA's main champions, publicly announcing its support of LTE. And, consequently, the CDMA Development Group, UMB's main advocate, declared that it was now agnostic on a next-generation mobile broadband technology, and would work to aid CDMA network operators migrate to their technology of choice.
- The ٣GPP, the standards body behind LTE and the GSM family of standards, has started work on LTE Advanced, a standard that will incorporate features into the first version of LTE to help it achieve the desired ١٠٠Mbps mobile throughput and ١Gbps stationary throughput; it has become evident that the first version of LTE will not be able to achieve these extremely high throughputs. Additionally, LTE proponents want to get the ball rolling for the launch of commercial LTE networks in the ٢٠٠٩/٢٠١٠ timeframe, to counter ٨٠٢.١٦e WiMAX network roll outs that have already started. LTE proponents did not want to delay trials by attempting to re-work the original version of LTE to meet the requirements of IMT-Advanced. In fact, it is expected that LTE will be submitted to the ITU for consideration as a technology that meets the IMT-٢٠٠٠ requirements so it can be formally declared a ٣G standard and be a legitimate spectrum contender.

٨٠٢.١٦e WiMAX was accepted by the ITU as fulfilling the requirements of IMT-٢٠٠٠, making ٨٠٢.١٦e WiMAX a formal ٣G technology and a legitimate contender for IMT spectrum. The IEEE is crafting ٨٠٢.١٦m specially to meet the requirements of IMT-Advanced so that ٨٠٢.١٦m can formally be called a ٤G technology.

The combination of these factors has shifted the ٤G landscape a bit, pushing ٨٠٢.١٦e mobile WiMAX and LTE squarely into the ٣G landscape, with many referring to these technologies as ٣.٩G technologies, or pre-٤G technologies. The true ٤G technologies, ٨٠٢.١٦m WiMAX and Advanced LTE, are, thus, not expected to debut until around ٢٠١٢, and perhaps not until ٢٠١٥. (In-Stat, ٢٠٠٨)

In a late summer ٢٠٠٨ meeting of the ITU, it was decided that technology has now moved sufficiently beyond what the ITU calls "enhanced IMT-٢٠٠٠ systems" (including HSPA, ٨٠٢.١٦e WiMAX and EV-DO), and that the selection process of suitable technologies for ٤G can now begin.

The ITU outlined the steps it plans to follow and the timeframe it expects for the process. At the meeting of ITU-R Working Party ٥D on October ٢٠٠٩, companies have submitted proposals for candidate technologies. The proposals were aligned around the ٣GPP's LTE Advanced along with the IEEE's ٨٠٢.١٦m WiMAX. The evaluation of the proposed technologies is expected to extend through ٢٠١٠. In October ٢٠١٠, the ITU plans to make a decision on which systems will meet the requirements of IMT-Advanced.

The ITU maintains that the key features of IMT-Advanced will include the following:

- A high level of common functionality, worldwide, while retaining the flexibility to support a wide range of services and applications in a cost efficient manner
- Compatibility of services within IMT and with fixed networks
- Capability of interworking with other radio access systems
- High-quality mobile services
- User equipment suitable for worldwide use
- User-friendly applications, services, and equipment
- Worldwide roaming capability
- Enhanced peak data rates to support advanced services and applications (١٠٠Mbps for high mobility and ١Gbps for low mobility were established as targets for research)

In order to reach the extremely high throughput requirements, LTE Advanced and ٨٠٢.١٦m WiMAX will likely include the extension of channel sizes to ٤٠MHz and beyond, up to even ١٠٠MHz. Although this kind of spectrum availability is practically impossible for most operators, the channels will have to be this wide to fulfill the theoretical throughput expectations.

Another area that both ٤G technology candidates are addressing is low latency, which pertains to the calling out for high-quality mobile services. Each is focusing on achieving a less than ١٠ millisecond roundtrip delay, and a less than ١٠٠ milliseconds delay to set up a new session.

LTE Technology Overviews

LTE. LTE is the ٣GPP's next-generation OFDMA-based technology, designed as the follow-up to WCDMA/HSPA. LTE, i.e. ٣GPP Release ٨, specification was locked by December ٢٠٠٨. LTE receives a tremendous amount of support from the ٣GPP community, and is also becoming choice of some CDMA mobile operators, like Verizon Wireless.

Some characteristics of LTE include the following:

- LTE's co-existence with legacy standards is often touted as its most attractive feature. Users will, theoretically, be able to transparently start a call or a transfer of data in an area using an LTE standard, and, should coverage be unavailable, continue the operation without any action on their part using GSM/GPRS or WCDMA, or even ٣GPP٢ networks, such as CDMA or EV-DO.
- Another element to LTE is System Architecture Evolution (SAE), which specifies LTE's mobile core network. SAE refers to the access independent, IP-based, flat network architecture with optimized interworking between legacy ٣GPP and ٣GPP٢ networks. This means that both CDMA service providers and GSM/WCDMA service providers will be able to evolve their networks to LTE–SAE. Consequently, LTE offers a simplified network architecture compared to past cellular technologies, where, for instance, WCDMA's radio network controller (RNC) elements are no longer necessary as separate entities, and the base stations are basically directly connected to the evolved packet core network.
- The technology was initially developed to support FDD modulation (most cellular technologies are based on FDD modulation, including WCDMA, HSPA, CDMA٢٠٠٠, and EV-DO), but TDD will also be supported. Although most IMT spectrum is configured for FDD modulation, TDD support is needed to provide for operators with unpaired spectrum capacity. China Mobile has been a primary mover in getting LTE to support TDD. In late ٢٠٠٧, China Mobile proposed what is now known as the "٨+٣ Proposal," which defined a new frame structure that would make a TDD version of LTE compatible not only with China's ٣G TD-SCDMA, but also with FDD LTE. That proposal was the basis for today's TD-LTE specification that the ٣GPP aims to complete by the end of ٢٠٠٨.

- Like WiMAX, LTE utilizes OFDMA on the downlink; however, LTE is different in that it uses single-carrier frequency division multiple access (SC-FDMA) on the uplink. SC-FDMA is technically similar to OFDMA but it is believed to be better suited for uplink from handheld devices due to battery power considerations. OFDMA tends to have a high peak to average power ratio (PAR).
- LTE promises a round-trip latency of data packets (i.e., the time it take to request data and then receive it) of ١٠ms.
- Supported channel bandwidths range from ١.٤MHz to ٢٠MHz.
- LTE promises peak data throughputs of ١٠٠+Mbps in the downlink, and ٥٠+Mbps in the uplink. The standard is promising peak download rates of ٣٢٦.٤Mbps for a ٤x٤ MIMO configuration utilizing a ٢٠MHz spectrum, and ١٧٢.٨Mbps down for a ٢X٢ MIMO configuration using a ٢٠MHz spectrum. A peak upload rate of ٨٦.٤Mbps utilizing ٢٠MHz of spectrum is promised. (UMTS Forum, ٢٠٠٨b)

LTE Advanced. LTE Advanced is the enhanced version of LTE that is being proposed by the ٣GPP. With basic LTE expected to fall quite short of the expected IMT-Advanced throughput requirements of between ١٠٠Mbps while mobile and ١Gbps while stationary, there is much interest in crafting LTE Advanced to meet the requirement of IMT-Advanced. In April ٢٠٠٨, the ٣GPP Technical Specification Group (TSG) Radio Access Networks (RAN) hosted an IMT-Advanced workshop in which over ١٥٠ representatives from network vendors and operators attended.

Some of the main conclusions around LTE Advanced included:

- LTE Advanced must be backwards compatible with LTE, as HSPA is backwards compatible with WCDMA.
- LTE Advanced will need to use channel bandwidths greater than ٢٠MHz as currently standardized for LTE (i.e., ٥٠MHz, ١٠٠MHz). However, for many operators, the consecutive allocation of ١٠٠MHz of spectrum is practically impossible, especially when operators will be supporting several different legacy technologies (HSPA, WCDMA, EV-DO, EDGE, CDMA, and/or GSM, etc.).
- There will need to be an increase in the number of antennas for MIMO beyond what is currently defined for LTE.
- MIMO will be combined with beam forming.
- The voice-over IP capacity will be increased.
- Cell edge data rates will be improved.
- LTE Advanced will offer improvement on the self configuration of the network.

٣G Landscape Today and ٤G Expectations

State of ٣G Today. HSPA networks have been rolling out for some time, with devices really starting to ramp up in the last few years. Throughputs are relatively fast; approaching ٣ to ٧Mbps downstream for many of the leading-edge carriers with HSDPA networks, and up to ٣.١Mbps downstream for EV-DO Rev A deployments.

In China, the only official ٣G standard is TD-SCDMA, with China Mobile starting trials in April ٢٠٠٨. Overall, Chinese operators have been extremely slow in deploying ٣G networks, which is tied to the fact that China wanted to have its own ٣G technology so it would not have to pay the high licensing fees commanded by WCDMA/HSPA or CDMA٢٠٠٠١X EV-DO.

On the CDMA side, it is doubtful that EV-DO Rev B will be deployed by any CDMA operators in the future. So, in the CDMA arena, it looks like EV-DO Rev A will represent the end of the CDMA path for most operators. Some leading-edge CDMA operators have already showed their intent to deploy LTE networks (such as Verizon Wireless, SK Telekom, and KT), and some have already deployed mobile WiMAX networks (KT, SK Telekom, and Sprint). A few have already built out parallel WCDMA/HSPA networks alongside their EV-DO networks, and some have expressed an interest in building out parallel GSM or WCDMA/HSPA networks alongside their CDMA networks. Consequently, the leading edge CDMA operators are expected to move to LTE (or to mobile WiMAX, in some cases) faster than GSM operators, who have more high-throughput options with HSPA (i.e., many levels of HSDPA, HSUPA, and HSPA Evolution).

Meanwhile, on the GSM side, many operators that have already deployed WCDMA/HSPA may want to deploy HSPA Evolution, delaying their uptake of LTE. Whether or not most operators jump to LTE quickly will depend on the operator's current investment in WCDMA/HSPA. Although HSPA Evolution represents a relatively "easy" infrastructure upgrade for operators already running HSDPA/HSUPA, new end devices will be required, and, meanwhile, some operators, like Verizon and NTT DoCoMo, are aggressively planning to build out LTE networks in the ٢٠١٠ timeframe, with Sprint and other S Korean operators already offering mobile WiMAX networks. Other mobile operators will not want to get too far behind in their offerings of next-generation OFDMA-based technologies given that the initial LTE and mobile WIMAX deployments are relatively successful. Additionally, HSPA Evolution doesn't require any more spectrum than HSPA, namely ٥MHz channel bandwidths; the ١٠ to ٢٠MHz channel bandwidth requirements of LTE (in order for LTE to deliver the promised throughputs, anyway) can be difficult for operators to spare.

HSPA Evolution is standardized by the ٣GPP in Release ٧. Specifications within Release ٧ not only provide for features that greatly increase throughputs, but also provide features that provide for lower latency, increased capacity, stronger VoIP support, and enhanced support for multicast services. Release ٨ may include support for multi-operator operation, downlink-optimized broadcast, and more advanced receivers.

There are three main elements to HSPA Evolution: it introduces simpler, IP-centric architecture for the mobile network, bypassing much of the legacy equipment; it provides for theoretical throughputs of up to ٤٢Mbps on the downlink, and up to ١١Mbps on the uplink; and, it provides for a number of connection and performance improvements over HSDPA/HSUPA. The higher order modulation of ٦٤QAM, (compared to ١٦QAM utilized for HSDPA/HSUPA) utilized on the downlink, combined with MIMO, provide for the achievement of such high throughputs. (UMTS Forum, ٢٠٠٨b)

Mobile Operators' Deployment Plans and Challenges. In order to try to determine if, and when, WiMAX and LTE networks will be rolled out, one must look to operator plans for network deployments. Many large, high-profile operators in the US, Western Europe, S Korea, Japan, and China have announced their plans for next-generation mobile broadband network deployments. Most GSM operators have announced their support for LTE, unsurprisingly staying within the large and loyal ٣GPP family. There has been more interest in CDMA operators' choice of LTE versus mobile WiMAX, since UMB has disappeared as a legitimate option. Many of the leading operators throughout the world have publicly announced their intentions.

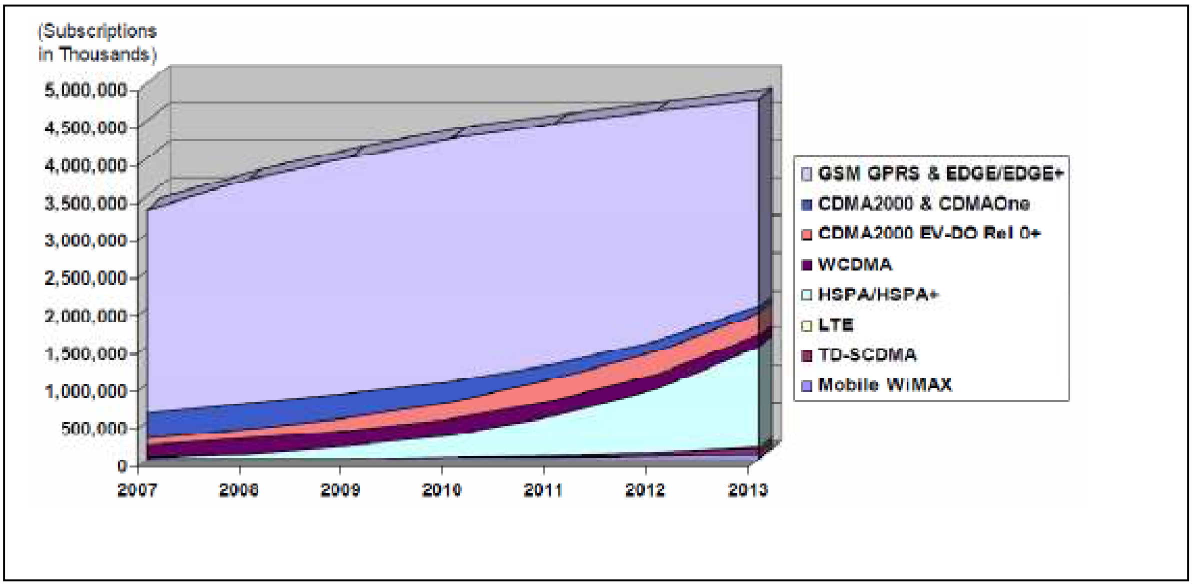
- In the US, the two large CDMA operators have chosen different paths—Sprint has chosen WiMAX and Verizon Wireless has chosen LTE with plans to roll it out commercially in ٢٠١٠. AT&T plans to roll out LTE in the ٢٠١٢ timeframe; the operator wants to evolve its HSPA network as much as possible, and expects to start rolling out HSPA Evolution in ٢٠٠٩.
- T-Mobile remains one of the leading operators that hasn't publicly committed to any one technology. Perhaps the T-Mobile will build out networks for both technologies, depending on the country or region of the network deployment. It is a member of the LTE/SAE Trial Initiative, has conducted LTE demos at technology shows, and has commented that it is working with LTE prototype devices.
- Korean operators, KT and SK Telekom, have publicly embraced LTE as their ٤G technologies, but they also launched ٨٠٢.١٦e WiMAX networks in ٢٠٠٦; it is assumed that they will support both technologies concurrently, as long as their WiMAX subscribers grow profitably. One of KT's best-selling WiMAX client devices is a dual-mode HSPA/mobile WiMAX USB modem. KT and SK Telekom made a big leap away from CDMA when they launched HSPA networks alongside their EV-DO networks in ٢٠٠٦.
- In Japan, NTT DoCoMo plans to rapidly launch LTE in late ٢٠٠٩/٢٠١٠, and has no plans to roll out HSPA Evolution. SoftBank plans to launch HSPA Evolution in ٢٠٠٩, and then launch LTE in the ٢٠١٢/٢٠١٣ timeframe. SoftBank is interested in WiMAX, but didn't get a WiMAX license for ٢.٥GHz. KDDI, however, did get a license for ٢.٥GHz and plans to launch WiMAX in the ٢٠٠٩ timeframe. KDDI, a CDMA/EV-DO operator, also plans to launch LTE in the future as well.
- China Mobile and China Telecom will build out LTE. China Mobile is pushing for deployment of its TDD LTE network in ٢٠١٠, while China Telecom is hoping to launch LTE in ٢٠١١.
- In Europe, most of the major operators plan to launch LTE networks in the ٢٠١٢/٢٠١٣ timeframe. Many of the operators are interested in evolving their HSPA networks as much as possible, and will upgrade to

HSPA Evolution prior to building out LTE networks. Vodafone, France Telecom (Orange), Telecom Italia, and Telefonica all will launch LTE networks. (In-Stat, ٢٠٠٨)

Cellular and Mobile WiMAX Subscription Forecasts

Overall, GSM/GPRS/EDGE is expected to remain dominant through ٢٠١٣. GPRS and EDGE provide bolt-on enhancements to existing GSM networks, allowing operators to enhance their GSM networks without investing in ٣G networks. EDGE promises data throughputs of close to ٢٠٠kbps in favorable conditions. Additionally, evolved EDGE can improve the data rate of GSM networks to a peak theoretical downlink throughput of ١.٢Mbps and a peak uplink throughput of ٤٧٣kbps, while increasing spectral efficiency, capacity, and coverage. Infrastructure vendors can implement most, or all, of the evolved EDGE features with little capital investment because features may be delivered as software upgrades to base stations.

In many parts of the world, ٣G spectrum is just starting to be doled out by countries' telecommunications and regulatory bodies. India, for instance, is in anticipation of government auctions of ٣G spectrum by the December of



٢٠٠٩. In most parts of Central and South America, ٣G has not yet been deployed.

Figure ١: Worldwide Cellular and Mobile WiMAX Subscription Forecasts per Technology, ٢٠٠٧–٢٠١٣ (in Thousands) (Analysys, ٢٠٠٨)

CDMA is expected to remain relatively flat, as a percentage of total worldwide cellular subscriptions, over the forecast period. As the remaining CDMA operators migrate more and more to EV-DO, CDMAOne, and CDMA٢٠٠٠ subscriptions are expected to drop off, with EV-DO subscriptions growing slowly through ٢٠١٢. In ٢٠١٣, EV-DO growth is expected to decrease, as CDMA operators' LTE and/or WiMAX networks begin to ramp up. However, CDMA/EV-DO networks are expected to have quite a long life, as CDMA operators, like Verizon Wireless and Sprint, will rely on CDMA/EV-DO networks to fill in coverage gaps as LTE and/or mobile WiMAX networks are built out.

WCDMA subscriptions are expected to decrease steadily over the forecast period, as most WCDMA operators deploy HSPA, and, consequently, shift to offering more and more HSPA-enabled end-devices.

HSPA is expected to show very healthy growth over the forecast period, as HSPA devices become more prolific and more cost-effective, and operators continue to beef up their HSPA networks. With HSPA, operators have a long path, where HSDPA and HSUPA provide a series of throughput enhancements. And, operators can then choose to deploy HSPA Evolution, which provides for very high throughputs, performance, and connection enhancements on the device side, and also offers operators the ability to flatten out a portion of their core networks in anticipation of migrating to the all-IP LTE.

Mobile WiMAX subscriptions are expected to show moderate growth over the forecast period. As ٢٠٠٧ was the second official year of South Korea's WiBro, overall mobile WiMAX subscriptions were still far fewer than a million. Across the world, mobile WiMAX is having success among service providers that are not mobile operators, many being regional telecommunications providers or multiple service operators. These service providers wish to offer a mobile broadband service, yet don't want to build out a WCDMA/HSPA network, and also don't want to wait for LTE.

LTE's first commercial roll-out is expected to begin in ٢٠١٠ in Japan, by NTT DoCoMo. NTT DoCoMo has led many development projects and trials around the technology over the years. In ٢٠١٠, Verizon Wireless plans to launch its commercial LTE network, and China Mobile is hoping to launch an LTE network the same year.

Overall, mobile WiMAX has a lead over LTE in the ٥-year forecast period, mainly due to timing. Mobile WiMAX deployments started in ٢٠٠٦, with Korea Telecom's launch of its WiBro service and Sprint/Clearwire launched its Xohm mobile WiMAX service in late September ٢٠٠٨. In ٢٠١٣, it is estimated that ١٢٠ million mobile WiMAX-enabled portable device shipments, and ٢٨ million LTE-enabled portable device shipments (see Table ١). (In-Stat, ٢٠٠٨)

Table ١: Total Mobile WiMAX and LTE Portable End-Devices Forecasts, ٢٠٠٨–٢٠١٣ (in Thousands) (In-Stat, ٢٠٠٨)

	٢٠٠٨	٢٠٠٩	٢٠١٠	٢٠١١	٢٠١٢	٢٠١٣
Mobile WiMAX Devices (K)	١,١٢٦	٧,٣٥٠	٢٢,٩٥٧	٤٦,٧٧٤	٧٧,٦٥٢	١١٩,٦٨٢
LTE Portable Devices (K)		١٤	١٩٢	١,٣٩٠	٧,٠١٦	٢٧,٩١٩

Meanwhile, LTE's first commercial deployment is expected in ٢٠١٠, by NTT DoCoMo in Japan and Verizon Wireless. First products are expected to be external clients, such as USB modems and laptop cards, as well as small volumes of handsets. Unlike the first WiMAX products, however, most LTE end-devices will be multimode, able to perform handovers to ٣G and ٢G cellular technologies, depending on which access technology is the most optimal based on the end-user's location. WiMAX devices, like Korea Telecom's offering of dual-mode HSPA/WiMAX USB modems, are expected to help drive shipments, although WiMAX cannot yet handle handovers to cellular technologies.

In the long-run, i.e., in the ٢٠١٥ timeframe, the momentum behind LTE is expected to significantly drive-embedded volumes in handsets, as well as in mobile PCs and other consumer electronics devices.

HSPA is expected to have a significantly long life, with the many versions and the promise of HSPA Evolution, which allows for high throughputs of ٢٠+Mbps without needing new spectrum. This is a primary factor delaying many operators' LTE roll-outs until the ٢٠١٢/٢٠١٣ timeframe.

WiMAX certainly has a varied and interesting line-up of backers: Intel, Sprint/Clearwire, Google, Cablevision, and a line-up of WiMAX chipset providers, and regional service providers. Intel is surely a powerful force in driving a technology's adoption (i.e., Wi-Fi), and its integration of WiMAX into its mobile PC platform is expected to significantly drive volumes of embedded clients. Unlike Intel's success of driving Wi-Fi usage and popularity, end-user utilization of WiMAX requires the end-user to subscribe to a service plan from an operator. This requirement of a service plan has tended to stifle widespread adoption of cellular modems in laptops in the past; however ٣G modem forecasts are promising due to the uptake in modems based on the high throughput technologies. And, one of WiMAX's strong points is its alleged low cost of adding mobile WiMAX to a laptop, which Intel claims to be approximately $٢٠ at this point, and falling rapidly over time.

There is a powerful coalition behind LTE, the main force being the GSM operators' loyalty to the ٣GPP family of standards. Additionally, CDMA operators, like Verizon Wireless in the US, as well as KT and SK Telekom in S Korea, have pledged to support LTE. The only major operator that has embraced WiMAX is Sprint. (UMTS, ٢٠٠٨a)

Conclusions

In conclusion, the following points are observed:

- LTE will provide significant efficiencies over existing ٣G technologies. Mobile providers have expanded their portfolios to include a diverse range of mobile service elements in order to drive both usage and revenue growth. Due to the bandwidth-hungry nature of such services, widespread distribution to consumers is dependent on an effective delivery infrastructure, for which LTE offers the most efficient progression path (at maximum use of the network) with a cost per MB of EUR٠.٠١ for LTE compared to EUR٠.٠٣ for HSPA and EUR٠.٠٦ for W-CDMA. (Analysys, ٢٠٠٨)
- Availability of handsets will drive the service uptake. Large screens, high-quality resolution and long battery lives are amongst the specifications that will enable effective delivery and an enjoyable user experience, especially for the services that LTE will enable more effective distribution. Comments from industry representatives spoken to for the report confirm that there is a need to invest in handset innovation in order to meet commercial launch dates starting in ٢٠١٠.
- Western Europe and Developed Asia are likely to account for the majority of LTE subscribers. These combined regions will account for between ٥٠–٦٠% of subscribers and between ٧٠–٨٠ % of revenues. The contribution from developing markets will continue to increase throughout the period though. (In-Stat, ٢٠٠٨)
- Projections for LTE suggest there is a strong case for deployment in developed markets. The projections indicate that break-even for operators could occur ٣–٤ years following deployment with net present value to the operator being in the order of EUR١–٣ billion. These projections assume that deployment utilizes an operator's existing base stations sites and radio spectrum assets. The case for operators in developing markets is more marginal and is dependent on the competitive environment. (Analysys, ٢٠٠٨)
- Mobile operators wanting to make the most of LTE need to lobby regulators for early access to spectrum at reasonable prices. ٢٠MHz allocations will be essential to achieving the highest throughputs with ٣G LTE. Mobile operators need to lobby for early availability of spectrum (such as the ٣G extension band) and present a convincing case that LTE will be as spectrally efficient as other technologies, to increase the probability of securing spectrum assignment.

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