Abstract

LTE Advanced is a preliminary mobile communication standard. Formally submitted as a candidate 4G system to the ITU-T, it is expected to be completed in 2011. It is being standardized by the 3rd Generation Partnership Project (3GPP) as a major enhancement of the pre-4G 3GPP Long Term Evolution (LTE) standard, which proved to be insufficient to satisfy market's demand.

The 3GPP group has been working on different aspects to improve LTE performance, using for this purpose the framework provided by LTE Advanced, which includes higher order MIMO, carrier aggregation (carriers with multiple components), and heterogeneous networks (relays, picos and femtos).

In this report we will briefly discuss the previous releases as well as the motivations that made this new release possible. Later on, we will see how LTE Advanced solves the problems detected in previous releases and the most relevant aspects of this standard. To end with, we will see which is the actual state of the standard, looking into the stages that have already been accomplished and the ones that are still going on.

Content

Introduction

It seems like only yesterday that the 3G technology finally arrived, and yet it is time to move on. The increasing demand of higher transmission rates, lower latencies and IP-based architecture mobile networks has pushed both the service provider companies and the regulators towards the creation of a technology standard, LTE.

Due to user's demand of new services with high quality of experience and the growth of killer applications like P2P data sharing and video streaming (which consume a very high bandwidth percentage of the total available and can introduce non neglectable jitter), the limits of LTE have been reached and, once more and although LTE is an unknown technology in most countries of the world, it is time to move on to the next stage: LTE-Advanced, the favorite one to become the fourth generation (4G) standard of mobile technologies.

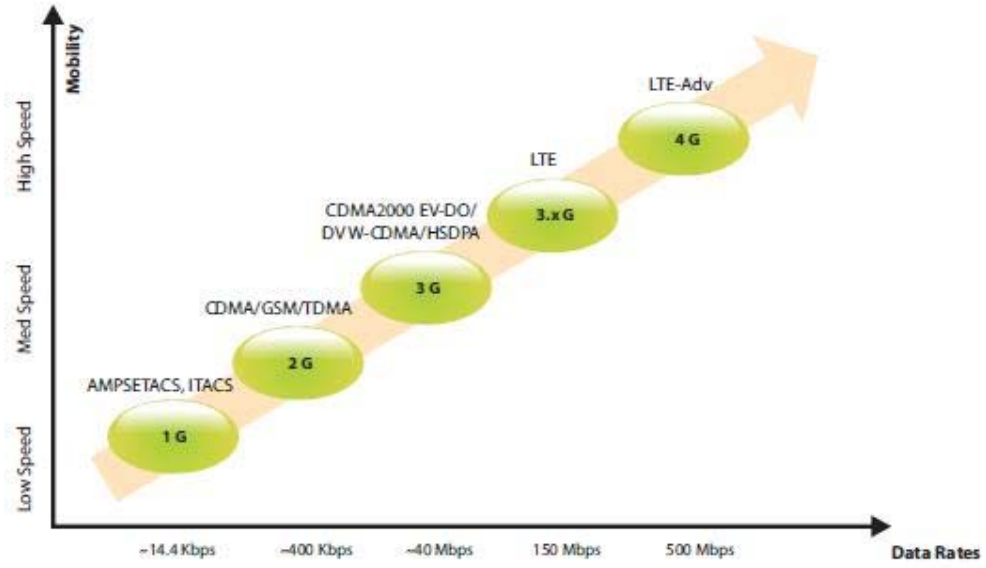

Figure 1. Evolution of radio access technologies [2]

As we can see in the previous figure, each new mobile generation increases the data rate and the mobility in almost an exponential way with respect to the previous standard.

But user's quality of experience demand and the appearance of new killer applications weren't the only motives for the development of LTE-Advanced. Here are three more motives that came from the side of the service providers:

- The wireless data traffic is increasing exponentially. We saw in the previous figure that the bit rates have to increase to deal with the new demands, but the network needs to be adapted to not suffer overcharges.

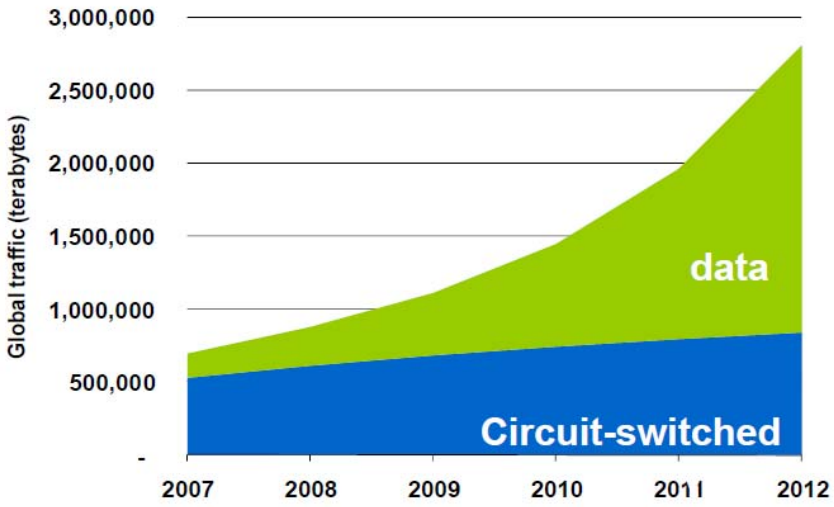

Figure 2. Wireless data traffic increase [3]

- The revenue is growing each time more slowly. There is a necessity from the service providers of lowering the cost of the data transmission. LTE-Advanced enables low-cost deployments and the cost per megabyte will be much smaller than in 3G.

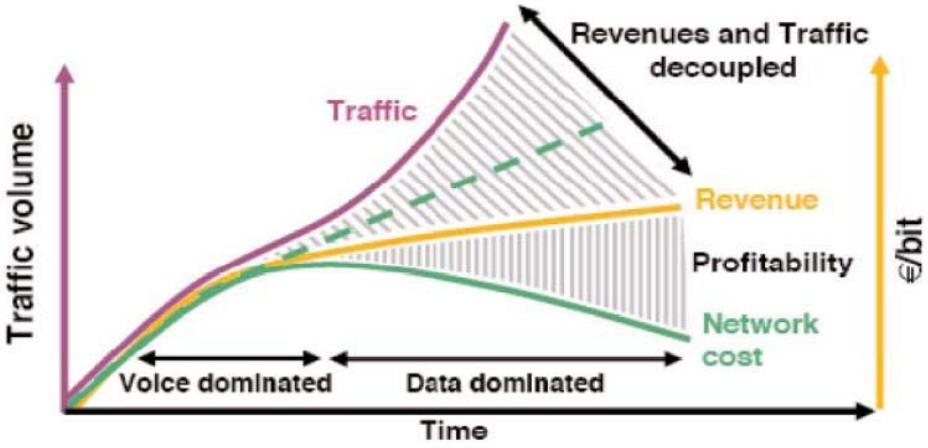

Figure 3. Downsize in the revenue growth [3]

- The radio link improving is reaching the limit. The next step will be using advanced topology networks that will provide benefits like a significantly higher network capacity, an extension of the range of the nodes and the relays will extend coverage and will improve capacity.

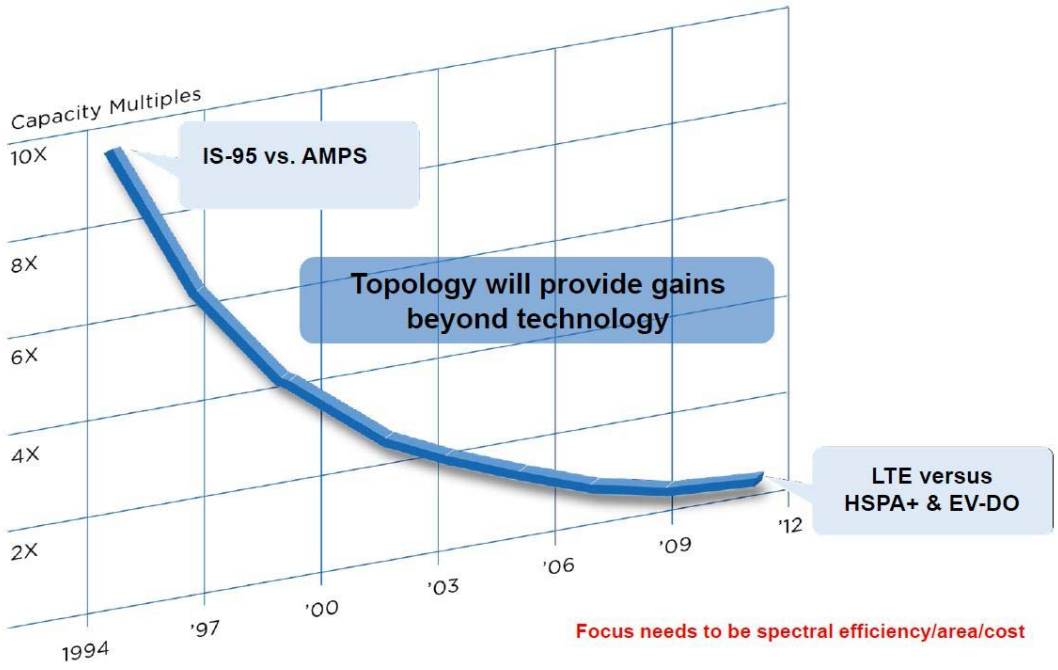

Figure 4. Link improvement reaching the limit [3]

Many service provider (network operators) are already aware of the explosion of the data traffic that is coming and are fully conscious of how quickly the demand of high quality networks (in terms of high capacity, low delays, stable connections and high bit rates) will produce once all the millions of users that now are not technological advanced enough join the mobile communications world. So every operator must ensure he is ready for the exponentially growing traffic incoming demand. And as we have seen before, the only cost-effective way of doing this in the long run is through more efficient technology.

Here is when LTE-Advanced comes into scene. It is important to remark that LTE-Advanced aims to provide a uniform user experience to users located at any point inside a cell by using heterogeneous networks.

New features of LTE-Advanced: from Release 8 to Release 10

LTE is the result of the standardization work done by the 3GPP to achieve a new high speed radio access in the mobile communications frame. It was introduced in the Release 8 in 2008. In 2010 the Release 9 has come to provide some enhancements to LTE and in 2011 Release 10 will bring LTE-Advanced, which will expand the limits and features of Release 8 to meet the requirements of the IMT-Advanced of ITU-R for the fourth generation of mobile technologies (4G), and the future operator and end user's requirements. LTE-Advanced terminals have to be compatible with LTE-Release8 networks and vice versa, LTE-Release 8 terminals have to be compatible with LTE-Advanced networks.

The key measure of LTE is the ability to provide very high bit rates. In addition, it provides high spectral efficiency, very low latency and support of variable bandwidth. Some of the LTE new features are:

- OFDMA, a multi-user version of the modulation scheme called (Orthogonal Frequency-Division Multiplexing) in the downlink. This gives robustness against multipath interference and connects with some advanced techniques also used like MIMO and frequency domain channel-dependent scheduling.

- Single-Carrier FDMA with Dynamic Bandwidth in the uplink. SC-FDMA has lower peak-to-average power ratio (PAPR) which is a major improvement for the user equipment (UE), as it improves the transmission power efficiency.

- Multiple antenna solutions. MIMO (Multiple Input Multiple Output) is probably the most important feature of LTE for improving the data bit rates and the spectral efficiency. It consists on the use of multiple antennas in both the receiver and the transmitter in order to use the multipath effects, which reduces the interference and leads to high transmission rates. MIMO works by dividing the data flow into multiple unique flows, and transmits them in the same radio channel at the same time. They will be merged using an algorithm or special signal processing.

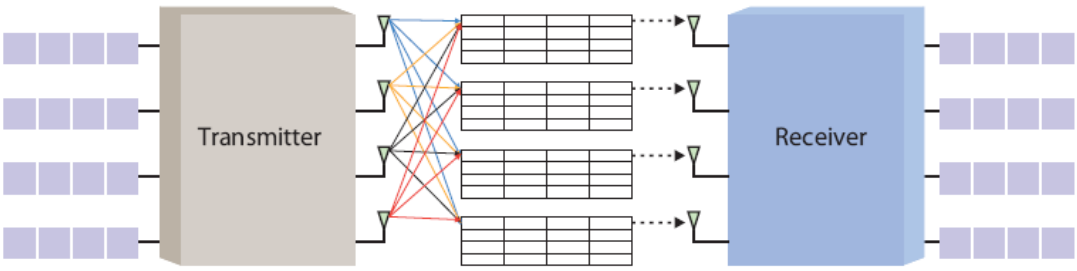

Figure 5. MIMO block

- Very low latency due to a short setup time and small transfer delays. This is a basic feature as many applications, especially the ones related to voice and video transfer, rely on low latency times.

- LTE can support variable bandwidths, in the range between 1.4 and 20MHz.

LTE-Advanced extends the features of LTE in order to exceed or at least meet the IMT-Advanced requirements. It should be a real broadband wireless network that behaves as an advanced fixed network like FTTH (Fiber To The Home) but with better quality of service. It also must fulfil operators' demands like a reduced cost (per Mbit transmitted), compatibility with all 3GPP previous systems and a better service providing in terms of homogeneity, constant quality of the connection and smaller latency.

Here we list some of the LTE-Advanced proposals to achieve the goals of this standard:

- Support of asymmetrical bandwidths and larger bandwidth (maximum of 100MHz). In LTE (release 8), the bandwidth could have different sizes but had to be the same in the downlink and in the uplink. In LTE-Advanced (Release 10) bandwidths can be different because due to actual demand in mobile networks, the traffic from the station to the user is bigger than the one from the user to the station. And they can be as asymmetric as they want within the limit of the 100 MHz LTE-Advanced provides. The sum of both bandwidths (downlink + uplink) cannot exceed 100 MHz. Carrier aggregation to achieve wider bandwidth is a key factor as well as the support of spectrum aggregation, to achieve higher bandwidth transmissions.

- Enhanced multi-antenna transmission techniques. LTE introduced MIMO in the data transmission and LTE-Advanced the MIMO scheme has to be extended to gain spectrum efficiency (which is proportional to the number of antennas used), cell edge performance and average data rates. LTE-Advanced considers a configuration 8x8 in the downlink and 4x4 in the uplink.

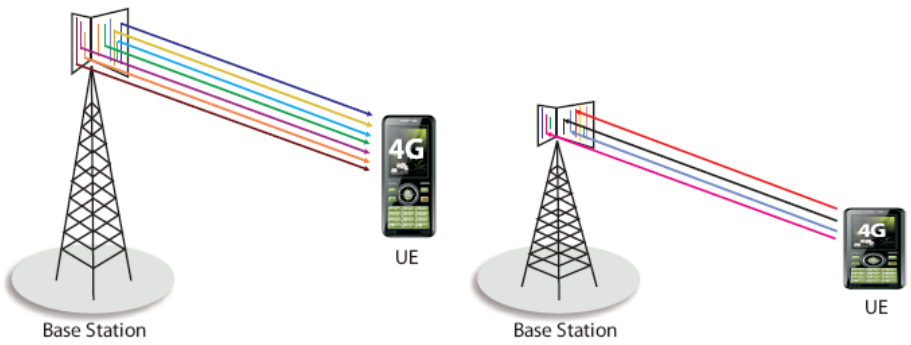

Fig a: DL Direction Fig b: UL Direction

Figure 6. MIMO scheme (8x4) [2]

- Coordinated multipoint transmission and reception (CoMP) which improves the received signal of the user terminal. Both the serving and the neighbour cells are used in a way that the co-channel interference from neighbouring cells is reduced. It implies dynamic coordination between geographically separated transmission points in the downlink and reception at separated points in the uplink. This mechanism will improve the coverage of high data rates and will increase the system bit rate.

- Relaying. Relaying increases the area covered and the capacity of the network. User's mobile devices communicate with the relay node, which communicates with a donor eNB (enhanced Node B, that's 3GPP's term for base stations). Relay nodes can also support higher layer functionality like decoding user data from the donor eNB and re-encoding the data before transmitting it to the user terminal.

  Type 1 relay nodes control their cells with their own cell identity, and among their tasks we can find the transmission of synchronization channels and reference symbols. This type of relays guarantee compatibility with previous releases as it appeared in Release 8 to provide service to Release 8 mobile terminals.

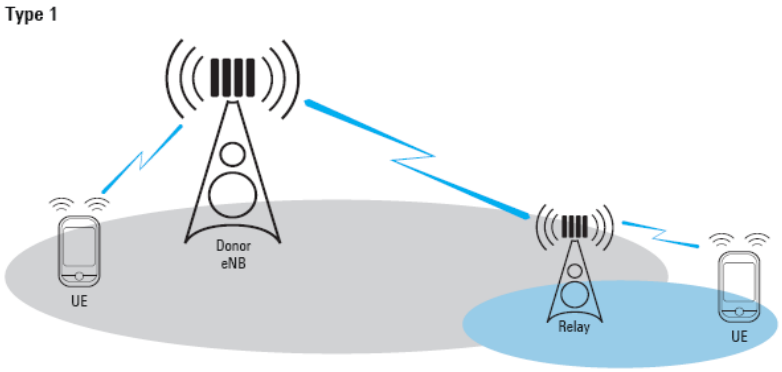

Figure 7. Type 1 relays [4]

Type 2 relay nodes don't own an identity, so the mobile user won't be able to distinguish if a transmission comes from the donor eNB or from the relay. eNBs transmit control data and relays transmit user data.

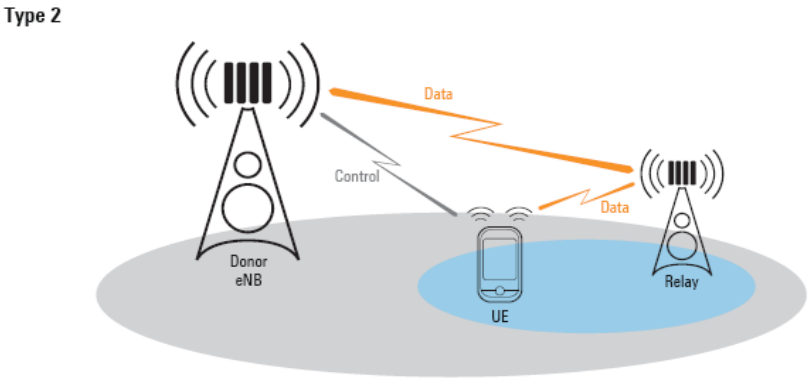

Figure 8. Type 2 relays [4]

There are many others features included in the Release 10, like a deeper reduction of delays, a new enhanced transmission scheme and enhanced techniques to extend the covered area using Remote Radio Requirements (RREs).

The next table will compare different aspects of LTE and LTE-Advanced.

Technology	LTE	LTE--A
Peak data rate Down Link (DL)	150 Mbps	1 Gbps
Peak data rate Up Link (UL)	75 Mbps	500 Mbps
Transmission bandwidth DL	20MHz	100 MHz
Transmission bandwidth UL	20MHz	40 MHz (requirements as defined by ITU)
Mobility	Optimized for low speeds(<15 km/hr) High Performance At speeds up to 120 km/hr Maintain Links at speeds up to 350 km/hr	Same as that in LTE
Coverage	Full performance up to 5 km	a) Same as LTE requirement b) Should be optimized or deployment in local areas/micro cell environments.
Scalable Band Widths	1.3,3, 5, 10, and 20 MHz	Up to 20–100 MHz
Capacity	200 active users per cell in 5 MHz.	3 times higher than that in LTE

Table 1. Differences between LTE and LTE-Advanced [2]

As we can see, LTE-Advanced highly improves LTE specifications. But apart from its superior features, it will increase the benefit for the operators as cost of transmitting information will be reduced and will provide a higher quality of service and a more reliable service.

New network topology

As the radio link can no longer be improved because we are reaching the physical limits, it is time to look in some other direction.

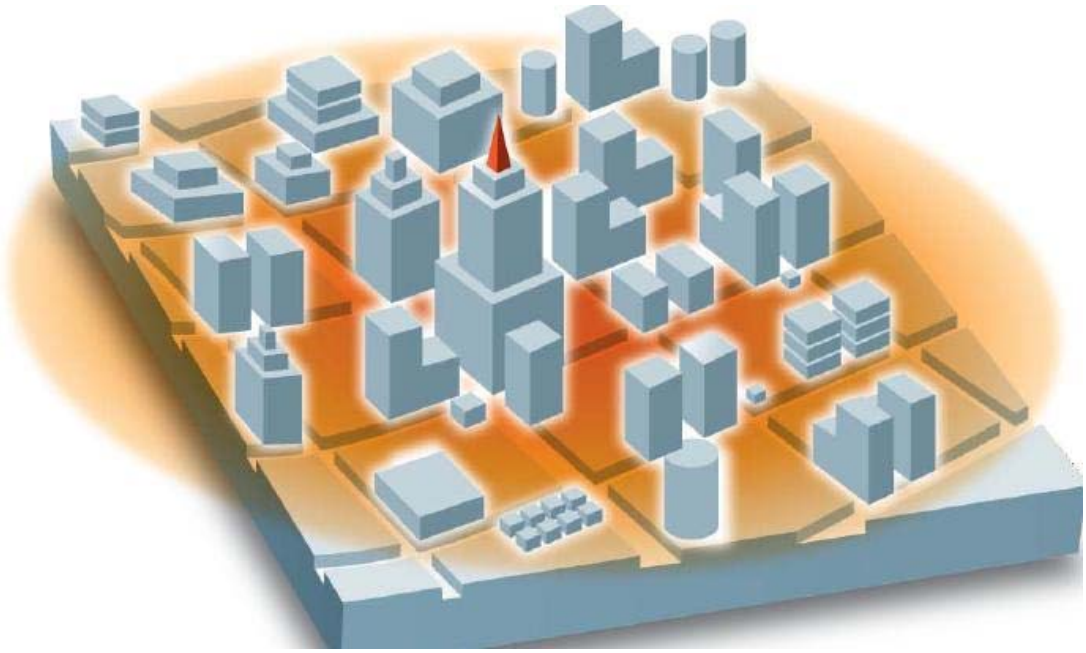

Figure 9. Traditional Macro Network [1]

The traditional network model settles the principles for wide area coverage, but still has to deal with many problems like cell splitting, indoor coverage, changes in the topology of the network, etc.

LTE-Advanced tries to get the network closer to the user to provide a uniform user experience and to increase the capacity of the network. For that purpose, it uses advanced topology networks.

Advanced topology networks provide the benefits and the performance increase we discussed in the previous chapter. Some of the characteristics of this type of networks are [1]:

- They are self-organizing networks; this will minimize the number of Drive Tests for example.
- Intelligent Node Association
- Support for relays
- Adaptive Resource Allocation
- Multicarrier (spectrum aggregation)
- Coordinated Beamforming

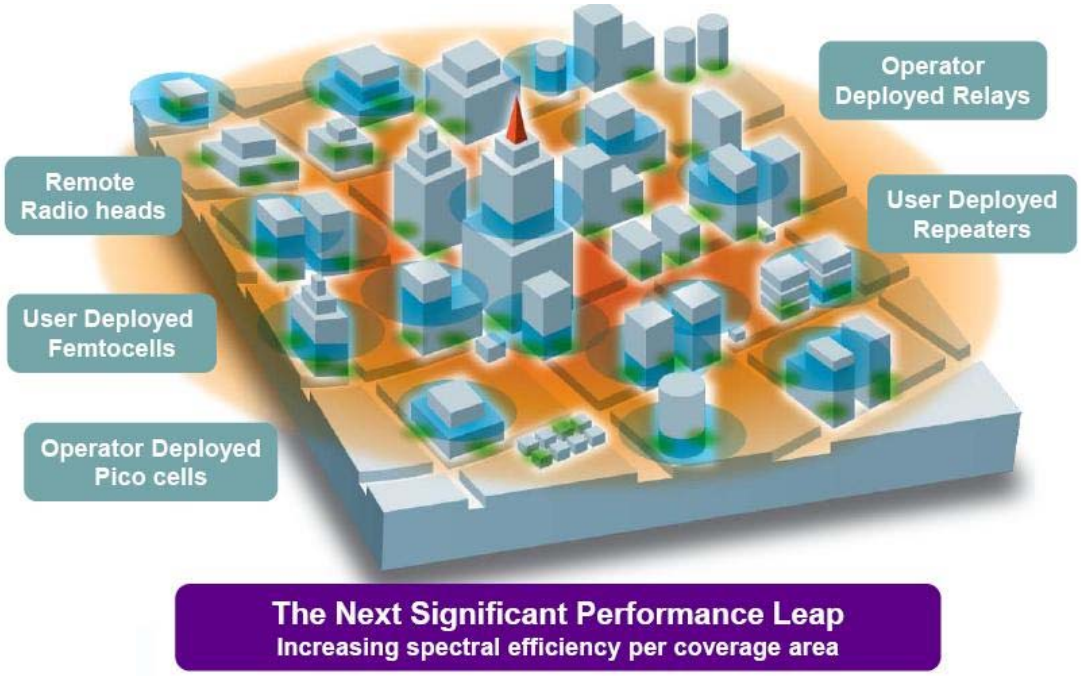

Figure 10. Advanced Topology Networks [1]

With the use of picocells, femtocells and relays we have a much more efficient and uniform network that will provide a higher quality of service to the final user.

Let's consider the scenario in figure 10. This cellular system consists of several macro base stations with a high transmission power (5-40W) while pico, femto and relay base stations are overlaid to the previous macro. These new base stations have a much lower transmission power (100mW-2W). While macro base stations are placed in a planned way, pico, femto and relay base stations are usually placed in a quite unplanned way. The low power base stations can be placed to improve the capacity of the macro cell in certain hot spots and to eliminate coverage holes.

Actual state of the standard

The last steps are being given. In a year time all the stages will be accomplished and the Release 10 will finally see the light.

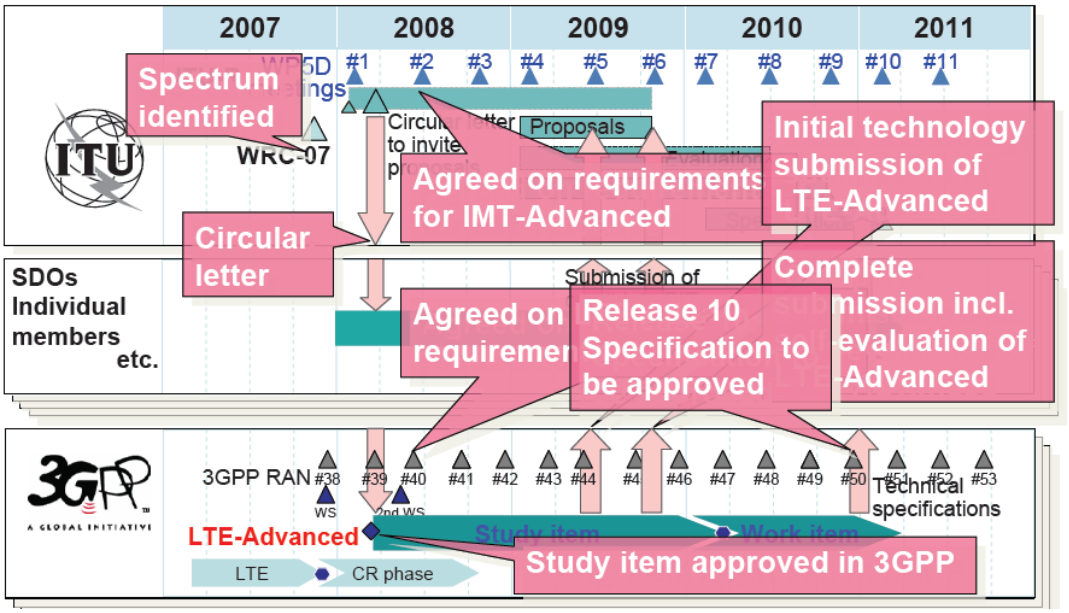

Figure 11. Standardization process [5]

LTE-Advanced is in the middle of the process of acceptation as the new 4G standard. In the year 2011 the IMT will give say whether or not LTE-Advanced meets the requirements to become the next generation standard of mobile technologies.

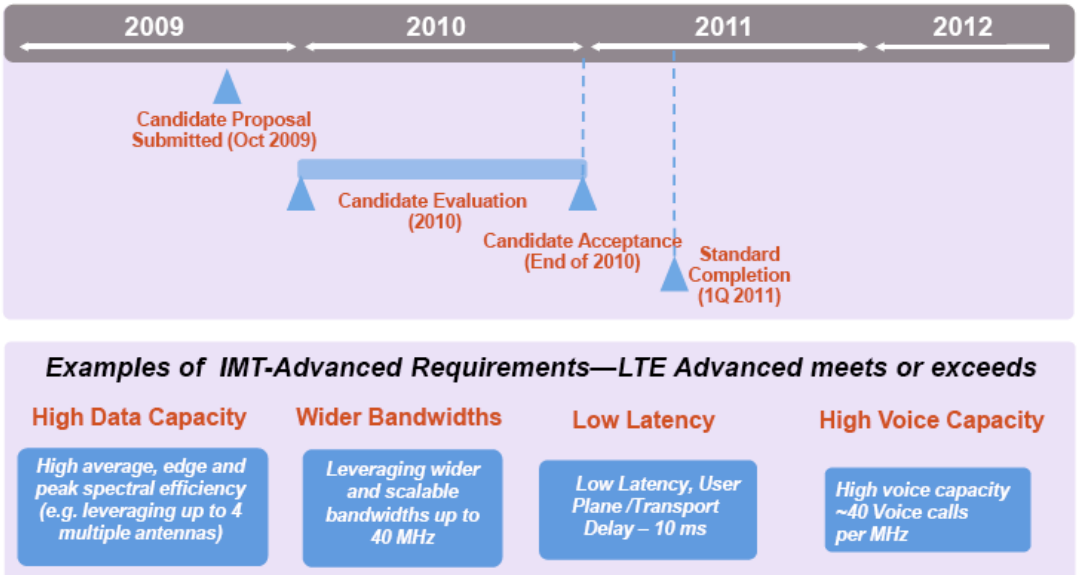

Figure 12. LTE as Global 4G solution [1]

Market impact

One question that could come out when we hear about the 4G when in many countries the 3G is not widely accepted by the users is: why is it necessary to invest in networks and new and powerful terminals?

We could find the answer in the global landscape. User's demands and expectations increase exponentially. Customers are starting to be satisfied with high speed fixed connections: they are fast, the cost is reasonable and it is very stable and reliable. But the there is an underlying global need of making everything wireless, placement independent and mobile. People want to work on a plane or in a park as they will do in their office. There is also a change in the behaviour of the customer. With the arrival of the so called Web 2.0 customers started to generate a huge amount of data traffic while until a few years ago mobile devices were used with only a direct communication purpose. So networks have to be adapted to deal with this new behaviour.

In February 2008 there were 20 million subscribers to HSDPA networks and this number increases exponentially, especially with the growing economical power and interest of emerging countries.

Network operators are thus presented a chance to provide their customers with a higher level product that could compete with fixed networks but with the advantage of mobility and the global compatibility. And they could bring new customers as they will give access to areas where there are no fixed networks or it is too expensive to be deployed. And as we saw before, LTE-Advanced provides a higher benefit as the costs have been reduced. This will also allow them to use more attractive rates for the user, which is maybe the mayor drawback of 3G penetration in many countries.

And while LTE-Advanced aims to the future, it doesn't mean a breakup with current and past technologies. In the standard it is clearly stated the need of compatibility with the previous standards and operators will be able to reuse most of the existing structure.

As a result of all this, LTE-Advanced will allow operators to revalue their existing networks and obtain new higher-profitable sources of business. And as a result of the new features that LTE-Advanced provides with and all the services that finally will be able to deliver, operators will be able to manage a wide variety of business products that will make their incomes grow as the revenue will be bigger than with the actual networks.

And for mobile terminal manufacturers this will be a tremendous opportunity to spread the number of models and families of products they actually have. The flexibility of this technology will be translated into much more powerful devices and they will be oriented towards an Internet and media direction.

The following table summarizes how LTE-Advanced will widen the possibilities of business and will create new service opportunities.

Service category	Current environment	LTE environment
Rich voice	Real-time audio	VoIP, high quality video conferencing
P2F messaging	SMS, MMS, low priority e-mails	Photo messages, IM, mobile e-mail, video messaging
Browsing	Access to online information services, for which users pay standard network rates. Currently limited to WAP browsing over GPRS and 3G networks	Super-fast browsing, uploading content to social networking sites
Paid information	Contentforwhich users pay over and above standard network charges. Mainly text-based information.	E-newspapers, high quality audio streaming
Personalisation	Predominantly ringtones, also includes screensavers and ringbacks	Realtones (original artist recordings), personalised mobile web sites
Games	Downloadable and online games	A consistent online gaming experience across both fixed and mobile networks
TV/ video on demand	Streamed and downloadable video content	Broadcast television services, true on-demand television, high quality video streaming
Music	Full track downloads and analogue radio services	High quality music downloading and storage
Content messaging and cross media	Peer-to-peer messaging using third party content as well as interaction with other media	Wide scale distribution of video clips, karaoke services, video-based mobile advertising
M-commerce	Commission on transactions (including gambling) and payment facilities undertaken over mobile networks	Mobile handsets as payment devices, with payment details carried over high speed networks to enable rapid completion of transactions
Mobile data networking	Access to corporate intranets and databases, as well as the use of applications such as CRM	P2P file transfer, business applications, application sharing, M2M communication, mobile intranet/ extranet

Table 2 Future market oportunities [6]