Long Term Evolution (LTE) and Beyond LTE: A Gentle Overview

Abdulkareem Adinoyi and Furaih Alshaalan
Research and Development, Saudi Telecoms, Riyadh, Saudi Arabia

Abstract

We provide a gentle overview and current market activities of the widely accepted 'pre-4G' (fourth generation) 3GPP long-term evolution (LTE) technology. Two main objectives are defined for the paper. First, it reviews the business part of LTE, as the chief telecom players (vendors and operators) see it. Second, it adds some academic flavors to the discussion by briefly exposing the technologies behind LTE and addressing the question, what is beyond LTE? In response, we focus our discussion on the so-called LTE-advanced (LTE's roadmap) which is expected to earn the blessings of ITU-R for IMT-Advanced (ITU, 2009) as the 'true' 4G technology.

Index Terms

LTE, OFDM/A, RRM, technology, market trend

1. Introduction

The telecom industry is often driven by market forces. The wireless service consumers are getting more sophisticated. Smart-phones, with their bandwidth-hungry applications are spreading. There is a continuous pressure on wireless network to deliver ubiquitous, reliable, high data rate wireless services in a spectrally efficient manner as well as with prudent power utilization. More often than not, users expect experience that far exceed that of a wireline network. The fourth generation (4G), or specifically pre-4G (LTE and Wimax) technologies have already passed the standardization phase, chip-sets and network elements are arriving or expected in the market. The most ambitious peak data rate obtained by first tiers vendors (Huawei and Nokia Siemens) falls short of 200 Mbps for the downlink (DL) transmission.

However, the 4G and beyond 4G networks are expected to deliver 1 Gbps in the DL and 100 Mbps for high mobility. This is a source of stress for the already-overstretched radio resources; wireless bandwidth and link budget (or power) are as expensive as ever. Therefore, a pragmatic network design approach is necessary and forms, in part, the theme of this paper. By this, we set the stage for discussing the next-generation networks that promise high-data rate connectivity anytime, anywhere. Towards this end, we identify network elements that would constitute part of the architecture of the evolved LTE, in addition to presenting the current activities in LTE.

2. The Long-Term Evolution

The 3GPP Long-term evolution (LTE), whose radio access is called Evolved UMTS Terrestrial Radio Access Network (E-UTRAN), is designed to be a flexible radio interface and expected to substantially improve end-user experience (low user plane latency, high sector capacity) with full mobility. At the center of its flexibility is the fact that LTE is designed to be 1) an all-IP technology; providing support for IP-based traffic with end-to-end Quality of service (QoS), 2) scalable; allowing flexibility in deployment, in terms of spectrum availability.

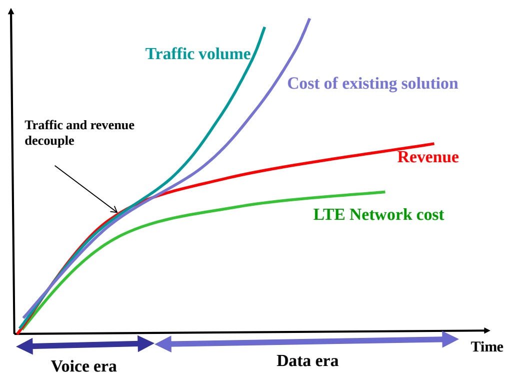

Fig. 1. LTE's vision, accommodating huge traffic.

Initial deployments of LTE are expected in 2010 across the globe among a pocket of operators. For some operators, such as Verizon US, LTE cannot come soon enough. Note that Verizon abandons its CDMA tradition for LTE. Currently, there are about 42 major (global) operators who have already signaled their commitment to deploy LTE as the ultimate evolution of their 3G networks (GSA, 2009). It is expected that 15 LTE commercial networks will be launched at the end of 2010. Among the early LTE adopters are the following: Verizon, TeliaSonera (Sweden), NTT DoCoMo, SK Telecom, Telenor Sweden, MetroPCS, Tele2 Sweden, to name a few. As indicated below, most telecom equipment vendors have LTE product road-maps (network and end-user devices) and these companies are engaged in joint trials. Therefore, service launching and device-readiness are more or less synchronized, a difficult but vital experience learned from 3G system deployment. Why the rush to LTE? The answer is partly depicted in Fig. 1, which shows LTE as an effective way to accommodate the growth in traffic volume and not allowing the cost of network roll-out to explode proportionally. Note that in the data-world (all-you-can-eat package era) revenue hardly increase with traffic volume. Not many subscribers have the appetite for increased subscription fee.

Innovations are the Key: This is where the war started. In third quarter of 2009, a sensational message from Huawei reads thus "Huawei pulls ahead in LTE patent ranking". Huawei confidently boasts that it had garnered 12% of all the LTE intellectual property rights (IPR) or patents granted by the European Telecommunications Standards Institute (ETSI) as of August 2009. These IPRs cut across many of the key LTE sub-sectors, namely physical-layer air interface, radio resource management and connection management. The acquisition of these IPRs raises the profile of this manufacturer with her clients and the news headline drives the point that Huawei is a partner that can be relied on for LTE solutions.

Nortel Networks, before her liquidation, was working on what they tagged then as the next generation of high-speed networks based on LTE technology. Nortel (Canadian telecom company) did not survive to see the birth of LTE, unfortunately. It was widely believed that Ericson and other vendors' bidding interests and Ericson's subsequent acquisition of the wireless department of Nortel was not unconnected to the huge investment that Nortel had had in LTE technology. Nortel's LTE assets were its experienced personnel and R&D achievements. For this reason,

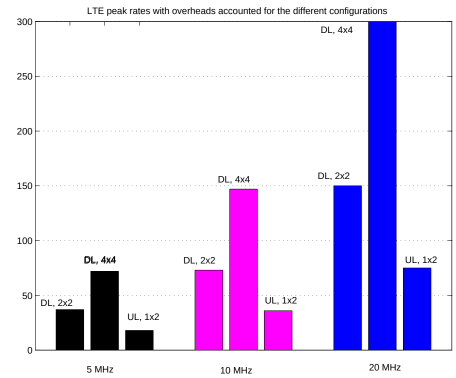

Fig. 2. The reported peak rates for LTE.

TABLE I
MANUFACTURERS AND LTE SOLUTIONS READINESS

Vendor	Solution Readiness
Huawei	Most solutions are ready
Ericsson	Ready for Verizon 2010 roll-out
NSN	Most solutions are ready
ALU	Ready for Verizon 2010 roll-out
Samsung	Some solutions are ready

Research In Motion (RIM), a Canadian wireless terminal manufacturer wanted to cash in these assets. RIM desires to earn a commanding advantage in LTE technology over any rivals by future-proofing their business, meaning RIM could avoid too much dependence on another company for LTE license thereby minimizing the amount of royalty paid out when they manufacture LTE devices.

The discussions above demonstrate the wave of interests and optimism that LTE is generating at the moment. That is on one front. On another front, a number of milestones have been achieved to demonstrate the viability of this technology through laboratory trials (Huawei, Nokia Siemens Networks), pocket field trials (Verizon and T-Mobile), among others. See Fig. 2 for rates that can be obtained using LTE and its scalability feature. The bottom-line is higher-speed connection can provide end-users with unprecedented mobile data services, such as high-definition video-on-demand and high-quality video conferencing, among others.

LTE Market: At the moment, there are mixed signals from the telecom equipment manufacturers. Almost all vendors have claimed that their current HSPA/3G network elements are easily upgradable to LTE. For example, NSN has flexi multimode BTS that it claims is LTE ready. Huawei also indicates that DBS 3900 (the evolved RAN or eNodeB) is of commercial grade. Observing the activities of the first tier LTE solution providers, a readiness chart is provided in Table I.

Regarding end-user devices, some samples of LTE modems, USBs and dongles are expected late 2009. Products from Motorola, Nokia, will be reaching the market soon. Huawei has earmarked fourth quarter of 2010 for

TABLE II

MANUFACTURERS AND LTE TERMINALS VENDORS

Vendor	Modems, data cards/USB dongles	Terminals
Huawei	1Q 2010 sample 4Q 2010-commercial	Q4 2011
Sony Ericsson	Q2 2010	2011
Samsung	2010	NA
Nokia	2010 (Internet Modem RD-3)	NA
ZTE	NA	Q2010/2011
LG Electronics	2010	NA
Motorola	2010	NA

commercial data cards and USB to get to market. However, the LTE chipset maker, Altair semiconductor predicts that the first LTE handsets will be commercial in the third quarter of 2010. It is not known however if the devices will gain mass market appeal right away. The general view is that LTE qwerty-terminals/handsets will not get to market until around 2011 with 2012 identified as the time it will reach a mass market level. It is worthy noting that 2012 is identified as LTE-year, when widespread (operators') deployment and launching of LTE will be witnessed.

The device vendors are active in trial programs with LTE/SAE Testing initiative. Thus, the level of activities in end-user devices at this stage of LTE development is quite encouraging. It is unprecedented that operators, device and chipset manufacturers, big and small, are cooperating to see the success of a technology. One benefit emanating from such cooperation is that it helps avoid the pitfalls in the launching of 3G. For those who need a reminder, there was this scenario of the existence of 3G technology but no widespread end-user devices to utilize it. For LTE, in the worst scenario, data cards, USB that are LTE-complaint could be in the market as early as the second quarter of 2010 corresponding with the first expected wave of LTE launch. The device vendor roadmap for LTE can be summarized in the chart below (Fig. 3). After the initial commercial network deployment, the expectations are that many class of devices (such as mobile internet devices, gaming consoles, etc) with LTE-capability embedded will start emerging. At the same time, research and development of multimode devices and product supporting multimode operation will continue. After this stage, device proliferation will occur recording high volume of chipsets, terminals, and thereby leading to economies of scale. Will this be the market breakthrough gap that the early majority technology adopters are waiting for? Or will it be too late? It is probably too early to tell.

3. Features and Technologies Behind LTE

Orthogonal Frequency Division Multiplexing/Multiple-Access: OFDM schemes divide available spectrum into a number of narrowband carriers, each carrying a part of the signal. On the other hand, OFDMA is effective in opportunistic channel assignments. In LTE, the spectral efficiency of OFDM is further enhanced with higher-order, spectrally-efficient modulation schemes such as 64-QAM, and powerful error correction technique such as turbo

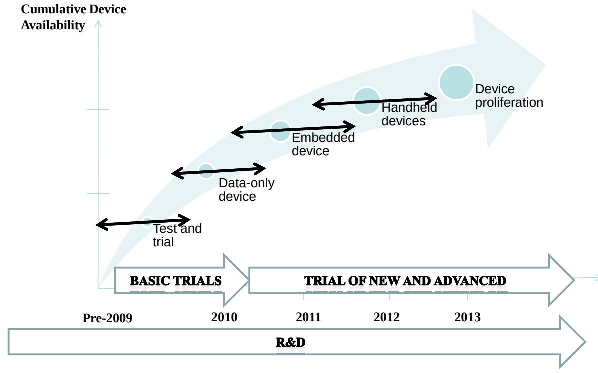

Fig. 3. The LTE device vendor roadmap.

coding. By contrast, single-carrier systems do not scale well with bandwidth (See Fig. 2). This spectral efficient transmission translates into lower cost-per-bit in service delivery, a desirable feature in the eye of an operator.

Single-Carrier FDMA: OFDM has some remarkable features. However, it suffers from some drawbacks and principal among these weakness are: susceptibility to carrier frequency errors (due either to local oscillator offset or Doppler shifts) and a large signal peak-to-average power ratio (PAPR). The high PAPR problem of OFDM is because the instantaneous transmitted RF power can vary dramatically within a single OFDM symbol. Note that OFDM symbol is a combination of a number of subcarriers. Subcarrier voltages can add coherently at some points within the symbol, thereby causing high instantaneous peak power, much higher than the average power. This reduces efficiency of the transmitter RF power amplifier which is very undesirable especially for hand-held (battery-powered) devices. Consequently, single-carrier frequency division multiple-access (SC-FDMA) has been adopted for LTE as a better choice for the uplink modulation technique than full-fledged OFDM.

Scalability: While UMTS is restricted a 5-MHz bandwidth for operation, LTE can operate with as little as a 1.4 MHz bandwith all the way to 20 MHz and still use one control channel, which results in greater spectral efficiency. This is good news to operators who be in position to embark on spectrum refarming.

Multiple-input Multiple-output (MIMO): Complementary to the OFDM/OFDMA are radio techniques like MIMO multiplexing and beam-forming. The implementation of MIMO technology plays a major role in improving the quality of signal (through diversity) and multiplexing opportunities and thus significantly boosting data throughput as can be seen in Fig. 2. At this moment, the standard supports up to four antennas per station.

IP-based and Flattened Architecture: One of the most significant features of LTE is its transition to a flat, all-IP based core network with a simplified architecture. The initiative for smooth migration of existing core network architecture to an all-IP system is performed in the Systems Architecture Evolution (SAE), now called Evolved Packet Core (EPC), to enable more flexible service provisioning in addition to facilitating interworking with fixed and non-3GPP mobile networks. Note that radio network controller (RNC) is dissolved in LTE, and its functionalities are shared among the eNodeB (LTE's BS) and MME (Mobility Management Entity), thus, helping to keep signaling overhead and latency low.

4. Total Cost of Ownership

What will dominate the network roll-out, in terms of the capital expenditure (CAPEX)? It is incumbent that these aspects be well understood.

- E-UTRAN: The main considerations here are: Availability of frequency band, cost of new spectrum and roll out strategies.
- Backhaul: The main components are: IP readiness, network topology and transport medium. The backhaul has to support higher capacities and lower latencies and have the ability to support IP traffic and all-IP architectures. It is common knowledge that todays backhaul networks are dominated by TDM (whether T1/E1 lines or SONET/SDH). Therefore, operators main challenge is to ensure efficient migration to an IP or Ethernet-based architecture. One option for a smooth migration process is for the backhaul to continue to support legacy services while new investments in legacy-only equipment are capped, and strategically moving investments and new services delivering towards IP-enabled equipment.
- Core: The main variable to watch out for are: The existing architecture, whether service is PS only, or VoIP.

5. The Components of Next-Generation Network: LTE-Advanced

According to 3GPP enhanced eUTRAN (the 4G technology), the candidate radio interface technology for LTE-Advanced should add the following to LTE: should maintain high degree of commonality of functionality worldwide, more flexibility (interworking with non 3GPP systems, more user friendly, etc), and ambitious high-data rate, among other lofty features. How will all this be achieved?

Advanced-RAN: The advanced RAN proposals, spot-coverage approach (Djukic and Yanikomeroglu, 2009) inclusive have assumed a dense network elements that will facilitate effective high-data rate connectivity to wireless users on demand. In spot coverage approach radio resources are dynamically assigned to users (not cells) on a temporary-basis. The advanced RAN therefore provides the infrastructure (ports) to enable user utilizes the assigned resources as it moves through the RAN coverage area. Furthermore, many advanced techniques will be employed as well and for LTE-Advanced, the research discussion will center around the following network components:

Spectrum Aggregation: Contiguous large spectrum may not always be available. Aggregation of separate non-contiguous spectrum may be required in the LTE-Advanced. At the moment spectrum aggregation appears to be a huge challenge. Researchers will be pre-occupied with looking for ways to confront this challenge.

Advanced-MIMO Enhancement of Peak Throughput: LTE currently has multi-antenna technologies, including spatial multiplexing (through MIMO). These key technology components are expected to continue to play an even more important role as part of LTE-Advanced. For antenna-limited scenario, cooperative communication through relaying can be evoked to help terminal emulate MIMO system.

Relay Technique and Cooperative Communications: Multihop relaying will be part of LTE-Advanced. The traditional multi-hop network uses relaying concept for providing nodes with shorter links and for combating shadowing so that higher signal-to-noise ratio (SNR) can be obtained, which can be translated to higher data rates and/or reduced error rate (high QoS). The SNR gains can also be used for coverage extension. In addition to the relaying functionalities, cooperative communication-based MH techniques (using relays or terminals) are ways small, antenna-limited wireless terminals can emulate multi-antenna system performance through distributed signal processing.

Coordinated Multipoint (CoMP) Reception and Transmission: In CoMP, the signals from a wireless device are received from several coordinated base stations. Though similar to MIMO system, a CoMP system however utilizes an array of antennas at different locations in contrast to co-located antennas of MIMO. This will be appealing to operators since network infrastructure is smartly utilized without the need to install more antennas.

Femtocell: Femtocells are very low-power home base stations, connected using standard broadband DSL or Cable service into the mobile operator's network. They offer excellent wireless coverage at home, but at lower cost than outdoor infrastructure. The femtocell may have matured for UMTS and 3G networks, current interest will be shifting to issues such as transport and core network architecture, security and interface of femtocell products as they relate to 4G.

6. Conclusion

The paper provides a brief overview of LTE system, covering the technologies and business aspects. Furthermore, the paper motivates discussion on issues that will pre-occupy developers as they work on LTE-Advanced, the evolution path to 4G wireless networks.

References

Djukic P., Yanikomeroglu H., and Zhang J., (2009), User-centric RRM and optimizable protocol design for beyond-4G RANs, *Wireless World Research Forum (WWRF22)* Meeting, Paris, France.

GSA, Global Mobile Suppliers Association, http://www.gsacom.com

Parkvall S., Dahlman E., Furuskar A., Jading Y., Olsson M., Wanstedt S., and Zangi K., (2008), LTE-Advanced-Evolving LTE towards IMT-Advanced, *Vehicular Technology Conference*.

3GPP, The Third Generation Partnership Project, http://www.3gpp.org.

ITU-R, International Telecommunication Union, http://www.itu.int/