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Review on LTE-Advanced Mobile Technology

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Abstract

Long Term Evolution-Advanced (LTE-A) is the next drive in the broadband mobile communication, which allows operators to improve networks performance and service capabilities. LTE-A targets the peak data rates of 1Gbps in the downlink and 500Mbps in the uplink. This requirement is only fulfilled by a transmission bandwidth of up to 100MHz. However the accessibility of such large part of the contiguous spectrum is uncommon in practice. Therefore LTE-A uses some new features on top of the existing LTE standards to provide very high data rate transmission. Some of the most significant features introduced in LTE-A are carrier aggregation, heterogeneous network enhancement, coordinated multipoint transmission and reception, enhanced multiple input and multiple output, and development relay nodes with universal frequency reuse. This review paper presents an overview of the above mentioned LTE-A key features and functionalities. Based on this review, in the conclusion we discuss the current technical challenges for future broadband mobile communication systems.

Keywords: LTE-Advanced, Heterogeneous Networks, Multiple Input Multiple Output (MIMO)

1. Introduction

Wireless mobile data traffic has been increased enormously in the last few years and is expected to increase rapidly. The number of mobile broadband subscriptions continues to grow at a rate as Internet did. Smartphones are now capable of displaying high-quality and real-time videos. These increasing demand are pushing the existing wireless mobile networks towards their limits such as causing a reduction in data throughput, decreasing the availability of resources and increasing data transmission delay. In order to meet the growing demand for high speed and diverse wireless broadband services, 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) is emerged and enhanced to LTE-Advanced(LTE-A), which is targeted to fulfill the requirements of International Mobile Telecommunications (IMT)-Advanced.

First of all, LTE-A should be backward compatible and should share the frequency bands with the previous release of LTE[1]. Beyond LTE, the most significant LTE-A Benefits are the ability to take advantage of advanced topology networks: optimized heterogeneous networks with a mix of macros with low power nodes such as picocells, femtocells and new relay nodes.

This new paradigm of network architecture brings the network closer to the user by adding many of these low power nodes, which improves the capacity and coverage, and ensures user fairness.

LTE-A also introduces multi-carrier solutions to be able to use ultra-wide bandwidth, up to 100 MHz of spectrum supporting very high data rates up to 1Gbps, which makes LTE-A a principled standard for 4G[2]. LTE-A is to fulfill the requirements of IMT-A. The key requirements are summarized as follows[3].

· 100Mbps and 1Gbps peak data rates for high and low mobility respectively
· Up to 350 km/h mobility support
· Enabling high-quality mobile services
· Minimum 40 MHz transmission bandwidth (up to 100 MHz is under consideration)
· Voice over IP (VoIP) capacity from 30 to 50 users/sector/MHz depending on the scenario
· Compatibility of interworking with other radio

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access technologies and systems

· Spectral efficiency from 0.7 to 3 bits/Hz/cell depending on the scenario

· Cell edge user spectral efficiency from 0.015 to 0.1 bps/Hz depending on the scenario

· User-friendly application, services, and equipment.

To meet above requirements, LTE-A physical layer main features and technique are summarized as follows.

· High transmission bandwidth using Carrier Aggregation (CA)

· Multiple input multiple output (MIMO) enhancement by using more antennas and enhanced antenna techniques in the uplink and downlink transmission

· Small cells and relay techniques

· Better cooperation between cells and coordinated multipoint (CoMP) transmission and reception

In this paper, LTE-A key features are briefly explained with discussion regarding the current challenges and future enhancing techniques. In section 2, the specifications of LTE and LTE-A are reviewed. In the following section, each key features of LTE-A is discussed. Within the section 4, the discussion on future enhancement technique is followed. Finally conclusion is in the section 5.

2. LTE System

During the last two decades, telecommunication industry has grown dynamically. With the evolutions of new advanced devices, the popularity of smartphone has brought the need for mobile broadband networks. In order to fulfill these demands, LTE was started by 3GPP with LTE standard Release-8, the complete set of standardization was published in March 2009[4], and it has already been standardized with release 9 as its final version. However the improvements offered by LTE are not enough to fulfill all the requirements of growing demands. Furthermore, 3GPP keeps working on further enhancements of LTE. The evolved versions of LTE under work (3GPP LTE Release 10 and beyond) is known as LTE-Advanced (LTE-A)[5].

The multi-antenna techniques could not always increase wireless transmission performance, due to the restriction on mobile device performance, complexity, and its cost limits. Orthogonal frequency division multiple access (OFDMA) is used in LTE downlink with subcarriers spacing of 15 KHz. Frequency resource assignment is done by the base station scheduler through assigning the sets of 12 consecutive subcarriers, called resource blocks (RB). Considering the 15 KHz spacing between subcarriers, the bandwidth of each RB is 180 KHz (12×15 KHz = 180 KHz). Number of RBs per cell is ranging from 6 to 100 corresponding to 1.4~20 MHz bandwidth as shown in Table 1. The Scalable bandwidth facilitates the deployment of LTE technology for mobile network operators. Small bandwidths can conveniently be used for reframing in lower frequencies such as 900 MHz while higher bandwidths are basically suitable for reframing in higher frequencies to provide high data rates.

This Table 1 shows that the Sampling rates for all LTE bandwidths are the multiplication of 3.84MHz in order to provide backward compatibility with Wideband Code Division Multiple Access (W-CDMA).

In uplink side, LTE uses a Single Carrier- Orthogonal Frequency Division Multiple Access (SC-OFDMA) technique. SC-FDMA has 6~9dB lower peak to average power ratio then OFDMA, which results in less power consumptions, low complexity and less expensive radio frequency amplifiers in the user terminals. In addition, using of single carrier minimizes the interferences caused by errors and imperfect orthogonality between

Table 1. Sampling rates for all LTE bandwidths

Bandwidth (MHz)	No. of resource block	No. of data subcarrier	FFT Size	Sampling rate (MHz)
1.4	6	72	128	1.92
3	15	180	256	3.84
5	25	300	512	7.68
10	20	600	1024	15.36
15	75	900	1536	23.04
20	100	1200	2048	30.72

the subcarriers.

3GPP LTE and LTE-A have defined up to 12 classes of user equipment's (UE) category. The new LTE category 0 was introduced in Release 12 of the 3GPP standards, which considerably reduced the modem complexity of the cellular system compared to other LTE categories. Qualcomm launched the first UE chipset that supports LTE carrier aggregation in June 2013, which is used in category 4.

3. Enhanced Features for LTE-A

3.1. Carrier Aggregation

Carrier aggregation (CA) is the most effective and key feature of the LTE-A in order to fully utilize the wider bandwidth of up to 100MHz while keeping backward compatibility of LTE. CA provides the wider bandwidth by aggregating two or more LTE carriers without any significant changes. With aggregating different carriers from different bands, CA provides higher peak data rates and increased average data rates.

LTE Release 8[6] provides CA enables the combination of up to five LTE carriers which results in high throughputs without wide contiguous frequency band allocations. It also can take asymmetrical bands into frequency division duplex (FDD). CA combination are divided into intra (contiguous and non-contiguous) and inter band.

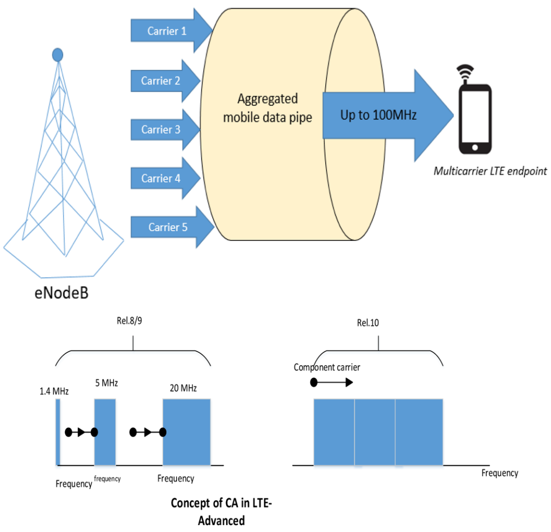

Fig. 1. CA concept for LTE-A.

In 3GPP Release 12, CA includes FDD and time division duplex (TDD) frequency bands, with supporting aggregation of two component carriers in uplink and three in downlink. This CA supports operation of dual connectivity between TDD and FDD.

In 3GPP release 13, it is planned to achieve a goal to expand LTE CA up to 32 component carriers that can be provided maximum data rates as well as the flexibility to aggregate large numbers of carriers in different bands. This enhanced framework will also useful for LTE-U (unlicensed) operation in the unlicensed spectrum where large blocks of spectrum are available.

However, most of existing work on CA for LTE-A is mainly focus on the downlink. There are only few studies in the uplink. General aspect and performance analysis of CA are detailed in[7]. CA works done does not offer any spectral efficiency for a fully loaded network. So the average throughput gain achieved by CA features is decreased by increasing the number of users.

This weakness on CA deployment is maybe improved by investigating potentially in the new ways of efficiently management and operation of an increased number of component carriers (CC). Here, one significant aspect is the requirement for novel CC selection and management methods. This may include an extension of the downlink and uplink control signaling as well as hybrid automatic repeat request (HARQ) feedback.

3.2. Heterogeneous Network (HetNet)

Heterogeneous cellular networks are very compelling approach for cellular networks to provide the better coverage and capacity. Current mobile networks are based on wide area macrocells which have a long coverage area even tens of kilometers and normally use three sectors per site. The bigger the cell size reduced the cell capacity as more users share the same cell capacity[8].

HetNet is simple solutions for capturing high traffic increase trend and having more coverage and capacity in the network base station. HetNets refers the network that contains both macros and small base stations (e.g. Micro, Pico, and Femto base stations).small cells can be added to provide more capacity and coverage. These small base stations are deployed within the coverage of macro cell coverage, the configuration of ABSs in enhanced inter-cell interference coordination (eICIC) shown in Fig. 2 below.

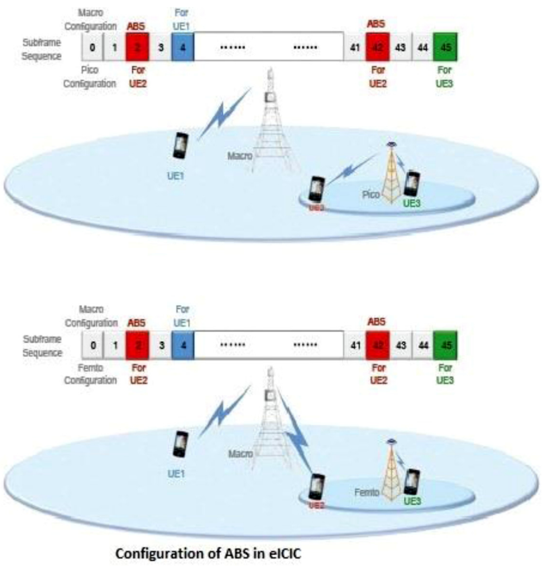

Fig. 2. Configuration of ABSs in (eICIC).

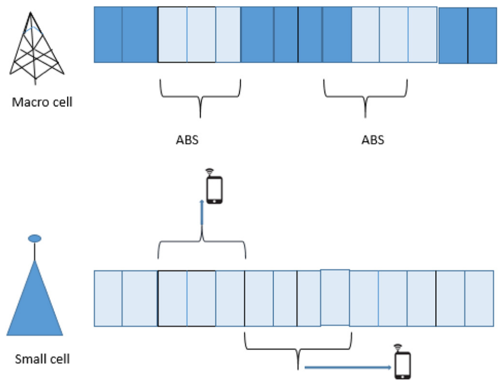

Fig. 3. Enhanced inter cell interference coordination (eICIC) functionality.

The major challenge in HetNet is to find suitable spectrum for small cells because all the available spectrum is assigned to the macrocells, where different cell layers use the same frequency. This may cause interference which should be effectively managed in HetNet. Small cells have low output power and the received signals at UE is not strong enough, in comparison with macro cells. 3GPP release 10 comes with feature enhanced inter-cell interference coordination (eICIC), also referred as time division multiplexing ICIC (TDM-ICIC). In this technique macro and small cells are coordinated in the time domain and inter-cell interferences

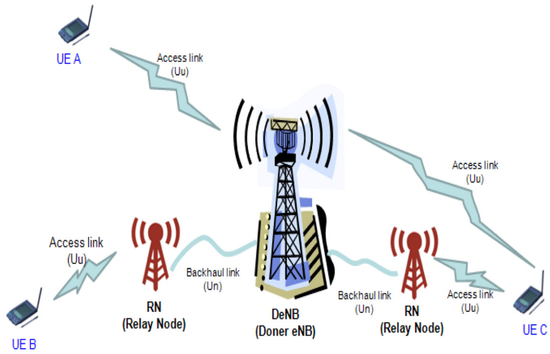

Fig. 4. Relaying in LTE-Advanced.

is avoided by preventing simultaneous transmission. Enhanced inter-cell interference coordination (eICIC) introduced almost blank subframe (ABSs), which are inserted to macro cell frames and small cell uses these gaps to serve the user equipment which receives strong signals from the macro cell. Fig. 3 shows the (eICIC) functionality.

3.3. Relaying

Relays are a key new feature of LTE-Advanced, introduced in Release 10 of the LTE specifications. Relaying being one of the promising deployment scenarios deploys low-power base stations known as Relay Node (RN) within the macro-overlaid network. This new feature of network architecture brings the network closer to the UEs, which eventually improves the coverage, capacity and user fairness of the entire network with a reduced cost. Relays are mainly used for the coverage expansion and throughput improvement in cell-edge, rural area, urban hot-spots, dead spots, indoor hotspots, events, and exhibition. The concept of relaying is not new but the level of sophistication continues to grow. An RN is connected wirelessly to the radio access network via a donor cell. The link between the DeNB and RN is called relay link or backhaul link whereas that of RN and UEs is referred as an access link.

As the name suggest, the mobile relay is the RN deployed on the top of the vehicle; buses, trams or trains to provide fixed access link to the onboard passengers of the vehicle. These days, the study of group mobility scenario as a new emerging scenario is gaining momentum. Mobile relaying technology for improving LTE network performance on the high-speed scenario is being investigated on 3GPP Release 11.

The MRS is connected to a Donor eNB (DeNB) via a wireless link called backhaul link and the link between onboard User Equipment (UEs) and MRS is referred as an access link. The backhaul link will have to cope with all the challenges of railway scenarios as described in the previous section: Doppler shift effects, synchronization problems, fast fading and temporal fading channel, etc.

According to transmission mechanism, relays can be characterized as Type 1 or Type 2 relay.

A. Type 1 Relay

It is an inland, half duplex, non-transparent relay and appears to users as a separate cell. This relay is a layer 3 relay with all the necessary Radio Resource Management (RRM) functionalities to support the handover and the mobility management, specifically; this relay has its own scheduler to serve on board users.

B. Type 2 Relay

Type 2 relays are in-band relays, which are transparent to users i.e. LTE Release 8 UE is unaware of type 2 relay in the cell and assume centralized resource scheduling by DeNB, thus, exploiting the cooperative nature of relay[9]. Normally, its deployment means to enhance the eNB signal in the donor cell. Some examples are the smart repeaters, Decode and Forward (DF) relays and L2 relays. These relays have not been standardized yet.

3.4. MIMO-Enhancement

MIMO is used to increase the overall bit-rate through transmission of different data streams on different antennas by using the same resources in both frequency and time domain, separated only through the use of different reference signals. Such data stream will be received by multiple antennas in the receiving end. In the Fig. 5 below it is shown that two different data streams are transmitted on two TX antennas and received by two RX antennas, using the same frequency and time domain which is separated only by the use of different reference signals.

One or two transport blocks can be transmitted per Transmission Time Interval (TTI). A major change in LTE-Advanced is the introduction of 8×8 MIMO in the downlink and 4×4 in the uplink. MIMO can be used when SNR is high, i.e. high-quality radio channel. For situations with low SNR, it is better to use other types of multi-antenna techniques to instead improve the SNR by means of TX-diversity.

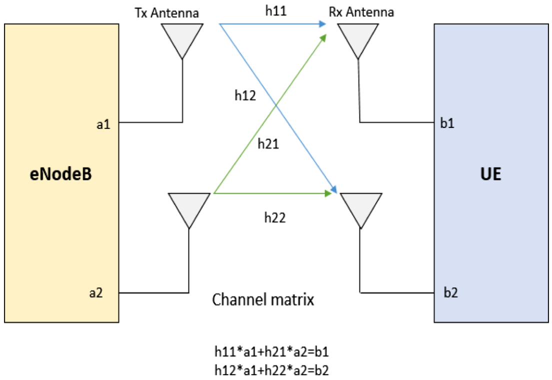

Fig. 5. Simplified Illustration of 2*2 MIMO (spatial Multiplexing).

3.5. Coordinated Multi Point Operation (CoMP)

In traditional telecommunication systems, each UE will be basically served by only one eNB at a moment. Signals come from other eNBs will become an interference to the UE. When the UE moves to the cell edge, it will communicate with more than one eNBs to prepare for handover. However, it is still being served by its original eNB. This is also the time when the UE receives strong interference, and data rate will be very low. The situation will become worse if the UE is moving with high speed.

Coordinated multipoint can be considered as a distributed MIMO system, in that geographically distributed nodes from multiple antennas and they cooperate to transmit to and/or receive from UEs. The main reason to introduce CoMP is to improve network performance at cell edges. In CoMP a number of TX (transmit) points provide coordinated transmission in the downlink, and a number of RX (receive) points provide coordinated reception in the uplink.

3.6. Universal Frequency Reuse

An interesting fact that governs cellular system design is that the signal power falls diminishes with distance. This feature helps in ensuring efficient resource utilization. It allows frequency resource to be reused at a spatially separated location such that signal power diminishes to the extent that it does not cause any significant interference. The distance at which the frequency resource can be reused is known as reuse distance and this concept is known as frequency reuse. The interference due to this reuse is known as inter-cell (also known as co-channel) interference. In universal frequency reuse or reuse-1, inter-cell interference is high because the reuse distance is 1. The frequency resource is utilized well as all RBs are available in each cell, albeit the edge users are prone to more interference because the RBs are reused by adjacent cells.

4. Discussion

There are no doubts breakthroughs in wireless networks innovation will obviously drive the economic and societal growth of the world in entirely new ways. There is instead of peak data rates, the actual data rate experienced by users is becoming the center of attention. Despite all improvements in LTE-Advanced system, cell-edge user data rates are far less than the peak data rates and the difference between cell-edge and peak data rates is too high. Currently, the actual data throughputs dramatically depend on the link quality and are limited by inter-cell interference. Although frequency reuse systems like LTE and LTE-Advanced are highly efficient in terms of overall efficiency, they suffer from high inter-cell interference at the cell boundaries. Hence, more developments on the interference management features such as CoMP transmission and reception, and eICIC are necessary. Furthermore, more enhancements in small cell deployments, spectral efficiency are needed as they can improve the radio link quality of the users.

The first commercial LTE-Advanced network launched in October 2012 when there is no any UE available compatible with LTE-Advanced. After releasing the first LTE-Advanced chipset in June 2013, several mobile network operators such as SK Telecom and LG Uplus have started to offer LTE-Advanced services to their customers.

Where 3GPP focuses on the release 13 finalization, the 3GPP RAN group has started working on the evolution of LTE specifications in release 14, targeting completion by June 2017. The release 14 study items are getting together and as of now a few items such as Radio Access Network (RAN) sharing enhancements have been set. On the other side, studies on the beyond-LTE-Advanced systems for the future wireless mobile communications networks – known as 5G have already started. If we considering the previous tendency and the time frame between the generations, 5G is envisioned to be in the picture by 2020 and LTE-advanced technology would have to be a competitor with that as well.

The required bandwidth can be provided by allocating new spectrum in higher frequency bands for cellular systems. Currently, ITU-R estimations show that at least 1280 MHz of spectrum bandwidth are required for the future development of IMT-2000 and IMT-Advanced by the year 2020. This may bring new problems to the networks due to the special characteristic of the shorter wavelength signals. Another solution for dealing with the spectrum scarcity issues is to use Cognitive Radio (CR) technology in the networks in order to enable terminals to opportunistically access the spectrum that is being underused. This CR technology offers efficient and flexible usage of the existing spectrum bandwidth and CR deployment seems inexorable for further evolution of LTE-Advanced networks.

5. Conclusion

This Paper describes the overview and enhancements of different components of LTE-Advanced provided within 3GPP release. Such as carrier aggregation (CA), Heterogeneous Network, Relay nodes, Multiple Input Multiple Output (MIMO), Co-ordinated multipoint transmission and reception, Universal Frequency reuse. CA can provide higher peak data rates by mitigating inter-cell interference and cell edge user experience improvement. CoMP transmission and reception can provide an improvement in coverage in noise limited scenarios. MIMO enhancement technique enhanced the average data rates depending on MIMO configuration. HetNet can enhance the average and cell edge data rates. Regarding universal frequency reuse ensure efficient resource utilization in a cellular network. Another solution for dealing with the spectrum scarcity issues is to use Cognitive Radio (CR) technology in the networks in order to enable terminals to opportunistically access the spectrum that is being underused. These LTE-Advanced components features need further enhancement and considered in future 3GPP releases and future radio access technologies.

Acknowledgments

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References

[1] Nokia Networks White Paper, "LTE-Advanced White Paper", (The advanced LTE toolbox for more efficient delivery of better user experience)

[2] I. F. Akyildiz, D. M. Gutierrez, and E. C. Reyes, "The evolution to 4G cellular systems: LTE-Advanced", Broadband Wireless Networking Laboratory, School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA 30332

[3] ITU-R M.2134, "Requirements related to technical performance for IMT-Advanced radio interface(s)", 2008

[4] The 3rd Generation Partnership Project (3GPP). TS 23.401: General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN).

[5] The 3rd Generation Partnership Project (3GPP). TS 36.101: Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN). Overall description. Stage 2.

[6] Rohde & Schwarz, "LTE / LTE-advanced technology update", In LTE-advanced seminar, fleet, 2013.

[7] Z. Shen, A. Papasakellariou, J. Montojo, D. Gerstenberger, and F. Xu, "Overview of 3GPP LTE-advanced carrier aggregation for 4G wireless communications", IEEE Communications Magazine, Vol. 50, no. 2, pp. 122-130, 2012.

[8] Ekram Hossain Editor "Heterogeneous Wireless Access Networks Architectures and Protocols", Springer.

[9] T. Liu, and M. Rong, "Utility-based joint routing and spectrum partitioning in relay LTE-advanced networks", IEEE 22nd International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC), Toronto, ON, 2011.