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# LTE-A and Beyond 5G Evolution

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***Abstract*- LTE is a newcomer technology standardized by 3GPP, which satisfies the requirements of IMT-Advanced, referred to as LTE-A. LTE seeks several objectives, e.g., higher data rates for purchasers, reduced latency, higher system coverage and capacity, and lower operating costs. Followed by LTE, 4G radio technology standard emerged, known as LTE-Advanced. LTE-A has been selected to allow higher cellular telephone network transmission speeds and data rates. LTE-A is LTE-compatible. LTE-A utilizes a constant LTE frequency band, yet it is not compatible with opposing 3G systems. LTE-A requires smaller latency compared to LTE. This paper presents the outstanding features and evolution of LTE to LTE-A. Then, the outstanding features of LTE-A will be summarized in an exceedingly tabular format, and the accomplishment of IMT-advanced requirements will be demonstrated.**

***Index Terms-*** LTE-Advanced, LTE Release 8, LTE Release 9, LTE Releases 10 and 11, LTE Release 11 to 13, LTE Releases 13 and 14.

## introduction

The first cellular system was established by Nippon Telegraph and Telephone (NTT) in Japan in 1979. The primary cellular network developed in the US was the Advanced Mobile Phone System (AMPS), a subsidiary of AT&T, established in 1983, which was the first-generation (1G) analog system. The second-generation (2G) systems (first established in 1991) were digital [1]. The Global System for Mobile Communication (GSM), based mostly in 1987, supported Time Division Multiple Access (TDMA) and Interim Standard 95 (IS-95) supported Code Division Multiple Access (CDMA) technologies are among 2G systems [2,3]. The foremost common systems are European originated from GSM and are deployed globally. The third-generation (3G) cellular systems emerged in 2001 in Japan by introducing the Wideband Code Division Multiple Access (WCDMA) standard [1].

The development of standard 3G cellular networks started by a gaggle of telecommunication unions. The third-generation partnership project (3GPP) was implemented in 1998 for the standard development of 3G supported GSM network, and additionally, the continual 3GPP2 pushed the IS-95 network towards the standard 3G. Both systems, which have endorsed the 3 G specifications and CDMA access technologies, were introduced publicly as the international mobile telecommunications-2000 (IMT-2000). They were disseminated as a 3GPP variant of the 3 G standard by the international telecommunication union, defined as Release 99 or the Universal Mobile Telecommunications System (UMTS). The standard published by 3GPP2 is known as CDMA-2000 [2].

In 2008, the fourth-generation (4G) mobile communication requirements were introduced by the International Telecommunications Union (ITU-R), labeled as the International Mobile Telecommunications-Advanced (IMT-Advanced). 3GPP and 3GPP2 began their attempts once this declaration was made to fulfill the requirements of 4G IMT-Advanced. The 4G project of 3GPP towards IMT-Advanced was named LTE (Long Term Evolution), and its further improvement is LTE-Advanced (LTE-A). 3GPP2 started their 4G project called Ultra Mobile Broadband (UMB) but stopped its further development in November 2008 and adopted LTE instead [2].

High data rates for applications, e.g., image transfer, Internet browsing, and streaming, are provided by 3G and 4G cellular networks [1].

## Background of LTE and relevant technologies

To develop a new cellular network standard, i.e., 3G, 3GPP sought to unite six telecommunications standard development organizations (TSDOs). These included the Association of Radio Industries and Businesses (ARIB), based in Japan, Alliance for Telecommunications Industry Solutions (ATIS), based in the USA, China Communications Standards Association (CCSA), European Telecommunications Standards Institute (ETSI), Telecommunications Standards Development Society (TDSI), based in India, Telecommunications Technology Association (TTA), based in Korea, and Telecommunication Technology Committee (TTC), based in Japan. They used CDMA-based radio access technology (RAT) for 3G rather than FDD-TDMA. In 1998, 3GPP was developed to allow global roaming between the European and US markets. In 2000, the initial standard version called UMTS or version 99 was released.

In contrast, RAT relies on WCDMA, and the evolution of 3GPP to version 7(+HSPA) is dependent on access technology CDMA. As the CDMA-based access technology network exceeded its limit to create the rising demand for a higher data rate, a new access system was supported by 3GPP to establish a substitute standard. The 3GPP team exploited the Orthogonal Frequency Division Multiple Access (OFDMA) technology instead of CDMA, referred to as long-term evolution (LTE) [2].

### Evolution of LTE to LTE-advances

LTE's original proposal came from Japan's DoCoMo NTT and was originally introduced as a research piece, uniting LTE's technical requirements in 2005. The LTE standard was finalized in 2008 [1]. The primary release of LTE is named the Release 8 [2]. The first publicly obtainable LTE service started adding Stockholm and Oslo in 2009, named Release 9. In 2009, a variety of carriers revealed programs began to convert their networks to the LTE network. These attempts started in 2010. Finally, LTE-A was adopted as a promising system for the 4G International Telecommunications Union-Standardization Sector (ITU-T). According to the schedule, it was supposed to be finalized in 2011 by 3GPP [1,4,5]. LTE-A technology was standardized in an incredibly wide range of releases beginning with Release 10 frozen in 2011. In the release, ideas included carrier aggregation (CA) to be used in several frequency ranges, enhanced MIMO technology, relays, and self-organizing networks (SONs). After Release 10, Releases 11 and 12 (frozen around 2012) were improved. Release 13 should contain additional improvements, and future new access technologies should be included in Releases 14 and 15. Technology included in Release 12 onwards is known as beyond 4G (B4G) [1].

### LTE Release 8

3GPP Release 8 is cited because of the initial standard LTE. The establishment of LTE's early theme was principally supported by macro- and micro-layout, yielding higher peak data rates than earlier +HSPA. There are improvements to system capability and lined areas included in this release. Other improvements embedded in LTE Release 8 include scaled backing operational prices, low latency, multiple antenna support, versatile bandwidth, and alliance with available systems [2,6]. In LTE, OFDMA-supported RAT and Single-Carrier FDMA (SC-FDMA) are used in the downlink and uplink, respectively. SC-FDMA is similar to OFDMA. This is another DFT technique introduced prior to OFDMA, often referred to as DFTS-OFDMA [2]. Spectrum flexibility is one of the key characteristics of the LTE RAT. LTE endorses both Time Division Duplex (TDD) and Frequency Division Duplex (FDD). The former is accomplished on TD-SDMA (or TDCDMA) and the latter on 3G-WCDMA. In LTE Release 8, the multi-antenna transmission was introduced as a completed part. Additionally, it supports diversity with numerous transmissions and receiving diverse downlinks. Beamforming and spatial multiplexing offer single-user MIMO (SU-MIMO) and multi-user MIMO (MU-MIMO) support for up to four antennas conferred in this release [2].

Various options were embedded in Release 8 of 3GPP, which significantly affect wireless networks. 3GPP Release 8 is the first LTE standard. Release 8 was introduced as an alternative to the UMTS radio network, EUTRAN, EPC, and various network core structures. All these together are known as LTE. In the UMTS space, this standard release contains some familiar developments for maintaining speed and increasing data traffic rates. Even if it's doable to achieve higher speeds, combining 2 UMTS carriers approximate to urge all the 10 MHz bandwidth, introduced as Dual-Carrier or Dual-Cell operation. The concurrent application of MIMO and 64-QAM also import the specifications for single-carrier operation.

Moreover, under ideal conditions of radio, it will reach the most throughput 42 Mbit/s within the downlink direction. Certain improvements have been offered for Voice over Internet Protocol (VoIP) applications, allowing the network to arrange a circuit-switched channel in GSM to relinquish a packet-switched VoIP call once the user roams out of the UMTS or LTE coverage space. This needed the mobile device to communicate at once with the UMTS network or LTE and GSM network in the previous releases. A small, yet necessary half included in Release 8 is "In Case of Emergency (ICE). Devices performing this operation enable users to avoid wasting the subscriber identity module (SIM) card with a customary technique. This information is often employed by ICE wherever the phone subscriber is incapable of distinguishing herself from contact relatives. Sadly, however, this widespread technique has not been adopted. Finally, Release 8 of 3GPP lays the basis for the management of femtocells, presented as Home Node B (HNB), in the standard and SON to promote the establishment and maintenance of base stations [7,8].

LTE Release 9

3GPP Release 9 is a simplified version of Associate-Grade LTE readable, including highlighted sections no considered critical to launching LTE. The SON and Femtocell (Home eNode-B and residential Node-B) started in Release 8 and continued during this Release. Meanwhile, other improvements include multicast and broadcast services, positioning systems, and enhanced emergency call function. For UMTS, Release 9 provides a range of pace downlink and uplink speed improvements. The combination of two neighboring 5MHz carriers in the direction of the uplink is distinguished by a method akin to the downlink in the last release.  This is because the most theoretical data rate is again doubled to 20 Mbit/s. The dual-carrier operation is currently combined with the MIMO operation in the downlink direction, increasing the throughput to 84 Mbit/s.

Moreover, a brand-new task item eliminates the dual-carrier constraint, where each carrier needs to be approximated by every alternative. Under such circumstances, the carriers are deployed in several frequency bands, e.g., 900 and 2100 MHz in Europe. Quality control is only allowed in one of these two bands. Adjacent cell measurements and call to alter cells are conducted consistent with one of these two bands. In several global elements, frequencies previously used for analog television are released by introducing digital standards. These frequency bands fall within the 700MHz range in the United States, and the 800MHz range in Europe, typically known as digital dividend bands. It has been granted for the wireless broadband web. 3GPP Release 9 includes required advances to use LTE in the European digital dividend bands. After application, it can be observed that this spectrum is incredibly wide among network operators in several countries wherever LTE networks are deployed. Until Release 9, GSM and GPRS's safety mechanisms were not modified, and their vulnerabilities were discovered. In this release, 3GPP offers another encryption algorithm known as A5/4, along with doubling the length of the cipher key (CK) to 128 bits. These two algorithms are the most and secure updates.

Release 9 of LTE presents several smaller improvements or optimizations for a variety of features, including:

- Multimedia Broadcast Multicast Services (MBMS) for LTE
- LTE MIMO: Dual-layer beamforming
- LTE positioning
- Public Warning System (PWS)
- Radio Frequency (RF) requirements for multi-RAT and multi-carrier base stations
- HeNB specification (femtocell)
- SONs [2,7]

At the end of December 2009, Release 9 was finalized. On 14 December 2009, the first commercial LTE was put into service in Norway and Sweden. Deploying LTE Release 9 supported interoperability between IEEE802.16 (WiMAX) and 3GPP WCDMA and 3GPP2 CDMA-2000 converged together [2].

### LTE Releases 10 and 11

LTE Release 10 was finalized in late 2010 to match its developments with Releases 8 and 9 regarding operation and capabilities. LTE Release 10 and higher are referred to as LTE-A that meet all IMT-Advanced requirements. Therefore, LTE-A could be a 4G mobile communication system that contains some further components of the previous version, including:

**Carrier Aggregation (CA)**

**Enhanced MIMO**

**Coordinated Multiple Point transmission and reception (CoMP)**

**Heterogeneous Networks (HetNets)**

**Self-Organizing Networks (SONs)**

**Machine-to-Machine (M2M) Communication**

**Device-to-Device (D2D) Communication**

**Wireless relaying [2,1,8]**

Carrier Aggregation (CA)

In CA, some carriers' elements are collected to support the high-bandwidth transmission. LTE-A will support CA to above 100 MHz. Advanced MIMO techniques will support 30 bps/Hz at the downlink requiring an antenna with 8 × 8 configuration with MIMO spatial multiplexing and 16 bps/Hz at the uplink requiring an antenna with 4 × 4 configuration. Wireless relaying provides in-depth cell coverage and higher operation for aspect cells. Home eNB (HeNB) will be a relay node (RN). The preparation of a heterogeneous LTE network involves hyperbolic requests for inter-cell interference coordination vital to a part of LTE-A. Once a UE is on the cell edge, the edge space receives a signal from the opposite main station that disorders within the UE. CoMP could be a solution for increasing the system potency at the cell edge in the presence of inter-cell impairment [3]. LTE-A network architecture is illustrated in Figure 1.

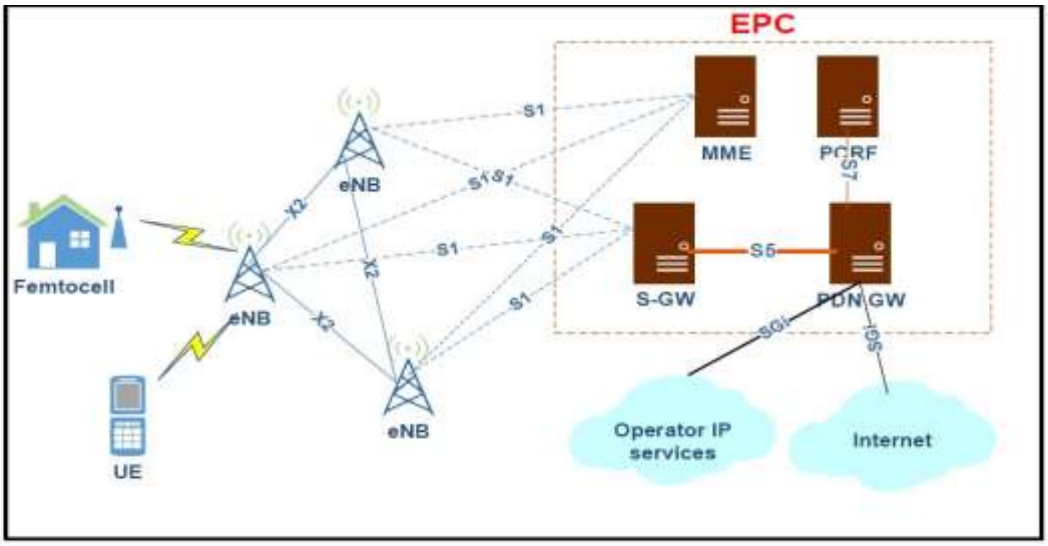


Fig. 1. LTE-A Network Architecture

The LTE structure exhibits numerous LTE-A network elements. All eNBs are attached to the Mobility Management Entity (MME) and Serving Gateway (SGW) of the Evolved Packet Core (EPC). eNB is an amalgamation of Radio Network Control (RNC) and 3G UMTS. SGW handles the routing and transfer of voice and data packets from User Equipment (UE) to the Packet Data Network (PDN).

Transferring between eNBs is within the scope of the SGW domain. Mobility Management Entity (MME) is responsible for signal control and appropriate GW selection during the initial registration process.

This is an important part of the transmission of a signal between 2G/3G and LTE networks. PDN-GW provides a connection between UEs and the external data packet network.

Policy and charging rules are managed by the Policy and Charging Rules Function (PCRF) [4]. LTE Release 10 and higher are referred to as LTE-A with more developments than the other two releases.

Other releases introduced a significant number of other improvements. Table 1 compared different releases of LTE (Releases 8 to 10). Improvements are assumed to have been applied in the latest versions [2,8,9].

Table I. Improvements in LTE releases

| **I.** | **Improvements in LTE releases** | |
|---|---|---|
| **Release 8** | **Release 9** | **Release 10 (LTE-A)** |
| • Spectrum flexibility<br>• Multi-antenna transmission<br>• ICIC | • Spectrum flexibility<br>• Multi-antenna transmission<br>• ICIC<br>• LTE positioning Multimedia Broadcast Multicast Services (MBMS)<br>• Home eNodeB (HeNB) specification | • CA<br>• Advanced MIMO techniques<br>• Wireless relaying<br>• eICIC<br>• CoMP transmission/reception<br>• Rely node [HeNB] (femtocell) |
| | (femtocell)<br>LTE MIMO: dual-layer beamforming | |

To increase the maximum data rate of a device, 3GPP Release 10 introduced a series of carriers (CA) within the same band or numerous frequency bands. This section can enable multiple carriers of 20 MHz to be a force and numerous bands from a European perspective. For instance, there may be a 20MHz carrier in the 1800MHz band and another 20MHz carrier in the 2600MHz band. There may also be a combination of carriers in the 800MHz digital dividend band. Most of the carriers are restricted to a 10MHz channel. There may also be a 20MHz carrier in the 1800MHz or 2600MHz bands, rendering it potential. Though this section has so far been a bit appealing in Europe because of supplying a 20MHz continuous spectrum in several bands, this section is especially standard across the North American market and several Asian countries. Numerous network operators are restricted to 10MHz carriers due to the limited spectrum in new bands set by network operators for LTE in previous years. Thus, higher data rates may be achieved in Europe by combining carriers in multiple bands. North American network operators like Verizon and AT&T have combined intensive 10MHz LTE channels in the 700MHz band with a special channel in the 1700MHz (uplink)/2100 MHz (downlink) band.

When LTE devices are typically equipped with two antennas for receiving MIMO on the receiver and transmitter side (2 × 2 MIMO), four and eight antennas are currently fixed on all sides (4 × 4 and 8 × 8 MIMO). However, it needs massive, new, and advanced antenna systems at the most stations in follow. There are dimensional physical challenges and two bound antennas due to size limits on the mobile device.

When bandwidth composition, modeling, and the variety of instant MIMO streams outlined to this point, on the far side, mobile devices' capabilities and the constraints of physical average and smart transfer conditions. Therefore, Releases 10 and 11 determine how to hide the grid's additional capability by finishing LTE macrocell covering areas at a 100-meter radius with small, low-powered cells covering just a single part of this area. This new structure is introduced as a heterogeneous network (HetNet) structure as a macrocell covering space. Various ways are fixed for these cells to match their central base station's transitions or management to avoid or scale back interference outcomes. Releases 10 and 11 determine various carrier upgrade steps for HSPA to combine four or eight 5MHz carriers. The uplink specification was extended to include MIMO and 64-QAM, as already specified for the downlink direction [7].

### Enhanced MIMO

The application of MIMO in Release 10, Release 11, and Release 12 of LTE-A is noted as enhanced MIMO, differentiating it from previous MIMO applications in LTE. Release 8 and Release 9 of LTE authorize up to 4×4 antenna configurations (4 for the receiver and 4 for the transmitter) in the downlink 2×2 antenna configurations in the uplink. Four critical modes of operation occur for LTE:

- **Spatial diversity:** The responsibility for transmission will be enhanced by exploiting multiple antennas. In other words, at the transmitter, completely different antennas transmit pre-coded versions of constant data. The receiver's antennas do different kinds of signal integration to produce an enhanced quantitative relationship between signal-to-noise (S/N) ratio.
- **Spatial Multiplexing (a.k.a. space-division multiplexing):** Wireless signals go from transmitter to receiver using various approaches of varying lengths, since the signal is reflected off the surfaces. Synchronous data streams (known as layers) will be transmitted using MIMO technology to exploit these methods. This parallel data transfer increases throughput. It needs to make the data streams orthogonal by transmitter precoding to simply differentiate them. Moreover, both spatial multiplexing and diversity utilize cell-specific reference signals (CRS) for channel estimation and signal reception.
- **Beamforming:** Many antennas' directivity and sensitivity patterns can be regulated by adjusting antenna phases fitly. This can be dramatically helpful when communicating with users at the boundaries of the property region. Full Dimension MIMO (FD-MIMO) is a brilliant technology for Release 12 and higher versions, where a comparatively large number of antennas (e.g., 16, 32, or 64) at the base station (Enhanced Node B (eNodeB or eNB) in 3GPP language) correct 3D beamforming for the expected users. In each azimuth/elevation direction, beams can be steered, making it more flexible than 2D beamforming.
- **Multi-User MIMO (MU-MIMO):** If multiple users can be co-scheduled on the equal frequency and time resources, system throughput can be improved. Centered on codebook-based precoding, this kind of MU-MIMO is supported in Releases 8 and 9 of LTE. Remember that intra-cell interference is not eliminated by this restricted method. In Release 10 of LTE-A, improvements to LTE-MIMO have been made, and a few more enhancements in Release 11. Moreover, the most significant LTE-A antennas range is 4×4 for the uplink and 8×8 for the downlink. A novel function is a dynamic framework for each switching of MU-MIMO and SU-MIMO at the eNB.

Here, different users' operating modes can be transparently applied to higher layers in a short period. This may be useful as a result of variations within the MIMO channel and traffic volume. Huge MIMOs (including 100 or more antennas) are conjointly being explored [1,10,11].

## Coordinated multipoint (CoMP) transmission and reception

This is a vital method used to stimulate cell boundary throughput and coverage and improve the system's performance. It was explicitly stated in Release 10 of LTE-A, and the specification showed up in Release 11 as well. The basic concept is that cell-boundary users can obtain downlink transmissions from multiple antennas. Alternatively, uplink transmissions returning from users can be coordinated by multiple base stations. Wherever such coordination occurs, several scenarios involve simple scheduling coordination up to intricate, joint transmission (JT) of signals. Coordination will be intra-site (within an identical base station), inter-site (among entirely separate base stations), and in heterogeneous or uniform environments [1,10,12,9].

## Self-Organizing Networks (SONs)

The self-organization of this sort traces back to Release 8 of LTE. Via reducing manual input and operation and speeding up the response time to cause events, self-organization strategies have advantages in lowering costs. Self-organization could include a base station (eNB) self-configuration, eNB self-healing in reply to network problems, and automated exploration of adjacent relationships. This would co-optimize coverage and capacity, interference control, relinquishing parameters, and freight reconciliation using the automatic reconfiguration of device, radio, and network parameters. Under LTE, self-organization functions have started, and new ideas are being explored by LTE-A.

The main ideas and needs are:

- **eNB self-configuration:** This means the automatic introduction of new eNBs into the given network. It involves using the component manager to set up IP property, download software system and transport/radio setup data, and establish S1 and X2 interfaces.
- **eNB self-healing:** This means the automatic identification, mitigation, and solution to any network problem. It prohibits users from being affected and minimizes maintenance expenses.
- **Management of automatic neighbor relations (ANR) list:** This includes automating the invention of neighbor relations
- **Self-optimization:** This involves automating the reconfiguration of the network, radio, and system parameters to realize one or more of the following goals:
  - Coverage and capacity optimization (CCO)
  - Load reconciliation
  - Optimization of relinquishing parameters
  - Interference management
  - Random Access Channel (RACH) parameter optimization [1,10].

## Heterogeneous Networks

The need to boost system capability in multiple orders of magnitude has resulted in smaller low-powered cellular layers underlaid on the existing macrocell layer. Among these small, low-powered cells are femtocells, metrocells, and picocells. For example, feminists are used indoors in residential buildings or business facilities, while metrocells and picocells are employed outdoors. Such a network with distinct cellular layers, each with its own unique features, like backhaul technology and transmission power, is a heterogeneous network (HetNet). HetNet cannot serve as an alternative to LTE-A because it is just a preparation strategy. Nevertheless, the heterogeneity of different cellular layers poses numerous critical challenges that influence the individual capacities that the general system can attain [1,10,9].

## Machine to Machine (M2M) Communication

This includes communication between machines as part of a network. It is jointly noted as Communications of the Machine type. This happens in technological contexts such as sensible networks and the Internet of Things (IoT). Bluetooth, mobile cellular networks, WiFi, and ZigBee, will enforce it. The new technology has reaped the benefits of quick implementation, reliable remote server access, and quality service. A problem with LTE-A M2M communication is that there could be a very large number of machines, each of which needing a limited amount of data communication bandwidth, resulting in unreliable, huge signaling burden and data overload. It will jointly scale back resources for machines that require high-rate transmissions. Research has been carried out on solutions, especially air interface (AI) support for M2M equipment [1,10,13].

## Device-to-Device (D2D) Communication

Another optional primary technology for LTE-A, embedded in Release 12, is the device-to-device (D2D) communication paradigm, which is likewise referred to as proximity services (ProSe). It alludes to cellular devices' flexibility in directly communicating without the need for network infrastructure access. Although the existing technologies, like WiFi-Direct or Bluetooth, have already provided this function, the operator cannot handle the communication mechanism and maintain secure user expertise. Besides, they cannot be incorporated into cellular networks. However, D2D can mitigate the effect of the cellular network and change the way the user switches between modes of D2D and normal cellular communication transparently. There are already numerous applications leading up to this modern communication technology.

Nevertheless, many other applications are likely to be discovered in the near future. What follows is a description of some of these applications. First, operators are increasingly intrigued by context-aware applications in a setting where many services can be delivered at the customer's location. The user can optimize direct communication using alternative devices to make the network's context-awareness as versatile as possible. Second, wherever network infrastructure is unavailable, support for public safety networks (PSNs) may be a major concern addressed by 3GPP via introducing D2D. Third, the rapid growth of M2M apps and IoT is a valuable feature of D2D because the direct control of electronic client devices from the owner's cellphone without the need for network overload is interesting. Fourth, D2D is commonly used by the engorged macrocell networks as an additional technique for dumping traffic. Therefore, operators are currently examining the possibility of using D2D functions.

Several aspects of D2D are of particular significance. First, there is a similarity between spontaneous cellular networks and D2D, widely investigated in previous works. However, there is a major difference between the two, i.e., D2D can acknowledge minimal support from the network for management functions or keep up the communication if needed. One of the study challenges is selecting the simplest networking mode for use, which will be discussed later in this section. Second, the spectrum to be used and how it is distributed are essential. Several air interfaces and unlicensed/licensed spectra provide a direct connection between UEs. The typical advantages and disadvantages of both options will be discussed here. This form of communication can display its quality in a highly integrated manner with the rest of the network. Hence, once D2D is exploited in the unlicensed band, network operators may also enjoy less interference and congestion in their network [1,10].

Wireless relaying

A relay node included in Release 10 of LTE-A transmits data between the base station (eNB) and the user (user equipment (EU)). Using the Uu interface, the receives from and transmits to the relay node. On the other hand, the user will employ the UN interface to receive from and transmit to the base station node. Thus, each base station and the user is feasible for a relay node. Using relays has the following advantages: offering coverage in new areas where conventional backhaul is not allowed (for example, fibers) or mobile settings such as trains, temporary deployment of the network, and improving cell boundary and low-SNR-region throughput. There are also certain economic advantages as they are more affordable than a fully-operated base station. The need for wired backhaul would be removed, and eventually, the whole capacity used to serve the population of users can be, albeit without relays [1,10].

LTE Release 11 to 13

LTE Release 11 was frozen in March 2013, so 3GPP released the Stable Protocol. The key options for LTE Release 11 include the following: Advanced IP Interconnection of Services (IPXS), Anonymous Call Rejection (ACR) in the CS domain, Network-provided Location (NETLoc) information to IMS, Non-Voice Emergency Services (NOVES), Optimized Service Charging and Allocation of Resources in IMS whilst Roaming, QoS Control based on Subscriber Spending Limits (QOS-SSL), support for 3GPP voice interworking with enterprise IP-PBX, System Improvements for Machine-Type Communications (MTC), and so on [2].

LTE Releases 13 and 14

Release 13 and Release 14 act as a 4G to 5G infrastructure bridge. Features of Releases 13 and 14 include:

Full Dimension MIMO (FD-MIMO)

Licensed-Assisted Access (LAA)

CA Enhancements

Machine-Type Communications (MTC)

Latency Reduction

Vehicle-to-Vehicle (V2V) communication

Superposition Coding (SC)

Multimedia and Multicast [1]

## Full-Dimension MIMO (FD-MIMO)

FD-MIMO is one of the major technologies for the evolution to B4G and 5G cellular networks. It aims to use multiple antennas mounted on a 2D array panel, so that slender beams are formed vertically and horizontally. Such beamforming enables eNBs to be simultaneously transmitted to multiple UEs to understand high-order multi-user spatial multiplexing. Figure 2 shows eNB associated with FD-MIMO using a 2D antenna array panel where each antenna vigorously allows the precoding in all antennas to be adaptive and dynamic. eNBs will simultaneously make direct transmissions within elevation and azimuth domains for different EUs using such precoding. FD-MIMO's ability to recognize high-order multi-user spatial multiplexing is the key to system performance. Since December 2012, numerous studies have been carried out by 3GPP to provide FD-MIMO specification support. The first step was developing an alternative channel model for potential antenna technology analysis based on 2D antenna array panels. This model offers the random features of a 3D wireless channel. In September 2014, a follow-up analysis of FD-MIMO was launched to evaluate the performance advantages of the normal improvements to 2D antenna array operation with nearly 64 antenna ports using a standard transparent method, e.g., vertical sectorization by antenna elements in the vertical direction. Compared with previous LTE releases, FD-MIMO has two key distinctive features. First, there are eight antennas on the far side, which has increased to 64 here, for example. FD-MIMO, therefore, significantly increases the spatial multiplexing and beamforming capabilities. Second, FD-MIMO Specification Support is targeted at antennas mounted on 2D planar arrays. The exploitation of the 2-D planar placement also helps reduce the antennas' shape issue for sensible applications.[4,1,14]

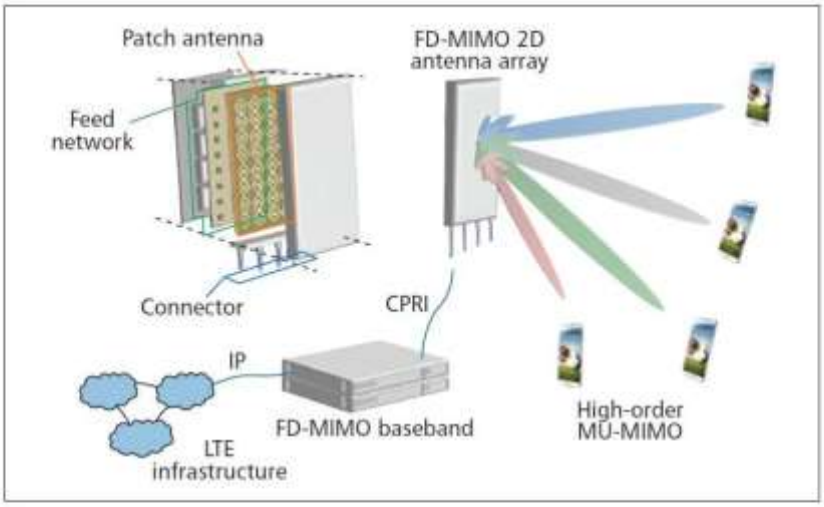


Fig 2. Conceptual diagram of an FD-MIMO system that realizes high-order MU-MIMO using a 2D antenna array

Licensed-Assisted Access (LAA)

LTE-A systems run in licensed bandwidth. Nevertheless, the bandwidth is prohibited and expensive. Therefore, there is a lot of concern about the further utilization of unlicensed bandwidth to accompany licensed bandwidth. It is complicated to coexist with unlicensed networks such as WiFi. The only mistreatment of unlicensed bandwidth was defined in the downlink transmission of Release 13. A few uplink practicalities were built for the use of uplink in future releases such as Release 14. By CA, unlicensed and licensed bands are included together in Release 13. A critical aspect of LAA is Listen-Before-Talk (LBT) function that tests if a band is active or idle before use. Release 14 will accept uplink CA. In Release 14, several protocol improvements will be introduced to expand LAA uplink [1,14,15].

CA Enhancements

As a natural approach to increasing the high rate and use of potent distributed frequency resources, CA of up to 5-element carriers with common TDD or FDD was laid out in Release 10 to support a most combined 100MHz bandwidth. Combining CA and MIMO yielded peak rates 3 and 1.5 Gb/s on the downlink and uplink, respectively. In Release 12, CA was extended to support the aggregation of FDD and TDD carriers. However, the constraint of aggregating the top five carriers remains unaddressed. This constraint limits business applications, considering the supply of a 5GHz unlicensed band, producing tens of 20MHz carriers. To boot, 3GPP is currently seeking to find out UE RF requirements to introduce CA with four downlink carriers. Business desires are expected to exceed the set limit of five downlink carriers in Release 12. Motivated by the above concerns, a new work item was approved for Release 13 to determine CA operation for up to 32 carriers (or cells), which might support a peak rate of 25 Gb/s. The most important specification impacts are uplink control signaling and reducing channel management cryptographic operations that a UE must perform. In accordance with the Release 12 design principle, channel decoding management operations needed for a UE will increase almost linearly with the number of planning cells the UE will support. In Release 13, CA limits this increase by eNBs, basically configuring the number of blind cryptographic operations a UE performs per carrier with various capabilities reported by the UE. The quantity of uplink control information (UCI) is enhanced to support HARQ-ACK information or channel state information (CSI) for a wide range of downlink carriers. Furthermore, a UE will be designed to transmit the UCI on a secondary cell (SCell) in addition to the primary cell (PCell) to reduce the control signaling overhead of the PCell.[1,14]

### Machine-Type Communication (MTC)

By Release 12, a cost reduction of around 500th for MTC user instrumentality was achieved relative to the lower-class LTE user equipment. It is expected that Release 13 will lead to another 500th drop in costs. This is also done, in part, by reducing the output power of the device to 20 dBm and its bandwidth to 1.4MHz. Narrow-band IoT (NB-IoT) is a different method embedded in Release 13. It has common objectives for the use of power, range, and quality of the device. However, it uses a 200kHz bandwidth that provides multiplied preparation legerity at the cost of a lower rate and multiplied delay. Remember that NB-IoT may also be suitable for 5G migration, promoting a considerable number of cheap devices [4,1,14].

### Latency Reduction

Latency is one of the major performance metrics for evaluating wireless communication systems. LTE supports a user plane latency of just 10 ms, and it is now accepted as a lower data latency system compared to previous generations of mobile radio technologies. However, considering various growing applications, tighter latency requirements have to be met, e.g., 1ms over-the-air (OTA) latency is being thought of as a vital requirement of 5G communication systems. 3GPP has started to study adoptable technologies for latency reduction, which are expected to be laid out in Release 14. Uplink data transmission includes a scheduling request (SR) from the UE, granting resources by the eNB, and transmission of data packets by the UE. The procedure of requesting a grant covers an immense part of the latency necessary for uplink data transmission, particularly for the transmission of small-sized payloads, such as TCP/IP acknowledgment (ACK)/negative-acknowledgement (NACK). Introducing a grant-less procedure, i.e., removing the request-grant procedure, would help achieve low latency for small packets. On the other hand, the request-grant procedure still helps serve huge packets because it enables efficient utilization of the precious spectrum resources. A further solution is to reduce the duration of the TTI. The TTI duration is 1 ms, depending on a two-slot subframe duration, corresponding to 14 OFDM symbols. Reducing the TTI length to one slot, i.e., 0.5 ms, or one OFDM symbol duration, i.e., 0.07 ms, can be sensible candidates because they allowed inheriting straightforward multiplexed signals and reduced TTI lengths. With the reduced TTI length, it would be natural to assume that the UE and eNB processing time are often proportionately reduced due to a smaller quantity of data. Figure 3 illustrates the latency incurred in the existing procedures. Table 2 shows the latency reduction by a grant-less procedure and TTI shortening. The OTA latency is under 1 ms for a grant-less procedure with a TTI length of one OFDM symbol [1,14].

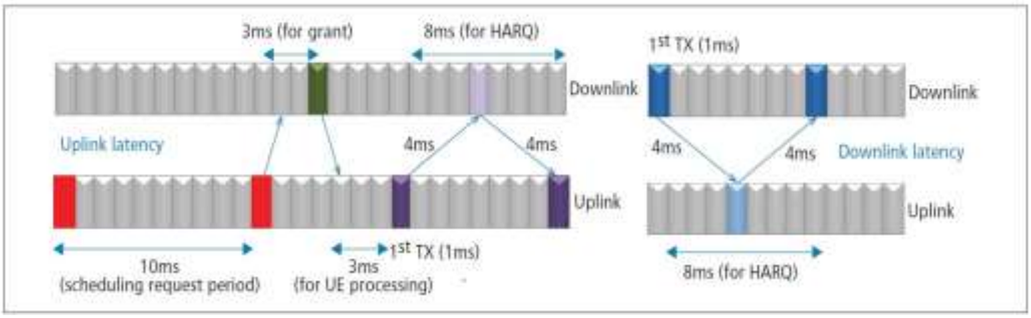


Fig 3. Uplink and downlink latency considering the grant procedure and HARQ, where the average delay of HARQ is 0.8ms assuming a 10% BLER and a maximum of 1 retransmission [14]

Table II. Latency analysis depending on TTI lengths, where UE processing time (UE Proc) is 1 TTI length for the grant-less case, and frame-alignment (FA) time slot is half the TTI length [14]

| TTI | SR | Grant | UE Proc | FA | TTI | Average HARQ delay | eNB Proc | Total uplink latency | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Grant procedure | Grant-less procedure |
| 1ms | 6ms | 3ms | 3ms | 0.5ms | 1ms | 0.8ms | 1.5ms | 15.8ms | 4.8ms |
| 0.5ms | 3ms | 1.5ms | 1.5ms | 0.25ms | 0.5ms | 0.4ms | 0.75ms | 7.9ms | 2.4ms |
| 0.07ms | 0.43ms | 0.21ms | 0.21ms | 0.04ms | 0.07ms | 0.06ms | 0.11ms | 1.13ms | 0.35ms |

## Vehicle-to-Vehicle (V2V) Communication

Vehicle-guided communication has several new and critical applications, including infotainment, monitoring traffic, the safety of vehicles, and telematics. Several studies have been carried out by 3GPP on the use of LTE networks to provide vehicle-to-vehicle (V2V) communication, vehicle-to-infrastructure (V2I) communication, vehicle-to-pedestrian (V2P) communication, or communication between alternate mobile users. This function is referred to as LTE vehicle-to-everything (V2X) communication. Alternative projects of wireless protocols exist for vehicles, such as IEEE 802.11p/WAVE (Wireless Access in Vehicular Environment). Nevertheless, LTE V2X is appealing owing to its potential for large space coverage, mobile user communication, and (spectrally) affordable V2I broadcast services. Release 13 lists the usage cases for V2X services and their specifications. The efficiency of certain LTE solutions for V2I, V2P, and V2V operation services is the subject of analysis to explain improvements that seem to begin in Release 14 [1,14].

### Superposition Coding (SC)

This is the application of downlink non-orthogonal transmissions without spatial separation. Assume a downlink transmission to a cell-boundary user and near-cell-center user as a related case. They are transmitted by the same beam. Typically, a greater transmitting power will be provided to the cell-boundary user. Its interaction with the cell-center user would be switched off until the cell-center user's corresponding signal is decoded. Release 13 described improvements in performance and requirements that could occur in Release 14 [1,14].

### Multimedia and Multicast

A LARGE PERCENTAGE OF NETWORK TRAFFIC VOLUME WITHIN THE YEARS TO RETURN IS RELATED TO MOBILE STREAMING VIDEO. PREPARING LTE BROADCAST (A.K.A. EVOLVED MULTIMEDIA BROADCAST MULTICAST SERVICES (EMBMS)) IS VERY INTERESTING TO PROVIDE MULTIPLE USERS WITH DOWNLOADING AND STREAMING CONTENT. ENHANCEMENTS TO THE EMBMS ARE USED IN CERTAIN APPLICATIONS, SUCH AS HIGHEST CONTENT, LINEAR TV, LIVE, VOD, AND SMART TV. CERTAIN IMPROVEMENTS MAY BE INCLUDED IN RELEASE 14, AND A FIERCE CARRIER WILL FINALLY BE THERE FOR EMBMS [1,14].

### IMT-Advanced Requirements

The 4G standard of mobile communications is set out in the requirements of IMT-Advanced. These requirements are imposed by ITU-R on every standard to turn into a 4G mobile communication system. Among these key requirements are IP core network, high peak data rates for stuck and mobile users, reduced latency during session initiation and termination, high-speed quality support, cell edge performance improvement, VoIP support, seamless property between a base station and a terminal across mobile networks, international roaming capacity, the capability of interworking with other radio access systems (backward compatibility), etc., for the key requirements and criteria for the analysis of IMT-Advanced [2,8].

### Conclusion

This paper reviewed the outstanding features of LTE from Release 8 to Releases 13 and 14. The first part of this paper demonstrated that 3GPP Release 10 met all IMT requirements and was even higher and acknowledged as a real 4G system. There are additional advanced releases of LTE, i.e., Releases 11 to 14, that are obtainable. Recently, 3GPP has been working on Releases 13 and 14 to develop more advanced systems than previous releases.

Abbreviations

LTE: Long-term evolution, IMT-Advanced: International Mobile Telecommunication Advanced, 3GPP: the third generation Partnership project

AMPS: Advanced Mobile Phone System, GSM: The Global System for Mobile, ITU: International Telecommunications Union

OFDMA: Orthogonal Frequency Division Multiple Access, CDMA: Code Division Multiple Access,

TDMA: Time-Division Multiple Access, NETLOC: Network-provided Location information, SCell: secondary cell, LBT: listen before talk, ANR: Automatic neighbor relation

UMTS: Universal Mobile Telecommunication System , HSPA: High Speed Packet Access plus , UTRAN: UMTS Terrestrial Radio Access Network, ICE: In Case of Emergency , SIM: subscriber identity module , SON: Self-Organizing Network, ck: ciphering key , MBMS: Multimedia Broadcast Multicast Services , PWS: Public Warning System , RN: relay node , HeNB: Home-eNB, RNC: Radio Network Control , MME: Mobility Management Entity , PDN: Packet Data Network, D2D: device-to-device communication, M2M: Machine to Machine Communication, ProSe: proximity services

1G:1st generation , 3G : 3rd generation ,2G: 2nd generation, 4G: fourth generation, eNB: Evolved NodeB , S-GW: Serving Gateway ,CA: Carrier Aggregation

FDD: Frequency Division Duplex , TDD: Time Division Duplex , SU-MIMO : single-user Multiple-Input Multiple-Output , SC-FDMA: Single carrier-Frequency Division Multiple Access , MU-MIMO : multi-user Multiple-Input Multiple-Output, LAA: Licensed Assisted Access , MTC: Machine Type Communications, FD-MIMO : Full Dimension MIMO

FA: frame alignment, eMBMS: evolved multimedia broadcast multicast service, SR: scheduling request, NB-IOT: narrow band internet of Things.

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