WHITE PAPER: **LTE Advanced**

Executive Summary

According to the Global Mobile Suppliers Association LTE (Long Term Evolution) is the fastest developing mobile system technology ever. Over 611 network operators in 174 countries are investing in the technology. With global mobile data traffic growing over 81 percent and 4G connections generating 14.5 times more traffic on average than a non-4G connection in 2013 naturally LTE is a worldwide success.

LTE was first introduced in 2008 as a 4G standard, but initially it did not meet the technical requirements set forth by the 3GPP. However, since this time its evolution path has been remarkable and it has even surpassed some of the 3GPP technical requirements with LTE Advanced. The variations of the original LTE technology offer much improved data speeds and bandwidth, along with many new key features; therefore, it is no wonder that LTE is gaining traction around the globe.

This whitepaper is a primer for anyone wanting to explore the evolution path of LTE and the key capabilities introduced by evolving standards that define LTE Advanced. It discusses the versions that have been introduced into the market, explores their advantages and history, and the regions where they are gaining traction.

When considering LTE and LTE Advanced it is critical that a business is architected for the future by ensuring their infrastructure is designed to enable LTE performance and LTE Advanced functions easily. This whitepaper also highlights ways in which JMA Wireless has approached this with its technology. It considers the future as part of the design and architecture to help ensure a business does not need to make substantial investments in order to take advantage of new technologies.

Evolution of Wireless Technology Leading up to the Advent of LTE

LTE is a progression of the digital cellular technology originally introduced in the early 1990s and coined 2G or second generation. 2G technology offered many benefits over its analog predecessor. With second generation communications, phone conversations and text messages were digitally encrypted, spectrum was used more efficiently to support the increasing number of mobile phone subscribers, and data services such as SMS (Short Message Service), text messages, photo sharing and MMS (Multi-media Messaging Service) were now possible.

Then in 1998 3G or third generation technology, based on mobile communications standards that comply with the International Mobile Telecommunications-2000 (IMT-2000) specifications, was introduced. 3G technology applied to a set of broader applications including not only wireless voice and messaging, but mobile and fixed wireless Internet access, video calls, and mobile TV. Later versions such as 3.5G, 3.75G and 3.9G expanded mobile broadband access to support several megabits per second (Mbps) connectivity to smartphones, tablets and laptops.

The evolution to fourth generation or 4G network specifications was first introduced in March 2008 by the International Telecommunications Union-Radio Communications Organization (ITU-R). Peak speed requirements for these new 4G networks were designated at 100 Mbps for high speed mobility communications (such as wireless connectivity while traveling on a train) and 1 Gbps for low mobility communications (such as wireless connectivity while walking or sitting stationary).

Unlike previous generations of mobile communications technology, 4G is only comprised of two standards – LTE and Wi-MAX. LTE is based on the previous GSM/EDGE and UMTS/HSPA standards, but also provides increased capacity and speed due to a different radio interface and core network improvements. Originally, the LTE technology was developed by the 3GPP (3rd Generation Partnership Project) based on Release 8 of a document series and Release 9 offered minor enhancements to it.

However, even though LTE and Wi-MAX were marketed as 4G wireless technologies they did not meet the technical requirements the 3GPP consortium adopted when developing new standards and were originally determined by the ITU-R organization regarding the IMT-Advanced specification. Then on December 6, 2010 the ITU-R determined that LTE and Wi-MAX could be officially considered 4G technologies even though they did not fulfill the requirements of the IMT-Advanced specification.

“True 4G” LTE Technology

Since its introduction in 2008, the LTE technology has been transforming and many different versions have been and continue to be introduced into the marketplace. Currently, LTE is deployed in approximately 20 different frequency bands, including 5 of the 6 channel bandwidth options. The most widely used spectrum for LTE technology offerings is 1800 MHz followed by the 2.6 GHz band.

In this whitepaper recent LTE versions will be explored. Their various key advantages and areas where they are gaining traction will be discussed.

LTE Advanced

The focus of LTE Advanced is to provide higher capacity in a cost efficient manner. 3GPP Release 10 defines LTE Advanced, which unlike its predecessor, completely fulfills the ITU's requirements for IMT Advanced, making it truly 4G. The 3GPP requirements include performance targets such as increased peak data rates (3 Gbps – downlink and 1.5 Gbps – uplink), higher spectral efficiency of 30 bps/Hz, support for an increased number of active subscribers simultaneously, and improved performance at cell edges. Plus LTE Advanced must be backwards compatible and fully operate with its predecessor, LTE. Finally, the 3GPP requires a commitment to continuous improvement efforts in the LTE technology.

Carrier Aggregation

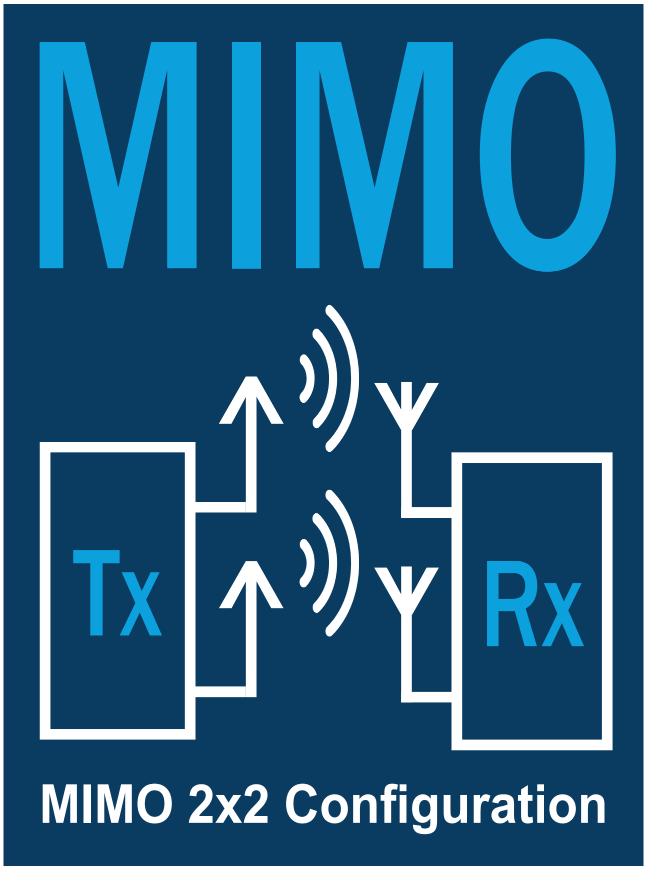
Carriers will gain many new features and enhancements as they upgrade their networks to the LTE Advanced technology. It offers increased capacity, higher bit rates and more bandwidth with a feature called Carrier Aggregation. Each aggregated carrier or component carrier can have a bandwidth of 1.4, 3, 5, 10, 15 or 20 MHz and a maximum of five component carriers can be aggregated to equal up to 100 MHz. Aggregation occurs across multiple carriers, multiple bands, and across licensed and unlicensed spectrum supporting LTE-TDD and LTE-FDD.

MIMO

In LTE Advanced there is enhanced usage of multi-antenna techniques such as MIMO (Multiple Input Multiple Output). The MIMO technique enables higher data rates than the standard technologies using multiple transmit and receive antennas to exploit multipath propagation.

By utilizing the multiple signal paths that exist between a transmitter and receiver MIMO significantly improves the data throughput available on a given channel with its defined bandwidth. With multiple antennas at the transmitter and receiver coupled with complex digital signal processing, MIMO sets up multiple data streams on the same channel resulting in increased data capacity. Furthermore, the MIMO technique intrinsically adds one or more diversity degrees in case of antenna malfunction; therefore, the other antennas can still operate independently.

LTE Advanced supports 8X8 MIMO in the downlink and 4X4 in the uplink to reach peak data rates and maintain higher spectral efficiency (bps/Hz).



CoMP

Another feature, CoMP or Coordinated Multi-point Transmission and Reception, is used mainly to improve capacity and provide a better user experience at cell edges. CoMP requires close coordination between a number of geographically separated eNBs (e-Utran Node B). They dynamically coordinate to provide joint scheduling and transmissions as well as support joint processing of the received signals.

HetNet

Finally, LTE Advanced supports advanced HetNet or heterogeneous network capabilities. It can ensure this via Relay Nodes (RNs). The Relay Nodes are low power base stations that enable enhanced coverage and capacity not only at cell edges and hot spots, but they also can be used to connect remote areas sans fiber.

LTE Advanced gained considerable traction in the marketplace this past year. Approximately 30% or 107 LTE operators are investing in LTE Advanced studies, deployments or trials. Presently, there are 49 commercially launched LTE Advanced networks in 31 countries.

Specifications	LTE	LTE Advanced
Standard	3GPP Release 9	3GPP Release 10
Bandwidth	1.4 MHz, 3.0 MHz, 5 MHz, 10 MHz, 15 MHz, 20 MHz	70 MHz Downlink (DL), 40 MHz Uplink (UL)
Data Rate	300 Mbps Downlink(DL) 4x4MIMO and 20 MHz, 75 Mbps Uplink(UL)	1.5 Gbps Downlink (DL), 500 Mbps Uplink (UL)
Theoretical Throughput	About 100 Mbps for single chain (20 MHz, 100RB, 64QAM), 400 Mbps for 4x4 MIMO. 25% of this is used for control/signaling (OVERHEAD)	2 times more than LTE
Maximum No. of Layers	2 (category-3) and 4 (category-4,5) in the downlink, 1 in the uplink	8 in the downlink, 4 in the uplink
Maximum No. of Codewords	2 in the downlink, 1 in the uplink	2 in the downlink, 2 in the uplink
Spectral Efficiency (peak,b/s/Hz)	16.3 for 4x4 MIMO in the downlink, 4.32 for 64QAM SISO case in the uplink	30 for 8x8 MIMO in the downlink, 15 for 4x4 MIMO in the uplink
PUSCH and PUCCH Transmission	Simultaneously not allowed	Simultaneously allowed
Modulation Schemes Supported	QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM
Access Techniques	OFDMA (DL), DFTS-OFDM (UL)	Hybrid OFDMA (DL), SC-FDMA (UL)
Carrier Aggregation	Not supported	Supported
Applications	Mobile broadband and VoIP	Mobile broadband and VoIP

450+ LTE networks are forecasted by 2016

LTE-TDD

LTE and LTE Advanced can be deployed in two different duplexing schemes. The first one, LTE-TDD or Long-Term Evolution Time Division Duplex technology (also referred to as TD-LTE), has been designated as the succession path for TD-SCDMA. It uses a single channel and a timed signal to separate uplinks and downlinks. Since LTE-TDD uses the same channel for reception and transmission it does not require paired spectrum. Also the downlink and uplink capacity ratio can be modified dynamically to match changing demands. However, compared to other versions of LTE a larger guard period may be necessary to maintain the uplink and downlink separation, which could compromise capacity. Nevertheless, LTE-TDD offers many benefits including higher spectrum efficiency, scalability, strong suitability for data-only devices and reduced hardware costs because a diplexer is not necessary to isolate transmissions and receptions.

Originally, LTE-TDD was developed and tested by a coalition of companies including China Mobile, Datang Telecom, Huawei, Nokia, Qualcomm, Intel, Samsung and ST-Ericsson. However, 58 companies in total made contributions to the 3GPP standardization process that specifically addressed LTE-TDD.

Trials of LTE-TDD technology began as early as 2010 in India. By 2011 China Mobile conducted technology trials in six cities. China Mobile, in particular, has been a proponent of the technology since LTE-TDD is the successor to TD-SCMDA, which is well established in China already. It has gained further traction in China this past year, along with other parts of Asia and the Pacific, making up 47% of the LTE-TDD networks deployed. However, with over 50 LTE-TDD networks currently in use and another 80 plus in the planning stage, the technology is being adopted in many other areas around the world too.

LTE-FDD

LTE and LTE Advanced can also be known as LTE-FDD or Long-Term Evolution Frequency Division Duplex, which is the migration path from 3G networks. With this duplexing scheme, LTE-FDD networks use two channels of paired spectrum separated with a guard period for uploads and downloads. However, the guard period does not affect capacity as it does with other versions of LTE. With LTE-FDD, capacity is determined by frequency allocated by regulatory authorities; therefore, it is not possible to change dynamically to support demands. Instead regulatory changes are normally required and capacity is usually allocated so that it is the same in either direction.

Originally, 52 companies from around the globe submitted contributions to the 3GPP standardization process regarding LTE-FDD. The technology configurations allow LTE-FDD to be deployed over 23 frequency bands supporting six potential channel bandwidths. It is more popular than LTE-TDD because it allows most operators to transform their existing 2G and 3G FDD networks into 4G.

LTE-TDD+LTE-FDD

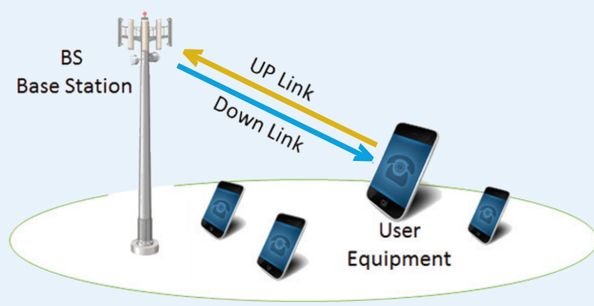
Combining LTE-TDD and LTE-FDD Networks

LTE-TDD offers the same features as LTE-FDD due to the efforts of the 3GPP and its member companies who were trying to avoid technology fragmentation and ensure better use of unpaired spectrum resources. However, some differences do exist. They mainly pertain to when an action occurs, not to why or how something is executed. The variances relate to the discontinuous downlink/uplink transmissions that are an inherent part of the TDD duplex scheme. There are also differences within each duplex scheme, which can be classified as options/configurations. As mentioned previously, LTE-FDD can be deployed over 23 frequency bands while LTE-TDD only supports 11 frequency bands due to different configurations.

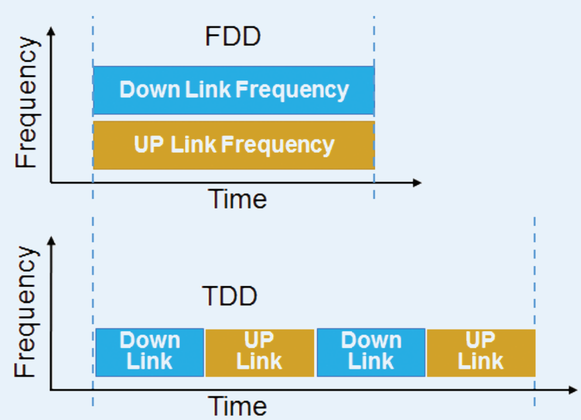
Explaining Duplex Schemes – FDD and TDD

Transmission for voice conversations needs to occur simultaneously in both directions. While data transmission can be virtually simultaneous or completely simultaneous in both directions. In order for transmission to occur, first its direction must be specified. The direction can be up or down or referred to as an uplink and downlink. Both are defined below:

- **Uplink: The transmission from the UE (user equipment) to the BS (base station).**
- **Downlink: The transmission from the BS (base station) to the UE (user equipment).**



User equipment and the base station must be able to transmit in both directions or have a duplex scheme, which can be FDD (frequency division duplex) or TDD (time division duplex). FDD uses two channels, one for transmitting and one for receiving. TDD uses one frequency, but allocates different time slots for transmission and reception.



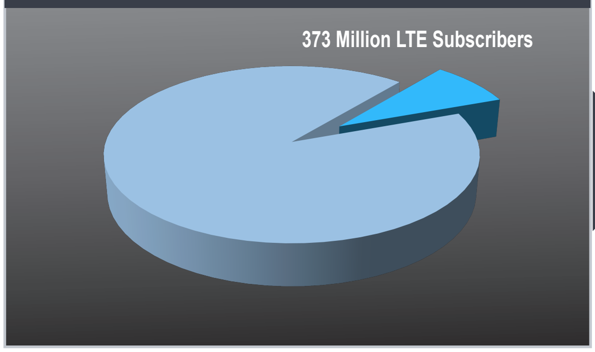
FDD and TDD Communication Schemes

LTE GLOBAL GROWTH

JMA WIRELESS

LTE Subscribers

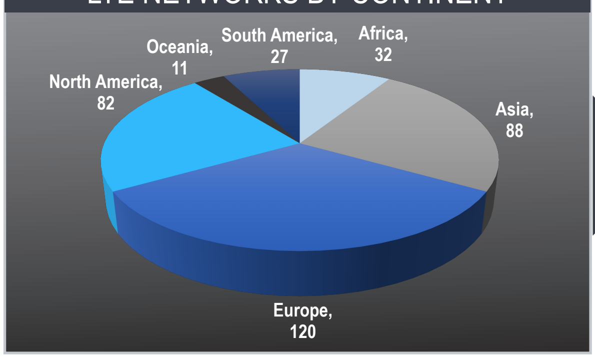
LTE SHARE OF GLOBAL SUBSCRIBERS



- Global mobile subscribers - all technologies: 4.7 billion
- LTE has 5.3% share of all mobile connections

LTE Networks

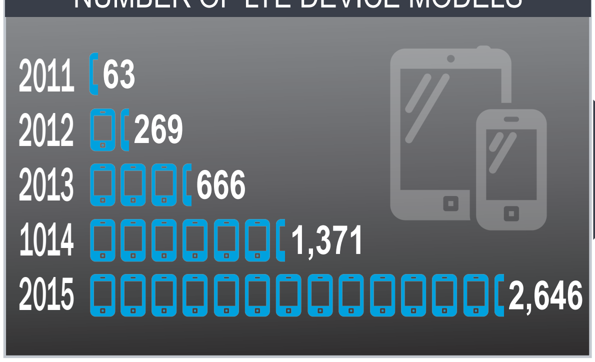
LTE NETWORKS BY CONTINENT



- 360 networks in 124 countries
- 566 LTE network commitments in 166 countries
- 45 more pre-commitment operator trials in 8 countries
- 611 total operators are investing in LTE in 174 countries
- 14 operators launched VoLTE-HD voice service in 7 countries

LTE User Devices

NUMBER OF LTE DEVICE MODELS



- Smartphones are the largest LTE device category
- There are 1,395 LTE smartphones representing 52.7% share of all LTE device types
- 969 devices support LTE TDD operation
- 186 LTE phones support VoLTE

March 2015, JMA Wireless

Initially spectrum availability will drive operators' choice between deploying LTE-TDD and LTE-FDD networks. However, it is predicted that over time a large number of operators around the world will implement both technologies to take advantage of all spectrum resources and to better support heterogeneous networks. LTE-TDD will be positioned in particular as an additional capacity layer for LTE-FDD networks. It will be used to offload worldwide mobile data traffic, which is predicted to increase by almost eleven-fold between 2014 and 2018 to an annual run rate of 190 exabytes (EBs) or 57 times the amount of mobile data traffic in 2010.

VoLTE

VoLTE (Voice over LTE) enables voice calls over LTE networks using an evolved version of Voice-over-IP (VoIP). It was originally developed because operators were searching for a standardized way to transfer voice over LTE networks. The One Voice profile for Voice over LTE was developed via a collaboration between forty plus operators. In addition, manufacturers such as Nokia and Alcatel-Lucent were involved in this development too. The technology is based on the IMS (IP Multimedia Subsystem) network with specific profiles related to voice service on LTE networks as defined by the GSMA in PRD IR.92.

With this technology, voice is transported as packets of data over the LTE networks. In order to implement VoLTE first technical changes have to be made in the carriers' networks as well as in the devices supporting it. New functionality is required in the core network. The devices must interact with the RAN (radio access network) differently. Plus they must operate in dual stack mode supporting both IPv4 and IPv6.

However, VoLTE offers subscribers improved call quality and longer talk times. In fact, VoLTE provides up to three times more voice and data capacity than 3G UMTS and six times more than 2G GSM networks. In addition, it supports HD audio and video for an improved user experience.

JMA Wireless Teko Platform: Ready for LTE Advanced and Beyond

Global wireless communications innovator, JMA Wireless, designs products that deliver powerful performance today, while ensuring an easy path to enable new technologies in the future. There is no need to "rip and replace" to support these advanced iterations. This philosophy and approach will ensure a business' infrastructure is ready for new versions of technologies such as LTE Advanced. Minimal to no changes have to be made to the existing network; therefore, providing an efficient and cost-effective solution to support the latest technologies in the marketplace.

The previously mentioned LTE Advanced capabilities such as Carrier Aggregation (CA), MIMO, and CoMP can be applied to DAS (distributed antenna system) deployments using the Teko platform.

- Multiple paths can be configured today where Teko systems are deployed, enabling venues to leverage LTE Advanced functions like Carrier Aggregation without making any changes to the venue.

- The Teko platform supports TDD and as the LTE Advanced networks evolve to TDD-FDD capabilities venues will be ready to enable this new capability.

- Teko is designed and deployed today to provide MIMO solutions that enhance end user performance, including 2X2 MIMO and 4X4 MIMO.
- CoMP allows for interleaved sector coverage utilizing the Teko system enabling the benefits of Inter-Sector Joint Reception CoMP to be extended to the DAS coverage. Intra-Sector scenarios are non-interfering and the Teko performance ensures no delays impact cyclic prefixes where multiple UL paths exist. These can be combined with MIMO capabilities where performance in Intra-sector leveraging antenna diversity capabilities of the BTS extended to DAS UEs.

In addition, below are just a few examples of the key future proof capabilities that JMA Wireless provides for LTE Advanced as well as for other technologies.

High Peak-to-Average Amplifier Ratio maintains excellent EVM performance and high-throughput to ensure LTE and UMTS performance as well as sector utilization efficiency.

Modular Sub-Rack prepares venues to be more adaptive to changing needs (i.e. new sectors) and easily introduces newer services into its existing DAS.

Transparently Adaptable Modulation allows new / upgraded technologies to be introduced into venues (i.e. LTE Advanced) without additional hardware or configuration changes.

Optimized Fiber Bandwidth Utilization enables venues to migrate to LTE Advanced while leveraging the existing fiber.

Software Configurable DAS Tray allows new / enhanced technologies (i.e. LTE MIMO) to be introduced into venues without replacing the existing DAS tray.

Adaptable BTS Interface Options enable reuse of existing sub-rack designs to adapt / migrate sites to different interface technologies.

Overall, venues utilizing a Teko DAS solution can expect a better end user experience as the platform delivers more precise and uniform coverage, providing lower UE transmit levels and thus lower interference.

Conclusion

The LTE technology has made many advancements since its introduction in 2008 by the 3GPP. One of the requirements mandated by the 3GPP is continuous technology improvements to support the growing mobile connectivity needs of subscribers. This is currently happening in the marketplace and companies involved with the technology are continuing to make enhancements. For example, recently there have been announcements regarding licensed LTE aggregating with unlicensed Wi-Fi spectrum to deliver high throughput data to smartphones, tablets and laptops.

Wherever the next version takes the LTE technology JMA Wireless will be there to support it. The company designs and builds wireless solutions with the future in mind. JMA Wireless ensures a business' architecture is future proofed to not only deliver increased efficiencies, but an overall improved return on investment.

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JMA Corporate Headquarters
7645 Henry Clay Boulevard
Liverpool, New York 1308
+1 315.431.7100
+1 888.201.6073
customerservice@jmawireless.com
www.jmawireless.com

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