Carrier Aggregation
Enabling LTE-A Technology

LTE-Advanced and features like carrier aggregation are the next step in the evolution of wireless networks.

SHIKHA NAGPAL

The standardisation of 3GPP Long Term Evolution has been completed in 2009 and numerous networks are in commercial operation around the globe. Still wireless broadband internet access, providing IP based services to mobile users, continues to grow rapidly worldwide. Therefore 3GPP has been working on further enhancements of the LTE air interface in 3GPP Release 10 and beyond. This new standard is called LTE Advance and fulfills all requirements as set by the ITU-R for 4G. It has been acknowledged by the industry that LTE Advanced will be the dominating 4G Technology globally. LTE Advanced promises to deliver peak data rates beyond a Gbps in up- and downlink by aggregation of multiple carriers up to 100 MHz. For new fragmented spectrum it increases flexibility, while keeping backward compatibility to LTE networks and terminals. By means of carrier aggregation LTE Advance can operate in bandwidths up to 100 MHz in contiguous or non-contiguous frequency allocations.

Carrier aggregation can tap LTE-Advanced

Carrier aggregation can tap the full potency of LTE-Advanced and solve the problems of spectrum availability. Vendors including Agilent Technologies, Aeroflex, Anritsu, and Spirent Communications have recently made news with regard to the test of LTE-Advanced carrier-aggregation technology.

Carrier aggregation helps carriers meet wireless uplink and downlink data-rate requirements for data-hungry applications and services—even when the carriers lack sufficient contiguous bandwidth to meet demand.

In the feasibility study for LTE-Advanced, 3GPP determined that today's LTE (Release 8/9) could meet most of the ITU's 4G requirements apart from uplink spectral efficiency and peak data rates. These requirements are being addressed in Release 10 LTE-Advanced with the following features: wider bandwidths, enabled by carrier aggregation; and higher efficiency, enabled by enhanced uplink multiple access and enhanced multiple antenna transmission (advanced MIMO techniques).

Release 8 LTE itself is new and complex, introducing such features as multiple channel bandwidths, different transmission schemes for the downlink and uplink, 2 transmission modes (FDD and TDD), and the use of multiple antenna techniques (MIMO). LTE-Advanced raises the bar on performance expectations, and the new technologies will have to co-exist and interoperate with each other and with legacy 2G and 3G deployments for years to come. The challenges for the engineers who design, test, and ultimately deploy LTE-Advanced are many.

Chaitanya Chakravarty M, Application Engineer–Wireless,EMG, Agilent Technologies

"Carrier aggregation (CA) is one of the key features of LTE-Advanced and is likely to be one of the earliest deployed technologies of LTE-Advanced. The basis of CA is to extend the maximum transmission bandwidth to up to 100 MHz, and that is done by aggregating up to 5 LTE carriers. When carriers are aggregated, each carrier is referred to as a component carrier. Two or more component

Chaitanya Chakravarty M
Application Engineer –Wireless, EMG,
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carriers are aggregated in order to support wider transmission bandwidths up to 100 MHz to meet peak data rate targets which are - 1Gbps in the downlink and 500 Mbps in the uplink. Three aggregation scenarios are possible, depending on the spectrum availability of the operators.

<u>Intra-band contiguous CA:</u> is a less likely scenario given frequency allocations today (If we look at current FDD spectrum allocation of the US for example, there are no allocations greater than 20MHz), however it can be common when new spectrum bands like 3.5 GHz are allocated in the future in various parts of the world. From implementation perspective, this type of aggregation is the least challenging in terms of hardware implementation.

<u>Intra-band Non-Contiguous CA :</u> can be expected in countries where spectrum allocation is non-contiguous within a single band, when the middle carriers are loaded with other users, or when network sharing is considered. This mode is postponed to Release 11

<u>Interband Non-Contiguous CA:</u> is the most realistic scenario since there is no contiguous wide spectrum to achieve the IMT-Advanced peak data rate

3GPP initially identified 12 likely deployment scenarios for Release 10. However, because of the number of the scenarios and limited time, some CA combinations were prioritized for Release 10. For intra-band CA, the first supported carrier bandwidths for FDD are 15 and 20 MHz in Band 1 and for TDD 10, 15 and 20 MHz bandwidths in Band 40. For inter-band, which is limited to FDD, bands 1 and 5 are supported for 10MHz CCs. Other combinations will be added in a release-independent manner."

Madhukar Tripathi, Regional Manager, Anritsu India Pvt Ltd

"Carrier Aggregation (CA) is one of the most fundamental and critical technologies used in cellular LTE-Advanced technology. Carrier Aggregation increases bandwidth and thereby increases bitrates which means higher data rate for consumer.

Carrier Aggregation was first introduced in 3GPP Release 10 and enhanced in 3GPP Release 11. Carrier Aggregation enables a network operator to combine radio channels within the same frequency band, or across different bands, to achieve much higher data rates and lower latency, allowing operators to use the technology in bandwidths wider than 20MHz. With Carrier Aggregation, LTE-A will allow aggregation of up to five LTE carriers, also known as component carriers (CCs), to

Madhukar Tripathi
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Anritsu India Pvt Ltd

With the continuous development and adoption of LTE-Advanced by telecom operators worldwide, the demand for Carrier Aggregation technology will pick up at a rapid rate. 2013 is just the beginning for Carrier Aggregation. We feel there will be demand for LTE-A related T&M in market in near future.

achieve a total effective bandwidth of 100MHz.

Carrier Aggregation allows 1Gpbs in the downlink and 500 Mbps in the upload, and targets to achieve wider bandwidth transmissions (higher data rates), more efficient use of fragmented spectrum, and more effective interference management for control channels in heterogeneous networks."

Shailendra Kalra, Director - Sales, Livingston India

"Carrier aggregation or channel aggregation enables multiple LTE carriers to be used together to provide higher data rates.To achieve these very high data rates it is necessary to increase the transmission bandwidths over those that can be supported by a single carrier or channel. Carrier aggregation is supported by both LTE's FDD and TDD variants. The target figures for data throughput in the downlink is 1Gbps for 4G LTE-Advanced. Even with the improvements in spectral efficiency it is not possible to provide the required headline data throughput rates within the maximum 20MHz channel. The only way to achieve the higher data rates is to increase the overall bandwidth used. The current standards allow for up to five 20MHz carriers to be aggregated, although in practice two or three is likely to be the practical limit. These aggregated carriers can be transmitted in parallel to or from the same terminal, thereby enabling a much higher throughput to be obtained

Implementing carrier aggregation in a network will mean that operators and infrastructure vendors will require a test mobile equipped with carrier aggregation, ahead of real mobile terminals becoming available. The variations permitted in carrier aggregation increase mobile device complexity. Receiving multiple frequencies with an overall increased bandwidth requires significant changes in the design of the receiver chain. End-user testing and base station testing therefore become extremely important.

The LTE networks with largest number of subscribers are generally limited to no more than 10MHz of contiguous spectrum .Dynamic Load balancing of LTE traffic between radio channels is the most compelling benefit of carrier aggregation, with the theoretical peak data rates for nearly all existing LTE subscribers increasing from 75Mbps to 150Mbps.

Many Western operators, including Verizon Wireless and EE are trialing the technology with commercial launches planned for the coming year. Some operators, however, need to wait until chipsets support channel bandwidths that are greater than 10MHz. TeliaSonera, for example, indicated that it has at least 15-20MHz radio channels in all of its markets so if it deployed carrier aggregation based on the capabilities of existing solutions, it would have to reduce the channel bandwidth for all legacy devices. In other words, not only would it not gain anything by deploying carrier aggregation it would also have to sacrifice performance for most of its installed base of devices.

Many chipset suppliers are initially targeting 10MHz + 10MHz implementations of carrier aggregation. This means that the peak end user throughput reaches 150Mbps with a Category 4 device. With a 20 MHz + 20 MHz implementation, peak speeds of 300Mbps are possible, just as peak speeds of 300Mbps are possible with 4x4 MIMO in a 20MHz channel."

Cellular infrastructure vendors need a reliable test mobile to test their networks ahead of the availability of real terminals and handsets, and providing them with carrier aggregation capability at this early stage is proving essential to the development of the eNodeBs that will be used to roll out LTE-Advanced.

Testing Carrier Aggregation

LTE-Advanced carrier aggregation is a complex and powerful technology enhancement. The variances permitted in carrier aggregation increase mobile device complexity. Receiving multiple frequencies with an overall increased bandwidth requires significant redesign in the receiver chain.

Primarily the increased data rate capabilities need to be tested on all layers (physical layer, protocol stack and E2E). It also requires verifying the correct end user behaviour in terms of correctly responding to RRC messages. At the base station, the major design challenge is at the transceiver frontend, which must support multiple band combinations. This requires the use of highly flexible switches, wideband power amplifiers and tuneable antenna elements.

Shailendra Kalra, Director - Sales, Livingston India

"With the advent of carrier aggregation, devices have to support multiple bands and multiple combinations of bands for aggregation which implies more power amplifiers and different receiver designs. Test system needs to support a number of network test and verification features and also needs to be able to create and run scripts to carry out tests in the various modes supported by the test mobile, which can be stored for later use. This includes the need for data logging while a test scenario is running, for later analysis of the test results, as well as customizable tools and charts for analysis.

Testing a mobile device that supports carrier aggregation will focus on the capability of the device to cope with the increased amount of data, which will be received with two receiving chains simultaneously thereby increasing the complexity of the transceiver circuits. It will be necessary for testing to take place on the physical layer, protocol stack and E2E. Cellular infrastructure vendors need a reliable test mobile to test their networks ahead of the availability of real terminals and handsets, and providing them with carrier aggregation capability at this early stage is proving essential to the development of the eNodeBs that will be used to roll out LTE-Advanced.

At the base station level, the major design challenge lies on the terminal side. Support of higher bandwidths and aggregating carriers in different frequency bands tremendously increases transceiver circuit complexity, including the design of components such as wideband power amplifiers, highly efficient switches and tunable antenna elements. This testing becomes significant because service providers use component carriers or elements from multiple operators that need to be compatible and with equivalent standards. Further the additional functionality provided to PHY/MAC layer and the adaptations to the RRC layer need to be thoroughly tested

In order to provide the equipment necessary to test LTE carrier aggregation, Livingston has partnered with companies like Spirent, Agilent, Rohde & Schwarz and Anritsu.It thus has a broad offering which includes signal generators , analyzers and scanners for performing physical layer tests on base stations, as well as base station emulators for physical layer and protocol tests for all kind of wireless devices and chipsets.

Chaitanya Chakravarty M, Application Engineer–Wireless, EMG, Agilent Technologies

"Carrier aggregation has several implications for the RF characteristics. From RF perspective, intra-band contiguous aggregated carriers have similar properties as a corresponding wider carrier being transmitted and received. However the output power dynamics are impacted by the UE architecture, which may be based on single or multiple PAs. When considering the PA configuration, one must take into account additional back-off requirements that may exist due to combination of carrier aggregation and the other new UL features such as clustering introduced in Release 10 which requires more stringent linearity requirements on the PA than was the case for Release 8/9. When using multiple component carriers, the maximum output power of a UE must be reduced in order to keep the amplifier in the linear region. UE maximum output power is a critical parameter that limits the UL coverage of a network so reduced transmission power means limited UL coverage. So for a UE, increasing the bandwidth does not always result in an increase of the user performance. Because of that, use of multiple uplink carriers needs to be an option that is only used for cases where UEs are not at the cell edge, thus ensuring that the cell-edge data rate is not reduced. The other test challenge is to analyze the multiple transmit and receive chains simultaneously. When an eNB transmits multiple component carriers to a UE, the multiple component carriers must arrive at the receiver at the same time, time alignment error of 1.3 µs for inter-band and 130 ns for intra-band are specified for downlink. This requires simultaneous demodulation of the multiple component carriers. Higher order MIMO will increase the need for simultaneous transceivers in a manner similar to carrier aggregation. However, MIMO has an additional challenge in that the number of antennas will multiply, and the MIMO antennas will have to be de-correlated. It will be especially difficult to design multiband, MIMO antennas with good de-correlation to operate in the small space of a 4G UE. Conducted testing of higher order MIMO terminals will no longer be usable for predicting actual radiated performance in an operational network. The introduction of clustered SC-FDMA in the uplink allows frequency selective scheduling within a component carrier for better link performance, and the PUCCH and PUSCH can be scheduled together to reduce latency. However, clustered SC-FDMA increases peak to average power ratio (PAR) by several dB, adding to transmitter linearity issues. Simultaneous PUCCH and PUSCH also increase PAR. Both features create multi-carrier signals within the channel bandwidth and increase the opportunity for in-channel and adjacent channel spur generation. Test tools will need to be enhanced with capability for signal generation and analysis of multicarrier signals in 4G power amplifiers.

The Solutions from Agilent's Side:

1. Agilent LTE-Advanced library as a part of ADS, The industry's first commercial design support for the physical layer of 3GPP Release 10. It enables system and algorithm developers to explore their new designs against the new standard. They can directly download test vectors to instruments for early and continuous hardware validation, accelerating design maturity. And the MIMO Channel Builder and Digital Pre-distortion applications also support Release 10.

2. LTE-Advanced signal generation and signal analysis tools, enabling design engineers to start testing LTE-Advanced physical layer implementations today. They include the flexible and easy-to-use Signal Studio that runs on all the Agilent signal generation hardware platforms including the PXB and the 89600B vector signal analysis (VSA) software that runs on signal analyzers, scopes and logic analyzers.

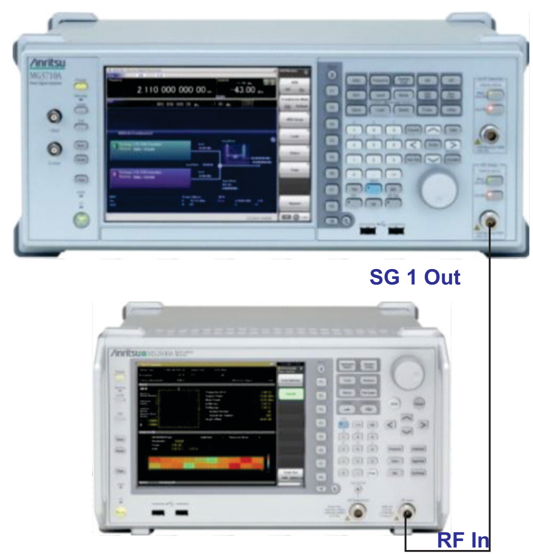
Madhukar Tripathi, Regional Manager, Anritsu India Pvt Ltd

"Substantial growth of mobile data usages will demand for right testing tools for LTE-A/ Carrier Aggregation. We see extensive test challenges in LTE-A device design & testing. Carrier Aggregation will also play a major role in interference management in LTE-A using SON systems. New spectrum band standardization will need right T&M for LTE-A success. Heterogeneous network creates more complex situations as far as testing is concerned."

Anritsu offers various Test solutions for LTE Advanced network& devices. LTE A networks are tested at various stages. This includes UE (peak data rates-UL/DL, Protocol Conformance Test, RF Conformance test), Handover test, Base Station & other components of mobile network.

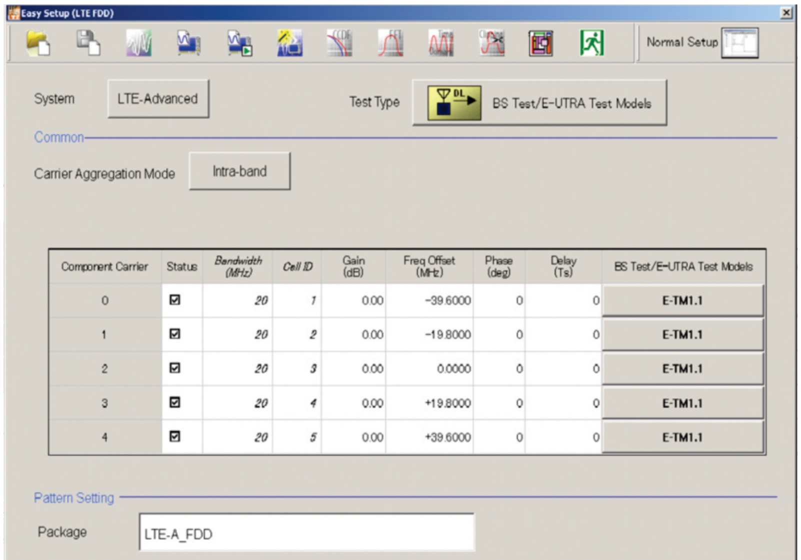
Example:

Measuring Five Continuous Intra-band Carrier Aggregations



Connection Setup (5 Intra-band Continuous Carrier Aggregations)

Anritsu MD8430A signaling tester is the first complete LTE Base Station Emulator. Couple the MF6900A Fading Simulator with the MD8430A Base Station Emulator to provide a reproducible



IQproducer Settings (5 Intra-band Continuous Carrier Aggregations)

fading environment that is essential for evaluating LTE. Our high-performance MS269xA Signal Analyzer provides complete LTE uplink and downlink analysis in a one-box platform that includes signal analysis and signal generation. Our MG3700A Vector Signal Generator produces realistic and reproducible LTE signals and our LTE IQProducer software provides a graphical interface that lets the user easily generate LTE-compliant waveforms.

Ideal tool for R&D: MS269xA Signal Analyzer is Vector Signal Analyzer and Vector Signal Generator in one box.

Anritsu Vector Signal Generator MG3710A is ideally suited solution to produce LTE –A signal for DL & UL to perform R&D testing on front end device or Base Station Radio components. MG3710A can generate all CA in one unit.

MG2691A Signal Analyzer/ MS2830A Signal Analyzer is single box for LTE –A test.

Anritsu Protocol Test Solution: Anritsu's MD8430A Signaling Tester was the only test instrument to win a prestigious CTIA Emerging Technology (E-Tech) Award, announced during the International CTIA WIRELESSS 2009 show in Las Vegas. The MD8430A, the industry's first LTE base station simulator, earned a second prize in the 4G-Service Creation & Development category of the E-Tech Awards, which recognize the finest wireless products and services

MD8430A Signaling tester with the new Rapid Test Designer (RTD) based solution for full VoLTE services. This technology has already been adopted in the field, proving its credentials and capability as a complete IMS signaling and LTE signaling solution within a single environment. Within the same test platform Anritsu also demonstrating full LTE-Advanced test capability with Carrier Aggregation. Carrier Aggregation technology can also be demonstrated operating on both RF and Protocol conformance test solutions.

The MD8430A is a highly accurate cost-effective solution for manufacturers of LTE chipsets and mobile devices to evaluate their products and improve time to market. Developed in conjunction with leading chipset manufacturers, the MD8430A augments Anritsu's broad 3GPP test suite, providing developers of wireless devices and systems with a single-source test solution company.

The MD8430A is designed with 4 RF units that enable 2x2 MIMO system handover tests in a simulated network environment. The base station simulator can conduct end-to-end testing at downlink speeds up to 150 Mbps and uplink speeds up to 50 Mbps. All critical 3GPP air-interface LTE protocol tests, including baseband coding/decoding processing tests; protocol sequence tests, such as position registration, origination, termination, handover, terminal and network disconnect tests; and application tests, are supported. Powerful L1/L2 cache analysis functions are provided as well.

MD8430A with RTD is ideal tool to perform Conformance testing according to GSMA standard TS.09

Battery Life test is also performed using MD8430A Signalling tester.Anritsu also leads Mobile Device Test System solution for LTE-A

MD8430A is central component of Anritsu Mobile Device test platform ME7834L &the ME7838L LTE RRM/RF RFCT. ME7834L provides both Carrier Acceptance Test (CAT)&Protocol Conformance Test (PCT). Anritsu support largest number of test cases on these platform which proves our leadership in LTE A testing.