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LTE Resource Guide

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Abstract

According to data released in January 2015, at least 360 operators have commercially launched LTE service in 124 countries. LTE-Advanced Carrier Aggregation (CA) deployment was the major trend in 2014, with 49 operators commercially launching it in 31 countries (Source: GSA). The primary reason for the transition from 3G technology to LTE is the benefits that this technology provides to both the consumer and operator, including increased bandwidth, lower network latency and lower cost per data bit to the carrier.

With any new technology comes a host of technical challenges, so these areas must be tested and optimized before deployment. For LTE/LTE-A, these challenges include optimizing and maximizing data rates under a variety of conditions, ensuring seamless handovers to current 2G and 3G networks, and verifying that the devices roam to the correct network when outside "home" area. Only after these and other parameters are tested and optimized can the quality of the LTE devices and network equipment be assured.

Anritsu is proud to offer a complete lineup of LTE/LTE-A R&D and Conformance/Carrier Acceptance Test solutions to ensure the performance and quality of LTE/LTE-A devices and network equipment. For LTE/LTE-A device-focused testing, the MD8430A Signaling Tester is the complete LTE network simulator, with capability to simulate up to six cells on four RF channels (including 2x2 and 4x2 MIMO), and optional fading using the MF6900A Baseband Fading Simulator. A variety of user interfaces are available for this instrument, including C-scenarios, Testing and Test Control Notation (TTCN), and the unique device Rapid Test Designer (RTD) graphical environment. The MD8430A is used as a building block in turnkey LTE test systems including both the ME7834L LTE Protocol Conformance & Carrier Acceptance Test System as well as the market-leading ME7873L RF Conformance & Carrier Acceptance Test System.

Anritsu also offers a complete portfolio of one-box solutions for functional test, application test, and RF test of LTE User Equipment (UE). The MT8820C Radio Communication Analyzer is focused on providing physical layer test capability for 2G, 3G, and 4G/LTE devices, with options for call-based/no-call parametric test, high-speed calibration, and functional test. The MD8475A Signaling Tester is focused on providing upper-layer test capability for the same range of devices, with capability for applications test, battery life test, and other types of functional test.

Anritsu offers several solutions for physical layer testing of LTE/LTE-A UE, Evolved Node Bs (eNBs), and components. The MS269xA and MS2830A Spectrum/Signal Analyzers support LTE-A Carrier Aggregation testing and can evaluate up to five Component Carriers (CCs) across up to three bands on one screen. They are also available with an integrated vector signal generator that can be used for LTE/LTE-A receiver or component testing. The MG3710A Vector Signal Generator offers dual RF outputs and two waveform memories per port, enabling the generation of up to four independently modulated signals. It is especially well suited to generating LTE-A Inter-band CA signals and for supporting complex interference rejection tests that require multiple modulated or CW signals. Up to four MG3710A's can be phase and pattern locked, enabling the simulation of up to 8-way MIMO signaling. For signal generation in any of these platforms, the PC- or instrument-based LTE IQproducer software provides a graphical interface that makes it easy for the user to quickly generate compliant FDD or TDD downlink or uplink waveforms. For field and other portable applications, Anritsu also offers LTE analysis using the PIM (Passive Intermodulation) Master, BTS Master, Cell Master, and Spectrum Master series of products, with available vector signal generator capability in the MT8220T BTS Master.

This LTE Resource Guide provides in-depth knowledge of LTE and LTE-Advanced and serves as an excellent educational and reference tool on the technology. Areas covered include modulation formats, network components, frame structures, and physical channels and signals, with focus on both LTE and LTE Advanced.

References

All 3rd Generation Partnership Project (3GPP) TS 36 series standards are available at:
http://www.3gpp.org/ftp/Specs/html-info/36-series.htm

- 3GPP TS 36.101: User Equipment (WIRELESS DEVICE) Radio Transmission and Reception
- 3GPP TS 36.104: Base Station (BS) Radio Transmission and Reception
- 3GPP TS 36.141: BS Conformance Testing
- 3GPP TS 36.201: Physical Layer - General Description
- 3GPP TS 36.211: Physical Channels and Modulation
- 3GPP TS 36.212: Multiplexing and Channel Coding
- 3GPP TS 36.213: Physical Layer Procedures
- 3GPP TS 36.214: Physical Layer - Measurements
- 3GPP TS 36.300: Overall description
- 3GPP TS 36.508: Common Test Environments for UE Conformance Testing
- 3GPP TS 36.521-1: UE Conformance Specification; Radio Transmission and Reception; Part 1: Conformance Testing
- 3GPP TS 36.521-3: UE Conformance Specification; Radio Transmission and Reception; Part 3: Radio Resource
- Management (RRM) Conformance Testing
- 3GPP TS 36.521-3: UE Conformance Specification; Part 1: Protocol Conformance Specification

LTE - The de facto Mobile Access Standard

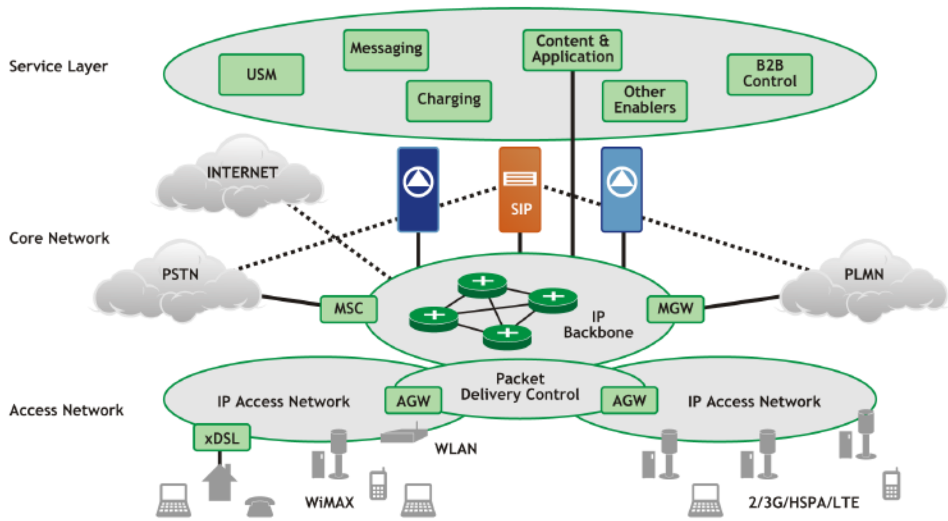


Figure 1 LTE supports the Next Generation Network by providing mobile access to an all-IP core.

Traditionally, operators have built multiple networks such as fixed telephone networks, cable TV networks, cellular telephone networks and data networks to provide fixed and mobile services to customers. The Next Generation Network (NGN) provides a flat all-IP core that interconnects multiple access technologies and provides a consistent and reliable user experience regardless of the access method, allowing the merging of these multiple access technologies into a single network. The NGN core will provide Quality of Service (QoS) support and a wide variety of applications and services. The NGN access network will provide mobility and routing management and ensure that the core sees any mobile network simply as another IP network. Mobile handover between access types will be seamless as the IP access network controls security, authentication, and billing for each of the access technologies.

LTE is the first access technology designed explicitly for the NGN, and is set to become the de-facto NGN mobile access network standard. It is designed to provide an always-on mobile data experience comparable to wired networks.

- LTE Release 8 supports peak data rates of up to 300 Mbps on the downlink and 75 Mbps on the uplink with a 20 MHz channel and 4x4 MIMO. A more common configuration of 20 MHz and 2x2 MIMO supports peak rates of 150 Mbps on the downlink and 50 Mbps on the uplink.
- LTE Advanced (Release 10) supports peak data rates of up to 1200 Mbps on the downlink and 600 Mbps on the uplink using both Carrier Aggregation (CA) and higher-order MIMO.
- LTE provides flexible duplex methods including both Frequency Division Duplex (FDD) and Time Division Duplex (TDD). This allows LTE technology to fit within either existing or new carrier spectrum allocations.
- LTE Rel. 8 supports scalable RF channel bandwidths from 1.4 MHz to 20 MHz.
- LTE Advanced supports CA with up to five 20 MHz carriers for a total of 100 MHz operating bandwidth.
- LTE interoperates with CDMA2000, W-CDMA and GSM systems. Multimode wireless devices support handover to and from these other systems.
- LTE provides a mechanism to interoperate in a limited fashion with other access technologies such as Wi-Fi (802.11)

OFDMA

The downlink LTE air interface is based on Orthogonal Frequency Domain Multiplexing Access (OFDMA), a multi-carrier scheme that allocates radio resources to multiple users based on frequency (subcarriers) and time (symbols) using Orthogonal Frequency Division Multiplexing (OFDM). For LTE, OFDM subcarriers are typically spaced at 15 kHz and modulated with QPSK, 16-QAM, or 64-QAM modulation.

OFDMA allows a network to flexibly assign bandwidth to a user based on bandwidth needs and the user's data plan. Unassigned subcarriers are switched off, thus reducing power consumption and interference. OFDMA uses OFDM; however, it is the scheduling and assignment of radio resources that makes OFDMA distinctive. The OFDM diagram in Figure 2 shows a scenario where the subcarriers assigned to a set of users are static for a period of time. In the OFDMA diagram, multiple users flexibly share the subcarriers, with differing bandwidth available to different users at different times.

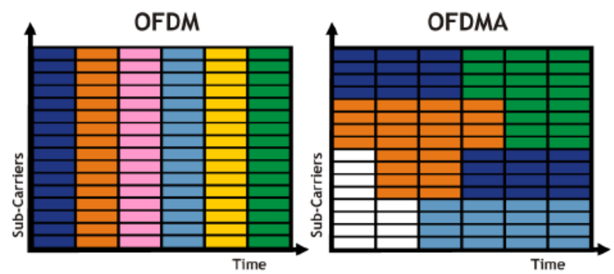


Figure 2 OFDM vs. OFDMA. Each color represents a burst of user data. In a given period, OFDMA allows users to share the available bandwidth.

SC-FDMA

In the uplink, LTE uses a pre-coded version of OFDM called Single Carrier Frequency Domain Multiple Access (SC-FDMA). SC-FDMA is used in place of OFDMA due to several factors, including the high current requirements for OFDMA-based power amplifiers and correspondingly short battery life. Lower Peak-to-Average Power Ratio for SC-FDMA-based power amplifiers results in extended battery life along with improved uplink performance.

In SC-FDMA, data is spread across multiple subcarriers.

This differs from OFDMA, where each subcarrier transports unique data. The need for a complex receiver makes SC- FDMA unacceptable for the downlink due to size and processing power limitations in a wireless device.

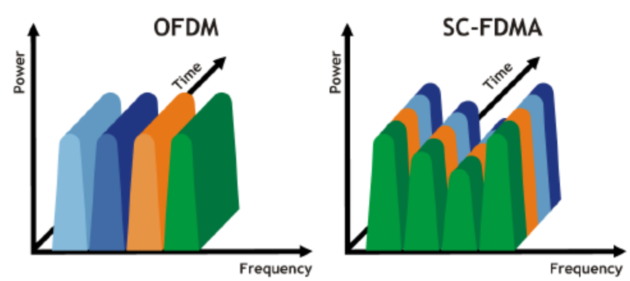


Figure 3 In OFDM, each frequency component carries unique information. In SC-FDMA, the information is spread across multiple subcarriers.

Multiple Input Multiple Output (MIMO)

Most modern wireless communication techniques use MIMO to increase the data rate to a user as well as to provide better coverage at the cell edge. Various techniques are available, including transmission of separate data streams from each antenna (spatial multiplexing), transmission of identical streams of data from each antenna (transmit diversity), reception on multiple antennas (receive diversity), and various combinations thereof. These techniques can be generalized as Single Input Single Output (SISO), Single Input Multiple Output (SIMO), Multiple Input Single Output (MISO), and Multiple Input Multiple Output (MIMO) as shown in figure 4.

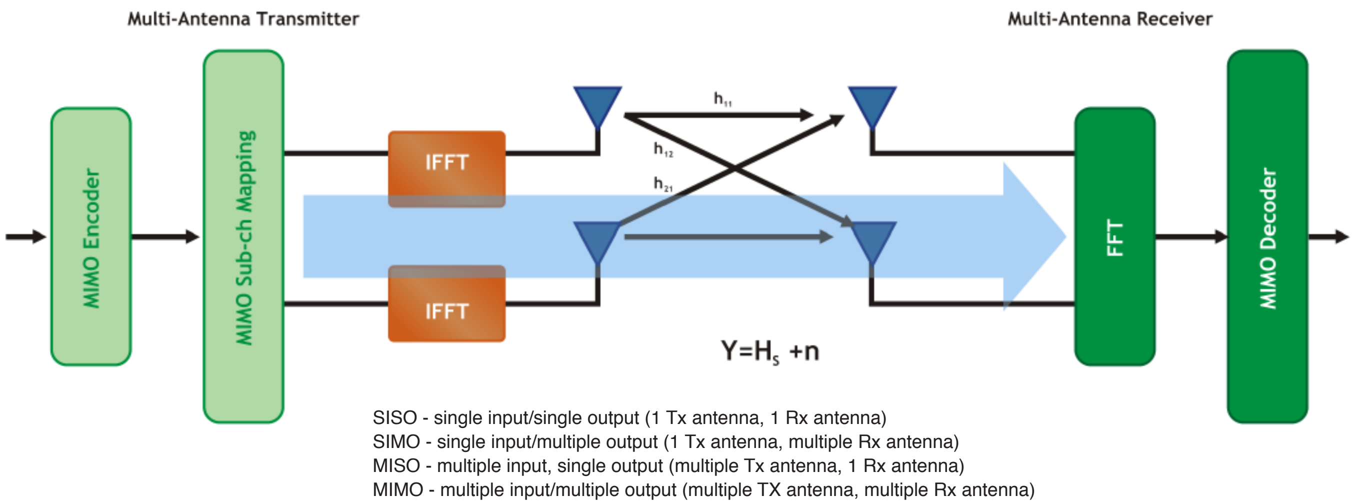


Figure 4 MIMO

For LTE Rel. 8, downlink MIMO configurations from SISO to 2x2 and 4x4 MIMO are supported, and the MIMO configuration changes dynamically based on measurement reports from the wireless device. For LTE Advanced, MIMO configurations up to 8x8 in the downlink and 4x4 in the uplink are supported in combination with Carrier Aggregation (CA), which uses multiple carriers.

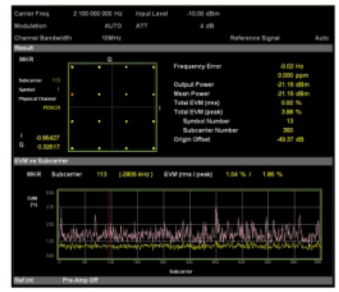
For LTE Rel. 8, when a user is close to a base station and propagation conditions are optimal, 2x2 MIMO may be used with a high data rate to the wireless device. When a user is at a cell edge, one or both of the diversity modes may be used to increase the Signal to Interference plus Noise Ratio (SINR).

Adaptive Modulation/Coding (AMC) and Spatial Multiplexing

Adaptive Modulation and Coding (AMC) refers to the ability of the network to dynamically set the modulation type and coding rate based on the current RF channel conditions, which are determined by Call Quality Indicator (CQI) measurement reports from the wireless device and re-transmission attempts from the HARQ (Hybrid Automatic Repeat Request) acknowledgement/re-transmission process. In addition to AMC, the MIMO mode can be dynamically set to Transmit Diversity or one of several Spatial Multiplex modes. This is based on additional channel conditions reported by the LTE device using the Rank Indicator (RI).

QPSK (4-QAM), 2 bits per symbol

The modulation used to transport data on each subcarrier can be QPSK, 16-QAM, or 64- QAM. This is illustrated in the pictures to the right, showing the ideal constellation for each type of modulation with each dot representing a symbol. In the QPSK case, there are four possible symbol states, and each symbol carries two bits of information. In 16-QAM, there are 16 symbol states, with each symbol carrying 4 bits of information. Lastly, in 64-QAM, there are 64 symbol states, and each symbol carries 6 bits. Higher-order modulation is more sensitive to poor channel conditions than lower-order modulation because the detector in the receiver must resolve smaller amplitude and phase differences as the constellation becomes more dense. Based on this, the network would set the modulation to a lower order if poor channel conditions are reported by the wireless device.



16-QAM , 4 bits per symbol

Coding refers to various error-correction methodologies that add extra bits to the data stream to allow for error detection and correction. Specified as fractions, Code Rates specify the number of data bits in the numerator and the total number of bits in the denominator. Thus if the Code Rate is 1/3, protection bits are added so one bit of data is sent as three bits. If errors are reported by the wireless device, the network would increase the error correction to compensate.

64-QAM, 6 bits per symbol

eMBMS

Operators need solutions allowing them to decrease network traffic while continuing to provide a similar level of service to customers. One of these solutions is MBMS/eMBMS.

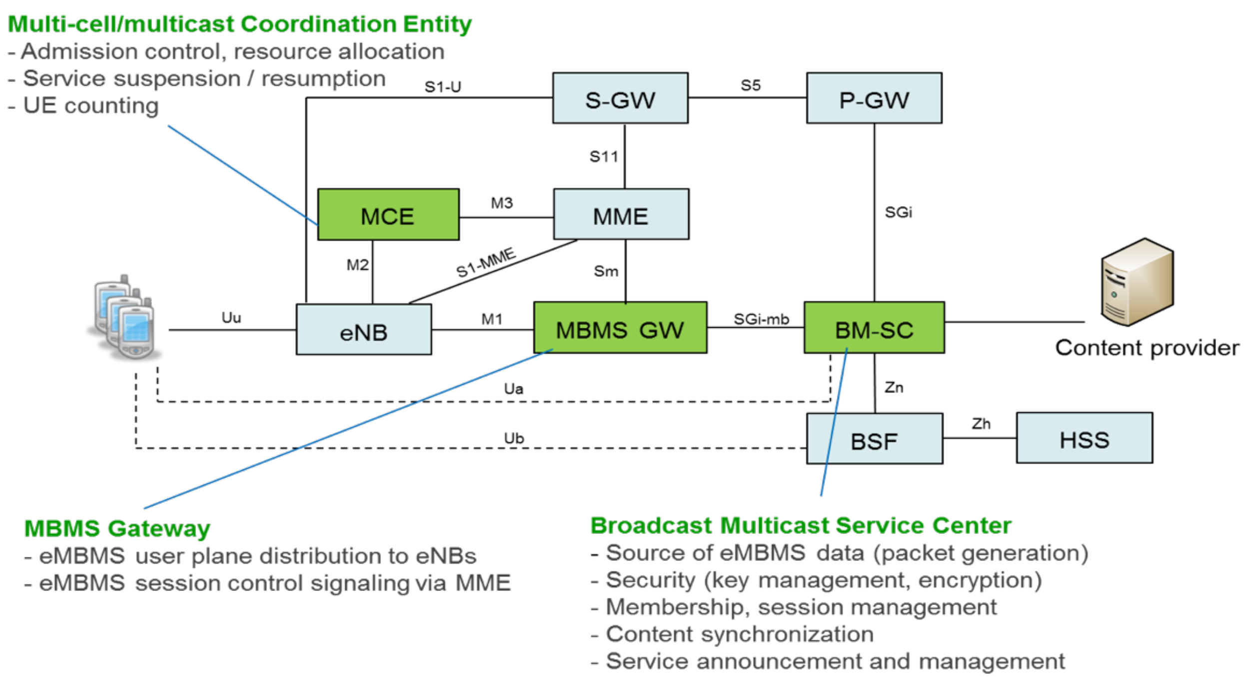
Multimedia Broadcast Multicast Services (MBMS) is a point-to-multipoint transmission method in 3GPP networks. It is designed to provide efficient delivery of broadcast and multicast services, mainly multimedia but also other streaming services such as software updates, both within a cell as well as within the core network. Broadcast transmissions can be done both in a single cell and across multiple cells in a synchronised way so that the UE can receive the broadcast signal from many receivers (and combine it which improves signal robustness). It can then also move within the range of the MBMS access network while staying tuned to the signal and without the need of being explicitly handed over between cells, which reduces signalling overhead.

eMBMS (enhanced Multimedia Broadcast Multicast Services) is the LTE version of MBMS. eMBMS is part of Release 9, and is designed to work for both FDD and TDD LTE. eMBMS provides functionality similar to other broadcast technologies such as DVB-H/T/SH, DMB or former MediaFLO, but has some advantages over these technologies, such as no additional infrastructure required, and no additional spectrum required.

eMBMS continued

For security purposes eMBMS-related signaling also uses the BSF (Bootstrapping Server Function) and the HSS (Home Subscriber Server). The BSF is used for HTTP Digest AKA (Authentication and Key Agreement); the BSF also performs key derivation and provides the keys to the BM-SC, which distributes the keys and uses them for data encryption.

To improve the transport efficiency the IP Multicast shall be used for the eMBMS payload distribution in the backbone network between the MBMS-GW and the eNBs that have joined the IP Multicast Group. Synchronization information (SYNC) is required between the BM-SC and eNB for the purpose of multi-cell operation, as all eNBs need to send exactly the same data with the same settings (MCS, mapping to physical layer) at exactly the same time.



eMBMS Logical Architecture

eMBMS reuses existing LTE, Core Network and Internet Protocols. There are two types of services available over eMBMS:

Download, based on FLUTE (File Delivery over Unidirectional Transport) with the option of file repair over unicast bearers.

Streaming, based on DASH (Dynamic Adaptive Streaming over HTTP) for content stream formatting.
The FEC (Forward Error Correction) is used in eMBMS transport protocols, allowing to correct some of the bit errors that can happen on the radio interface. Due to the unidirectional nature of eMBMS streams other low-latency correction schemes are not available as they would require feedback from the receiver. However, the file download service enables P2M file repair based on feedback from UEs over unicast bearers.

LTE NETWORK COMPONENTS

Major LTE Network Elements and Functions

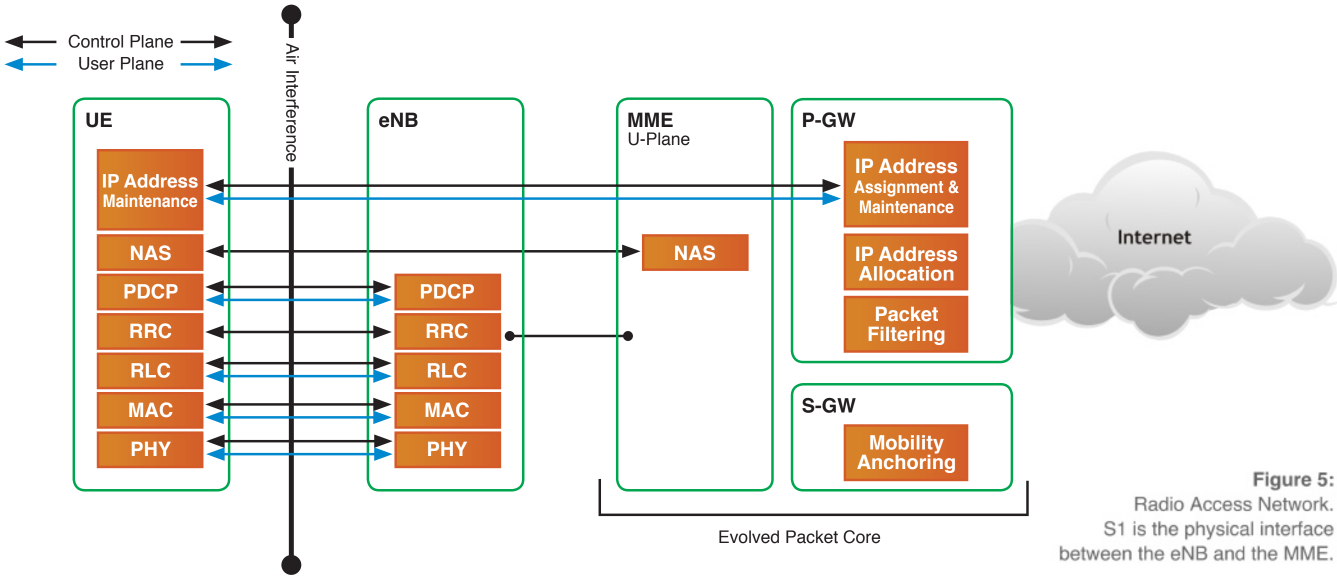


Figure 5:
Radio Access Network.
S1 is the physical interface between the eNB and the MME.

User Equipment (UE)

- Access device for user.
- Provides measurements that indicate channel conditions to the network.
- Includes the UICC (SIM card).

Evolved Node B (eNB)

- Hosts the PHYsical (PHY), Medium Access Control (MAC), Radio Link Control (RLC), and Packet Data Convergence Protocol (PDCP) layers.
- Controls user-plane header-compression and encryption.
- Provides Radio Resource Control (RRC) functionality for the control plane.
- Radio Resource Management-admission control, scheduling, enforcement of negotiated uplink QoS, cell information broadcast, ciphering/deciphering of user and control plane data, and compression and decompression of downlink and uplink user-plane packet headers.

PDN Gateway (P-GW)

- Provides connectivity between the UE and external packet data networks (PDNs) by being the point of egress and ingress for UE traffic (A UE may have simultaneous connectivity with more than one P-GW for accessing multiple PDNs).
- Performs policy enforcement, packet filtering for each user, charging support, lawful Interception, and packet screening.
- Acts as the anchor for mobility between 3GPP and non-3GPP technologies such as Wi-Fi and 3GPP2 (CDMA2000 1xRTTand EV-DO).

Major LTE Network Elements and Functions continued

Mobility Management Entity (MME)

- Acts as the key control node for the LTE network.
- Responsible for idle mode UE tracking and paging procedures.
- Controls bearer activation/deactivation process.
- Selects the Serving Gateway (S-GW) for a UE at initial attachment and at the time of intra-LTE handover.
- Authenticates the user by interacting with the Home Subscriber Server (HSS) [Not shown in diagram].
- Serves as the termination point for the Non-Access Stratum (NAS) signaling. NAS signaling is responsible for generation and allocation of temporary identities to UEs and checks the authorization of the UE to camp on the system.
- Serves as the termination point for ciphering and integrity protection for NAS signaling.
- Handles security key management.
- Provides control plane function for mobility between LTE and other access networks.

Serving Gateway (S-GW)

- Routes and forwards user data packets.
- Acts as the mobility anchor for the user plane during inter-eNB handovers and as the anchor for mobility between LTE and other 3GPP technologies.
- Terminates the downlink data path for idle state UEs and triggers paging when DL data arrives for the UE.
- Manages and stores UE contexts, e.g. parameters of the IP bearer service and network internal routing information.

EPS Data Bearers and IP Access

The services provided by an LTE network are IP services, and are accessed by the UE via the PDN Gateway; the data is carried on data bearers. While a complete discussion of all the aspects of a data bearer is beyond the scope of this guide, there are some aspects that are useful to understand. Data bearers are connections between the UE and the P-GW and they sit “higher” than the radio bearers as shown in Figure 5.

In an LTE network deployment, there may be multiple PDN Gateways present. Each will be used for different services, depending on how the operator has designed their network. A simple way to think about this is that one P-GW could be used for access to the public internet and another could be used for access to operator provided services (such as VoLTE). Proper testing of a UE requires the network simulator to be capable of simulating the proper P-GW configuration as defined in either the industry test plan or the operator Carrier Acceptance Test Plan.

There are two types of data bearers in LTE: Default and Dedicated. The Default Bearer is set up as part of the initial connection between the UE and the P-GW; Dedicated Bearers may be set up and torn down as needed. Different services require different levels of performance, which introduces the concept of Quality of Service. The QoS Class Identifier (QCI) is used to communicate the different levels of service during the setup of the Data Bearer. The Table below (Figure 5.1) is taken from 3GPP TS 23.203 and shows the different types of QoS available for Data Bearers.

QCI	Resource Type	Priority	Packet Delay Budget	Packet Error Loss Rate	Example Services
1	Guaranteed Bit Rate	2	100 ms	A	Conversational Voice
2		4	150 ms	B	Conversational Video (Live Streaming)
3		3	50 ms	B	Real Time Gaming
4		5	300 ms	C	Non-Conversational Video (Buffered Streaming)
5	Non-Guaranteed Bit Rate	1	100 ms	C	IMS Signaling
6		6	300 ms	C	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7		7	100 ms	B	Voice, Video (Live Streaming), Interactive Gaming
8		8	300 ms	C	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
9		9	300 ms	C	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)

Figure 5.1 Table showing the different types of QoS available for Data Bearers

When testing with a Network Simulator, it is not always necessary to simulate the actual performance of the Data Bearer as defined by the QCI, but it is necessary to support the signaling to properly configure the Data Bearer.

[1]3GPP TS 23.203: Policy and Control Architecture And it needs this path to find it: http://www.3gpp.org/ftp/Specs/html-info/23-series.htm

FRAME STRUCTURES

Frame Structures

In LTE, downlink and uplink transmissions are organized into frames that are 10 milliseconds (ms) long. A frame is divided into 10 subframes that are 1 ms each, and a subframe is divided into 2 slots that are 0.5 ms each. Each slot contains 7 symbols, where Ts (Sample Time) is the amount of time dedicated to each OFDM sample, and is the basic unit of time for LTE. Ts is defined as Ts = 1/(15000 x 2048) seconds or about 32.6 nanoseconds. The frame, subframe, and slot structure for LTE is illustrated in Figure 6.

Two frame types are defined for LTE: Type 1, used in Frequency Division Duplexing (FDD) and Type 2, used in Time Division Duplexing (TDD). Type 1 frames consist of 20 slots with slot duration of 0.5 ms as discussed previously. Type 2 frames contain two half frames, where at least one of the half frames contains a special subframe carrying three fields of switch information including Downlink Pilot Time Slot (DwPTS), Guard Period (GP) and Uplink Pilot Time Slot (UpPTS). If the switch time is 10 ms, the switch information occurs only in subframe one. If the switch time is 5 ms, the switch information occurs in both half frames, first in subframe one, and again in subframe six. Subframes 0 and 5 and DwPTS are always reserved for downlink transmission. UpPTS and the subframe immediately following UpPTS are reserved for uplink transmission. Other subframes can be used for either uplink or downlink. Frame Type 2 is illustrated in Figure 7.

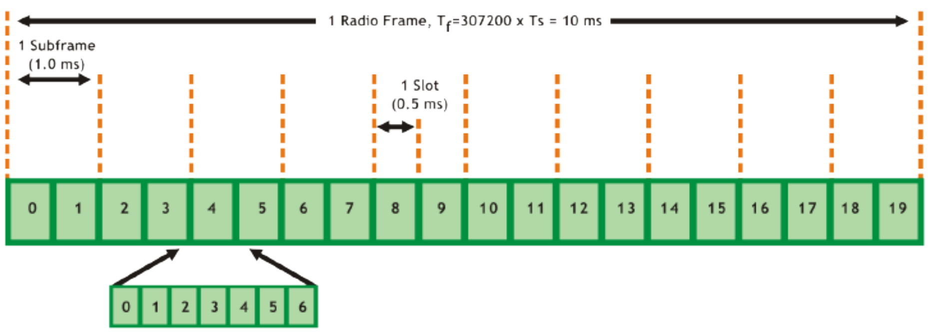


Figure 6: Type 1 Frame Type.
Timing and symbol allocations shown for FDD with normal cyclic prefix (CP).

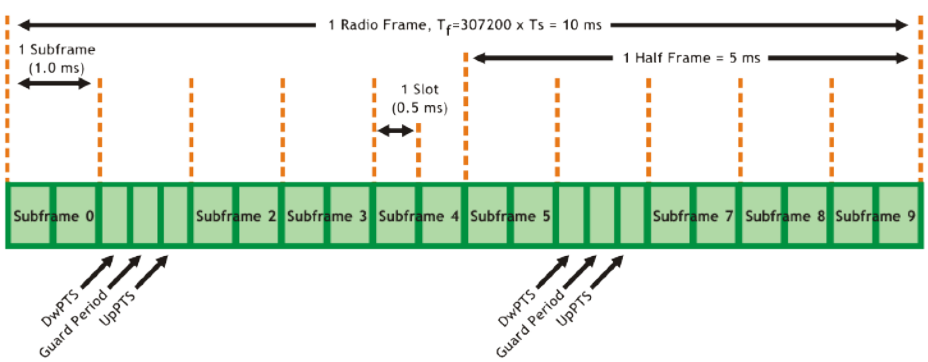


Figure 7: Type 2 frame type. Special fields are shown in Subframes 1 and 6.
Guard period separates the Downlink and Uplink. This TDD example represents a 5 ms switch point.
A 10 ms switch point would not have the special fields in subframe 6.

FRAME STRUCTURES

LTE Frame Structure and Bandwidth Concepts

As explained previously, in LTE, 10 one ms subframes comprize a 10 ms frame, two 0.5 ms slots comprize a one ms subframe, and 7 symbols comprize a 0.5 ms slot. Moving from this time-domain viewpoint to one taking into account both time and frequency aspects, the smallest modulation structure in LTE is one symbol in time vs. one Resource Element (RE).

Resource Elements are further aggregated into dimensions of 7 symbols by 12 subcarriers. The number of symbols in a RB depends on the Cyclic Prefix (CP) in use. When a normal CP is used, the RB contains seven symbols. When an extended CP is used due to extreme delay spread or multimedia broadcast modes, the RB contains six symbols. Figure 8 shows the relationship between a slot, symbols and Resource Blocks. N^{DL}_{RB} is the symbol used to indicate the maximum number of downlink Resource Blocks for a given bandwidth.

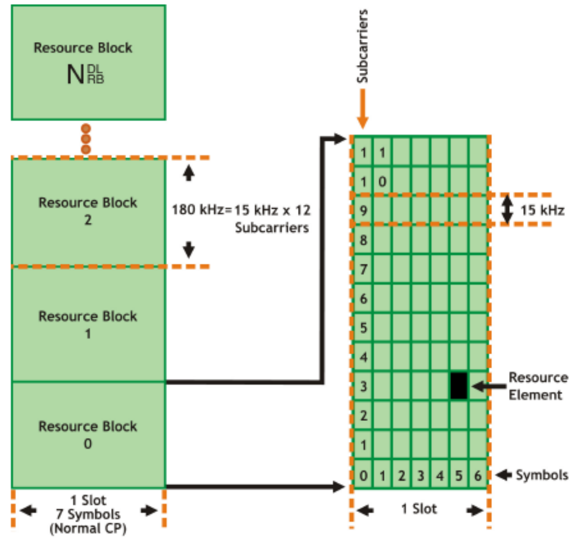


Figure 8: Relationship between a slot, symbols and Resource Blocks. N^{DL}_{RB} is the symbol used to indicate the maximum number of downlink Resource Blocks for a given bandwidth.

Physically, channel bandwidth is the width of the channel in frequency as measured from the lowest channel edge to the highest channel edge. Inunpaired spectrum, channel bandwidth is simply the width of the channel in frequency. In paired spectrum, channel bandwidth is the width of the uplink or downlink in frequency (typically the same for LTE, although asymmetric bandwidths are allowed for LTE Advanced).

The number of RBs that can fit within a channel varies proportionally to the bandwidth of the channel. Logically, as the channel bandwidth increases, the number of RBs can increase. The Transmission Bandwidth Configuration is the maximum number of Resource Blocks that can fit within the channel bandwidth with some guard band. For a channel with the maximum channel bandwidth of 20 MHz (for LTE Rel. 8), 100 RBs can fit within this bandwidth. These concepts are shown in Figure 9.

Spectrum allocations are managed by local regulatory agencies such as auction or other similar means. The spectrum allocated may be paired spectrum for use with FDD communications, or unpaired spectrum for use with TDD communications.

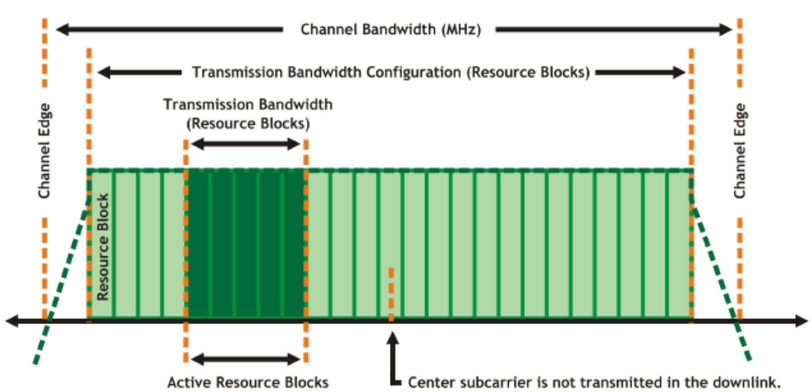


Figure 9: Relationships between Channel Bandwidth, Transmission Bandwidth Configuration, and Transmission Bandwidth.

Channel Bandwidth (MHz)	Maximum Number of Resource Blocks (Transmission Bandwidth Configuration)	Maximum Occupied Bandwidth (MHz)
1.4	6	1.08
3	15	2.7
5	25	4.5
10	50	9.0
15	75	13.5
20	100	18.0

Figure 10: Transmission Bandwidth Configuration.

PHYSICAL CHANNELS & SIGNALS

LTE Downlink Channels and Signals

The LTE frame is defined in terms of physical channels and physical signals, which are positioned by the LTE standard at specific positions in the frame in terms of subcarriers and symbols, respectively. Channels are defined as carrying information receivedfrom higher layers. Signals are defined asoriginating at the physical layer. The next sections will review the functions of these physical layer channels and signals as well as their positioning in the frame structure.

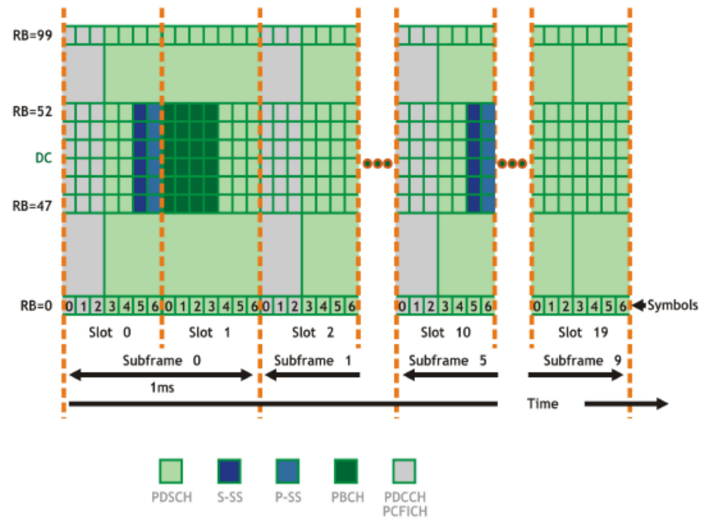


Figure 11: This diagram of a downlink frame using FDD and normal CP shows the relative location of the various physical channels. Frames in systems using extended CP or TDD would be slightly different.

Downlink Physical Channels

Physical Downlink Shared Channel (PDSCH)
Used to transport user data, the PDSCH is designed for high data rates. Modulation options include QPSK, 16-QAM, and 64-QAM. Spatial multiplexing is exclusive to the PDSCH. The RBs associated with this channel are shared among users.

Physical Broadcast Channel (PBCH)
The PBCH is used to send cell-specific system identification and access control parameters every 4th frame (40 ms). The PBCH uses QPSK modulation.

Physical Control Format Indicator Channel (PCFICH)
The PCFICH is used to inform the wireless device how many OFDM symbols will be used for the PDCCH in a subframe. The PCFICH uses QPSK modulation.

Physical Downlink Control Channel (PDCCH)
The PDCCH is used to transmit uplink and downlink resource scheduling allocations to the wireless devices. The PDCCH maps onto resource elements in up to the first three OFDM symbols of the first slot of a subframe and uses QPSK modulation. The value of the PCFICH indicates the number of symbols used for the PDCCH (not shown in diagram).

Physical Multicast Channel (PMCH)
The PMCH carries multimedia broadcast information and, like the PDSCH, has multiple options for modulation including QPSK, 16-QAM, or 64-QAM. Multicast information can be sent to multiple wireless devices simultaneously (not shown in diagram).

Physical Hybrid ARQ Indicator Channel (PHICH)
PHICH carries ACK/NACKs in response to uplink transmissions in order to request retransmission or confirm the receipt of blocks of data. ACKs and NACKs are part of the HARQ mechanism (not shown in diagram).

Downlink Physical Channels

Reference Signal (RS)
Wireless devices use the RS for downlink channel estimation. They allow the wireless device to effectively demodulate the downlink signal.

RS's are the product of a two-dimensional orthogonal sequence and a two-dimensional pseudo-random sequence. There are three different sequences available for the orthogonal sequence and 170 possible sequences for the pseudorandom number (PRN), resulting in 510 possible RS sequences. The RS uses the first and fifth symbols under normal Cyclic Prefix (CP) operation, and the first and fourth symbols for extended CP operation; the location of the RS on the subcarriers varies.

Primary and Secondary Synchronization Signal (P-SS and S-SS)
Wireless devices use the Primary Synchronization Signal (P-SS) for timing and frequency acquisition during cell search. The P-SS carries part of the cell ID and provides slot timing synchronization. It is transmitted on 62 of the reserved 72 subcarriers (6 Resource Blocks) around DC on symbol 6 in slot 0 and 10 and uses one of three Zadoff-Chu sequences.

Wireless devices use the Secondary Synchronization Signal (S-SS) in cell search. It provides frame timing synchronization and the remainder of the cell ID, and is transmitted on 62 of the reserved 72 subcarriers (6 Resource Blocks) around DC on symbol 5 in slot 0 and 10. The S-SS uses two 31-bit binary sequences and BPSK modulation.

LTE Uplink Channels and Signals

Uplink Physical Channels

Physical Uplink Control Channel (PUCCH)
The PUCCH carries uplink control information and is never transmitted simultaneously with PUSCH data. PUCCH conveys control information including Channel Quality Indication (CQI), ACK/NACK responses of the UE to the HARQ mechanism, and uplink scheduling requests.

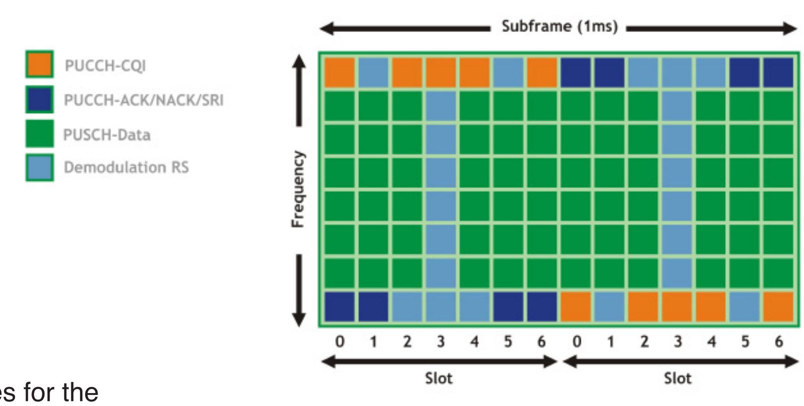


Figure 12: LTE Uplink Subframe with Normal Cyclic Prefix.

Physical Uplink Shared Channel (PUSCH)
Uplink user data is carried by the PUSCH. Resources for the PUSCH are allocated on a sub-frame basis by the UL scheduler. Subcarriers are allocated in units of RB's, and may be hopped from sub-frame to sub-frame. The PUSCH may employ QPSK, 16-QAM, or 64-QAM modulation.

Physical Random Access Channel (PRACH)
The PRACH carries the random access preamble and coordinates and transports random requests for service from UE's. The PRACH channel transmits access requests (bursts) when a wireless device desires to access the LTE network (call origination or paging response).

Uplink Reference Signal

There are two variants of the UL reference signal. The demodulation reference signal facilitates coherent demodulation, and is transmitted in the fourth SC-FDMA symbol of the slot. A sounding reference signal is also used to facilitate frequency-dependent scheduling. Both variants of the UL reference signal use Constant Amplitude Zero Autocorrelation (CAZAC) sequences.

PHYSICAL CHANNELS & SIGNALS

LTE Bands, Channel Bandwidths and Frequency Allocations

LTE Operating Bands indicates the carrier frequency to be used. Not all LTE frequency bands support all bandwidths. The chart includes both FDD and TDD bands.

LTE FDD/TDD Bands

3GPP TS 36.101-1 V10.3.0 (2011-06) Table 5.5-1E-UTRA operating bands			
E-UTRA Operating Band	Uplink (UL) Operating Band BS Receive / UE Transmit	Downlink (DL) Operating Band BS Transmit	Duplex Mode
	^{F}UL low - ^{F}UL High	^{F}DL low - ^{F}DL High	
1	1920 MHz - 1980 MHz	2110 MHz - 2170 MHz	FDD
2	1850 MHz - 1910 MHz	1930 MHz - 1990 MHz	FDD
3	1710 MHz - 1785 MHz	1805 MHz - 1880 MHz	FDD
4	1710 MHz - 1755 MHz	2110 MHz - 2155 MHz	FDD
5	824 MHz - 849 MHz	869 MHz - 894 MHz	FDD
6*	830 MHz - 840 MHz	875 MHz - 885 MHz	FDD
7	2500 MHz - 2570 MHz	2620 MHz - 2690 MHz	FDD
8	880 MHz - 915 MHz	925 MHz - 960 MHz	FDD
9	1749.9 MHz - 1784.9 MHz	1844.9 MHz - 1879.9 MHz	FDD
10	1710 MHz - 1770 MHz	2110 MHz - 2170 MHz	FDD
11	1427.9 MHz - 1447.9 MHz	1475.9 MHz - 1495.9 MHz	FDD
12	698 MHz - 716 MHz	728 MHz - 746 MHz	FDD
13	777 MHz - 787 MHz	746 MHz - 756 MHz	FDD
14	788 MHz - 798 MHz	758 MHz - 768 MHz	FDD
15	Reserved	Reserved	FDD
16	Reserved	Reserved	FDD
17	704 MHz - 716 MHz	734 MHz - 746 MHz	FDD
18	815 MHz - 830 MHz	860 MHz - 875 MHz	FDD
19	830 MHz - 845 MHz	875 MHz - 890 MHz	FDD
20	832 MHz - 862 MHz	791 MHz - 821 MHz	FDD
21	1447.9 MHz - 1462.9 MHz	1495.9 MHz - 1510.9 MHz	FDD
22			
23	2000 MHz - 2020 MHz	2180 MHz - 2200 MHz	FDD
24	1626.5 MHz - 1660.5 MHz	1525 MHz - 1559 MHz	FDD
25	1850 MHz - 1915 MHz	1930 MHz - 1995 MHz	FDD
33	1900 MHz - 1920 MHz	1900 MHz - 1920 MHz	TDD
34	2010 MHz - 2025 MHz	2010 MHz - 2025 MHz	TDD
35	1850 MHz - 1910 MHz	1850 MHz - 1910 MHz	TDD
36	1930 MHz - 1990 MHz	1930 MHz - 1990 MHz	TDD
37	1910 MHz - 1930 MHz	1910 MHz - 1930 MHz	TDD
38	2570 MHz - 2620 MHz	2570 MHz - 2620 MHz	TDD
39	1880 MHz - 1920 MHz	1880 MHz - 1920 MHz	TDD
40	2300 MHz - 2400 MHz	2300 MHz - 2400 MHz	TDD
41	2496 MHz - 2690 MHz	2496 MHz - 2690 MHz	TDD
42	3400 MHz - 3600 MHz	3400 MHz - 3600 MHz	TDD
43	3600 MHz - 3800 MHz	3600 MHz - 3800 MHz	TDD

Note: Band 6 is not applicable

Figure 13: Bands and Channel Bandwidths.

PHYSICAL CHANNELS & SIGNALS

Technology Additions to LTE for LTE Advanced

LTE Advanced is designed to be backwards compatible with LTE Rel. 8 and 9. Based on this target, LTE Advanced has “advanced” in 3 key areas including Carrier Aggregation, advanced MIMO techniques, and enhancements in the uplink.

Carrier Aggregation (CA) - In LTE Advanced, multiple carriers can be used together to increase throughput in the downlink and/or uplink. Up to 5 Component Carriers (CCs) can be used together with a maximum bandwidth of 100 MHz (5 x 20 MHz). Contiguous and non-contiguous CCs are allowed, and possible combinations include inter-band contiguous, inter-band non-contiguous, and intra-band. Due to the wide variety of possible bands involved in CA, three band combinations scenarios have been standardized in Release 10 including:

Band 40 contiguous   Band 1 & 5 inter-band   Band 3 & 8 inter-band

Advanced MIMO - LTE Advanced allows for increases in number of antennas on both the transmit and receive sides, as well as the potential for higher throughput from multiple spatial streams. Four to eight antennas can be used on the transmit side in the downlink, with the baseline configuration being 4x4. Peak rates of 1200 MB/s can be reached with an 8x8 configuration and optimum propagation conditions. One to four antennas can be used on the transmit side in the uplink, with the baseline configuration being 2x2. Peak rates of 600 MB/s can be reached with a 4x4 configuration and optimum propagation conditions.

New LTE device categories 6, 7, and 8 have been created for LTE Advanced to reflect the use of CA and Advanced MIMO as shown in Figure 14.

Enhanced Uplink - Two basic enhancements have been made to the uplink for LTE Advanced. First, LTE Rel. 8 was designed such that an LTE device would never use the PUCCH unless it had no data to send, and would normally combine control and data information into the PUSCH. This has been optimized in LTE Advanced, and sending of information on the PUCCH and PUSCH have been decoupled.

LTE Rel. 8 and SC-FDMA modulation was also designed such that data could be sent on the PUSCH only in contiguous subcarriers. While this was not optimal, transmission of data on non-contiguous subcarriers is now allowed for LTE Advanced.

.

Category	Peak Rate Mbps		Modulation		RF Bandwidth	Downlink MIMO	
	Downlink	Uplink	Downlink	Uplink	Downlink	2 Streams	4 Streams
1	10	5	QPSK, 16QAM, 64QAM	QPSK, 16QAM	20 Mhz	NA	NA
2	50	25	QPSK, 16QAM, 64QAM	QPSK, 16QAM	20 Mhz	X	NA
3	100	50	QPSK, 16QAM, 64QAM	QPSK, 16QAM	20 Mhz	X	NA
4	150	50	QPSK, 16QAM, 64QAM	QPSK, 16QAM	20 Mhz	X	NA
5	300	75	QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM	20 Mhz	X	X
6	300	50	QPSK, 16QAM, 64QAM	QPSK, 16QAM	20-40 Mhz	X	X
7	300	150	QPSK, 16QAM, 64QAM	QPSK, 16QAM	20-40 Mhz	X	X
8*	1200	600	QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM	20-40 Mhz	X	X

*Category 8 supports 8 streams

Figure 14: LTE UE Categories

*Additional combinations have been agreed for Release 11, but this has not been finalized as of this date

Wi-Fi Offload

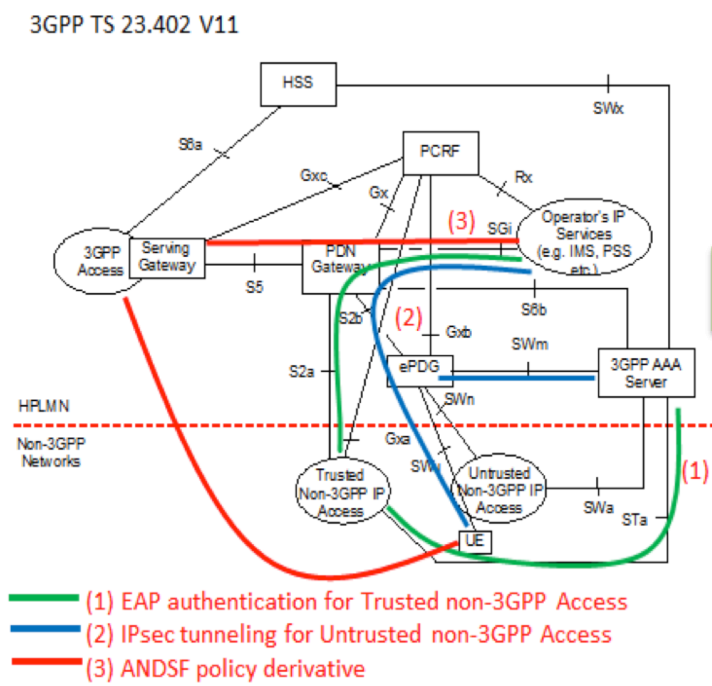
Core Network Features

Two important features of the System Architecture Evolution (SAE) used in Next Generation Networks are all IP operation and the connection of non-3GPP Radio Access Technologies to the Core Network. Wi-Fi is a good example of either a "Trusted" or "Non Trusted" network as shown in the diagram below.

IMS services and other operator specific services are expected to be carried out across different radio access networks connected to the Evolved Packet Core (EPC). Today, most mobile devices support WLAN technology, and many consumers actively seek out Wi-Fi connections. The increasing coverage and capacity of WLAN means that WLAN and 3GPP network interworking is increasingly important.

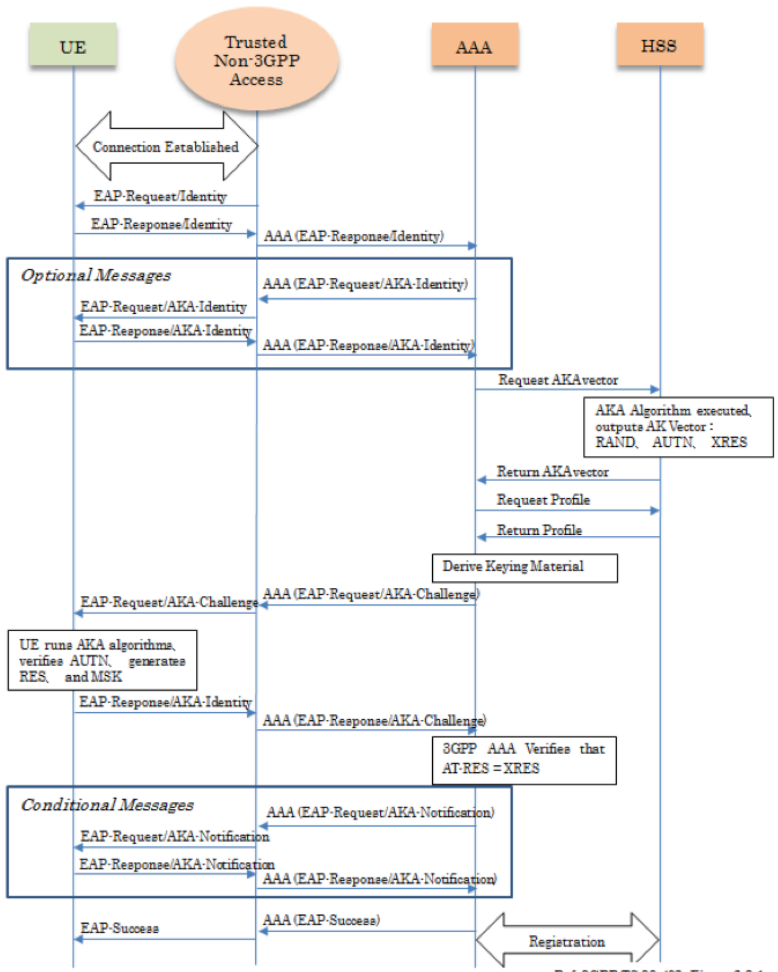
3GPP have previously defined WLAN interworking as early as release 4, but the specification was not widely adopted. Today, smartphone and tablet users often move back and forth between cellular and Wi-Fi connections. As consumers' demand for data grows more insatiable, along with the changing economics of carrier plans, the next generation mobile-data offloading is expected to include some significant improvements enabling deeper integration between cellular and Wi-Fi data connection.

Wi-Fi Network in SAE Architecture:



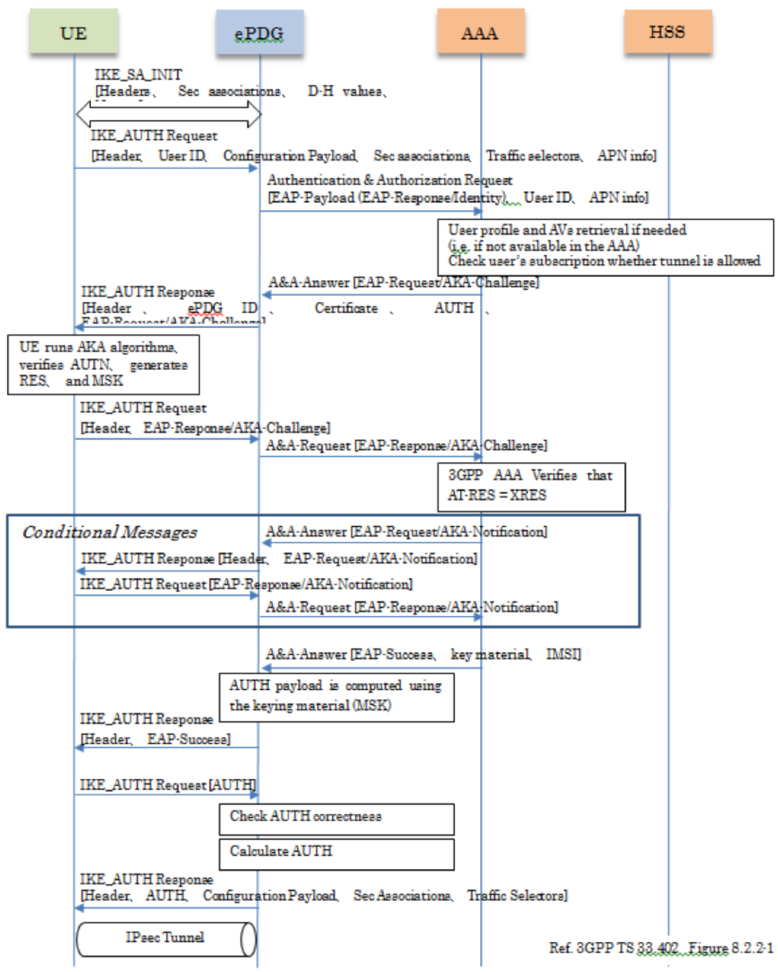
In TS 24.302, 3GPP defines how non-3GPP networks, like Wi-Fi networks, can access the EPC. It also classifies Wi-Fi networks into trusted and non-trusted categories to provide more seamless interoperability with trusted access points owned by carriers or their roaming-partners. With a trusted network, the EPC's Authentication, Authorization and Accounting (AAA) server can pre-establish communication with Wi-Fi access points to authenticate a mobile device's Wi-Fi session using SIM-based identity and keys (TS 33.402) as shown in the figure below. This simplifies the Wi-Fi association process and enables a carrier to seamlessly continue IP services over the Wi-Fi access point. When the mobile device is connected to a non-trusted Wi-Fi network, it needs to establish an IP Secure Tunnel with the evolved Packet Data Gateway (ePDG), as shown in the figure below, to authenticate the session with the network's AAA server before it can continue to access cellular data services over Wi-Fi.

UE Association with Trusted Wi-Fi Network:



Ref. 3GPP TS 33.402 Figure 6.2-1

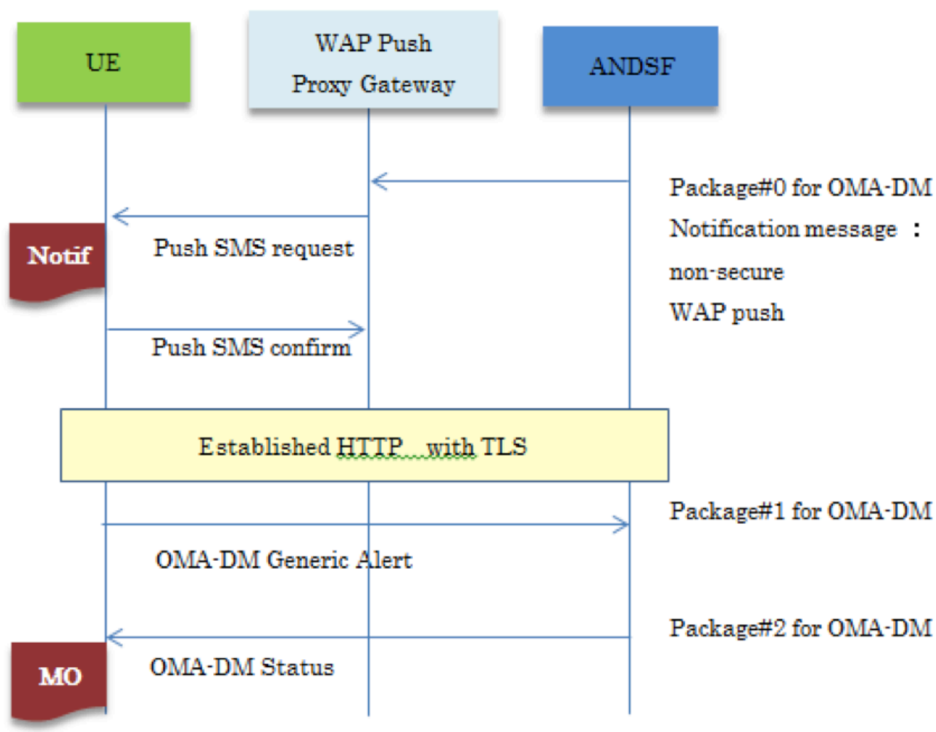
UE Association with Nontrusted Wi-Fi Network:



Besides streamlining the Wi-Fi association procedure and providing of cellular services in the Wi-Fi network, 3GPP, in TS24.302, also defines the Access Network Discovery and Selection Function (ANDSF) to allow carrier-initiated mobile data offloading processes. ANDSF introduces the mobility management capability between cellular and Wi-Fi networks. When appropriate, the carrier can notify mobile devices to discover a specific WLAN SSID and offload selected services from the cellular connection.

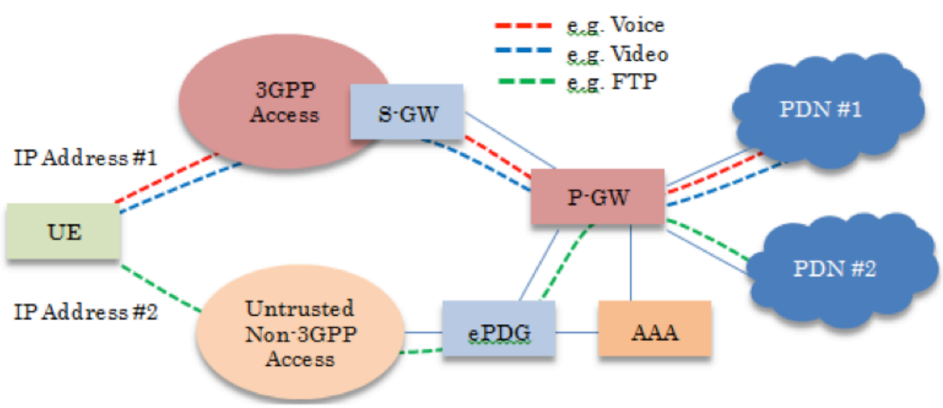
ANDSF is a management object signaled to mobile devices over the TCP layer (via the EPC S14 interface). When a device is connected to the EPC, usually over a 3GPP access network, the ANDSF server's IP address is supplied in the Protocol Configuration Option of the signaling messages. After the device initiates contact with the ANDSF server, it receives an XML-based message that provides information and instruction on the nearby WLAN network's location and access policies as shown in the figure below. The device is notified of suitable Wi-Fi access points, which might not have been otherwise identified by the user. Depending on user settings and local environment variables, the device may choose to automatically associate with preferred Wi-Fi access points after discovery.

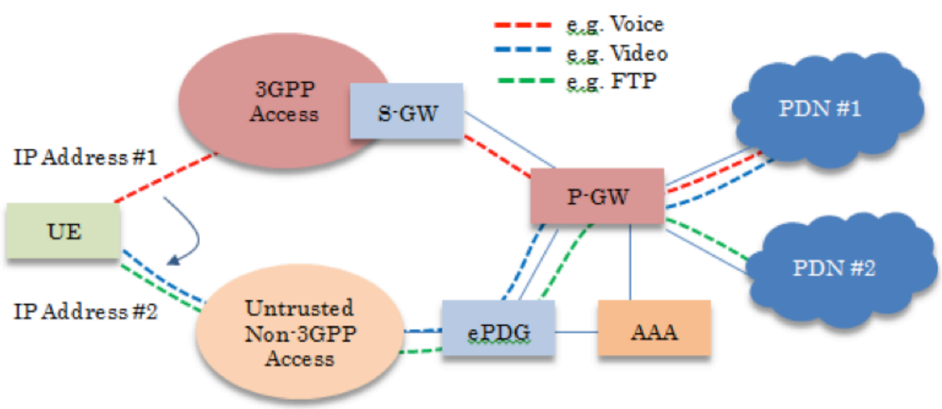
Network Notification via ANDSF:



For devices capable of IP Flow Mobility (IFOM) or Multi Access PDN Connectivity (MAPCON), the 3GPP network can use the Inter-System Mobility Policy (ISRP) feature of ANDSF to redirect IP traffic on an individual application level. In a congested environment such as sports or concert events, network operators can leverage Wi-Fi access points to balance their cellular network load and optimize their communication, streaming, and multi-cast services over different radio access technologies. The figures below show two different paths for data traffic utilizing these capabilities.

User Traffic Flow during IFOM/MAPCON:





SIGNALING TESTERS

MT8820C Radio Communications Analyzer

The MT8820C 4G LTE One-Box Tester is a multi-standard 2G, 3G, and 4G LTE tester with capability for UE calibration, RF parametric testing, and functional testing, including call processing or no-call based testing. Standards supported include LTE, W-CDMA/HSPA to Release 10, CDMA2K to 1xEV-DO Rev. A, TD-SCDMA/HSPA, and GSM/GPRS/E-GPRS. Several high-speed calibration modes are also included such as Anritsu's "TX/RX Sweep" mode, allowing calibration of TX and RX in parallel. For current users of either the MT8820B or MT8820A, the MT8820C is a drop-in replacement with backwards compatibility.

The MT8820C makes testing of LTE physical layer parameters easy and simple, including measurement of both TX and RX parameters. Parameter setups and pass/fail limits for tests defined in 3GPP 36.521-1 are pre-programmed, including easy setup of uplink and downlink RB allocations. Options are available for 2x2 MIMO including IP-layer throughput at up to 150 Mbps downlink data rates for a CAT4 device, and options for LTE-Advanced Carrier Aggregation including downlink data rates up to 300Mbps for a CAT6 device with 2x2 MIMO and Carrier Aggregation.

MD8475A 2G to 4G/LTE Signaling Tester

The MD8475A Signalling Tester is an all-in-one Network Simulator supporting LTE FDD, W-CDMA/HSPA, GSM/(E)GPRS, and CDMA2000® 1XRTT/1xEV-DO Rev. A. It supports service and call-processing tests for multimode LTE smartphones and mobiles with excellent cost-performance.

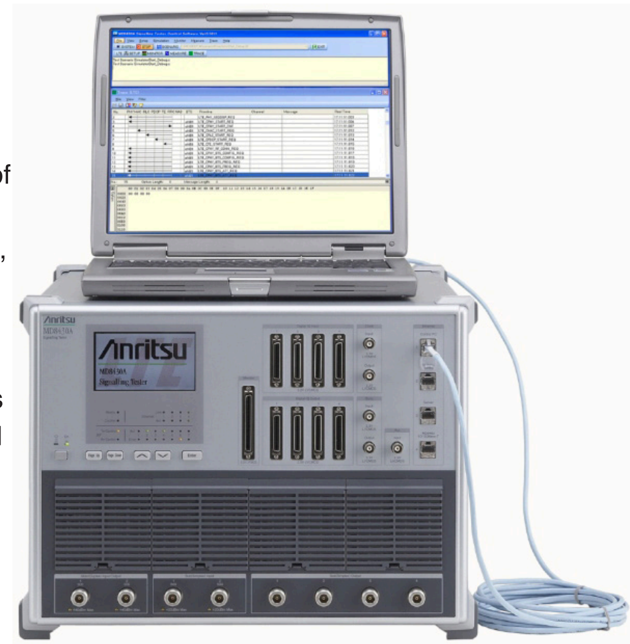
A wide range of test environments are supported for the general mobile verification phase, such as max. throughput performance tests, stress tests, and battery consumption tests of multimode LTE mobiles using 2x2 MIMO, as well as LTE-W-CDMA and LTE-GSM CS-Fallback*, call connection reliability and stability tests at handover*in a 2-cell environment, communication tests at low RF power, and service verification using LTE Multiple-PDN and SMS in a 2-cell environment.

In addition, test conditions are easily set using a state-machinebased GUI, cutting test environment configuration work.

* Support for CDMA2000 scheduled in the first half of 2011.

SIGNALING TESTERS

MD8430A LTE Signaling Tester



The MD8430A is the first complete LTE Signaling Tester, allowing for simulation of multiple eNBs with both 2x2 and 4x2 MIMO, as well as portions of the LTE Core Network. It allows for protocol-based testing of LTE UEs at RF and higher layers, and is integrated as a fundamental component of Anritsu's Protocol Conformance, RF/RMM Conformance, and Carrier Acceptance Test (CAT) systems.

Anritsu's LTE Signaling Tester (MD8430A) allows the user to test any of the LTE UE layers from the Physical Layer (PHY) to the Non-Access Stratum (NAS). In addition, applications can be tested under real-world conditions using an external server. The MD8430A's built-in baseband capability allows for FPGA-based prototype testing at either sub-speed or real-time, and helps speed time to market for LTE wireless devices.

The LTE Signaling Tester (MD8430A) can be automated with the user's choice of 3 PC-based user interfaces (UIs) including the graphical Rapid Test Designer (RTD) software, C-Scenarios, or TTCNbased Protocol Conformance Test (PCT) software. Inter-RAT handover between technologies is enabled using a system including the MD8480C GSM/W-CDMA Signaling Tester or MD8470A CDMA2K Signaling Tester as well the appropriate UI software.

Model/Name	MD8430A-010 LTE Function Test Model (FTM)	MD8430A-012 LTE MIMO Test Model (MTM)	MD8430A-014 LTE Handover Test Model (HTM)	MD8430A-020 LTE Standard Test Model (STM)	MD8430A-030 LTE Performance Test Model (PTM)
Interface	RF and Digital I/Q				
Frequency Band	20 MHz maximum				
UE Category	Category 1,2,3				
Maximum Data Rate (DL)	75 Mbps	100 Mbps	75 Mbps	100 Mbps	
Maximum Data Rate (UL)	50 Mbps				
Number of Simultaneous Tx Frequencies	1		2 (2x2MIMO), 4 (SISO)		
MIMO	No	2x2 MIMO	No	2x2 MIMO	2x2 MIMO, 4x2 MIMO
Maximum Number of Base Station	Active + Adjacent BTS: 1 (Max. Active BTS: 1)		Active + Adjacent BTS: 4 (Max. Active BTS: 2)		Active + Adjacent BTS: 6 (Max. Active BTS: 2)
Hard Handover (inc. at MIMO)	No		Between same frequency and different frequencies		

FADING SIMULATOR

MF6900A Baseband Fader

The MF6900A Fading Simulator provides a stable, repeatable faded testing environment when connected to the MD8430A using a baseband interface. The MF6900A can also be used in LTE mode with the MD8475A or in W-CDMA mode with the MD8480C. Once connected, it provides a simple and accurate way to add fading profiles to any test scenario under either SISO or MIMO conditions.

Digital baseband processing in the Fading Simulator (MF6900A) assures reproducible fading profiles. As there are no analog or RF circuits, periodic calibration is eliminated, making the MF6900A as easy to maintain as it is to use. In inter-RAT systems including both the MD8480C GSM/W-CDMA Signaling Tester and the MD8430A LTE Signaling Tester, included fading profiles allow rapid test setup since the fading profiles are pre-configured and ready to use immediately. The MF6900A is expandable to accommodate four input ports and four output ports. Software updates add functionality such as 4x2 MIMO.

Interface	Digital I/F (LVDS)
Channel Structure	SISO, 2x2 MIMO, 2x1 MISO, 1x2 SIMO (with MD8430A connected and MX690010A installed) Moving, Birth-Death, Tx/Rx/TRx Diversity (with MD8480C connected and MX690020A installed)
Path Number	12 paths/channel
RF Frequency	100 MHz to 6000 MHz, 1 Hz resolution
Relative Path Delay	0 to 600 _s, 0.1 ns resolution, 0.1 ns setting accuracy (relative to delay 0)
Relative Path Gain	-50 to 0 dB, 0.1 dB resolution, 0.05 dB setting accuracy
Doppler Frequency	0 or 0.1 Hz to 20 kHz, 0.01 Hz resolution
Fading Type	Constant Phase, Pure Doppler, Rayleigh, Rice
	Fading Profiles
SISO	Case1, Case2, Case3, Case4, Case5, Case6, Case 8, VA3, VA30, VA120, PA3, PB3 [3GPP TS25.101 V7.12.0 (2008-05), TS34.121-1 V8.3.0 (2008-06)] EPA, EVA, ETU [3GPP TS36.101 V8.2.0 (2008-05)]
2x2 MIMO/1x2 SIMO	EPA, EVA, ETU [3GPP TS36.101 V8.2.0 (2008-05)]
Moving	Moving propagation conditions [3GPP TS25.101 V7.12.0 (2008-05)]
Birth-Death	Birth-Death propagation conditions [3GPP TS25.101 V7.12.0 (2008-05)]
Tx/Rx/TRx Diversity	Case1, Case2, Case3, Case4, Case5, Case6, Case 8, VA3, VA30, VA120, PA3, PB3 [3GPP TS25.101 V7.12.0 (2008-05) , TS34.121-1 V8.3.0 (2008-06)]

SOFTWARE

MX786201A Rapid Test Designer Software

The Rapid Test Designer (RTD) is a revolutionary new tool that significantly speeds up the development and deployment of modern wireless user equipment (UE) by greatly simplifying the way in which tests are created, executed, and analyzed. This is achieved by using a graphical flow-chart interface and many innovative tools within the RTD environment. Users can concentrate on testing specific functions and protocols within the UE without having to be expert on all the 3GPP protocol layers.

As 3GPP specifications evolve, tests are easily maintained using the automatic update feature. The graphical flowchart also makes visual inspection much simpler when sharing tests within a team. Analysis of test results can be simplified by matching against pre-determined criteria. This provides the user with a high level view of test campaigns and preliminary judgement without the need to investigate logs in detail. A comprehensive analyzer is provided to examine the message flow between the UE and the simulator.

The RTD system provides a flexible simulation of LTE / UTRAN / GERAN and cdma2000 networks depending on the hardware selected. This can be a single cell simulation for simple terminal development up to complex simulation controlling a mix of cells by adding additional hardware.

The system is capable of unattended operation using automated tools such as the internal test sequencer and can be slave to a larger test system.

CONFORMANCE TEST

ME7873L LTE RF Conformance Test System

The ME7873L LTE RF Conformance Test System allows the user to verify conformance of a UE's RF layer to 3GPP LTE standards. The ME7873L LTE RF Conformance Test System is the world's first GCF validated LTE RF test platform (test cases validated at CAG#22 in April 2010), supporting the most GCF-approved test cases. Prewritten, validated test cases are available for the system, conforming to GCF Work Items and PTCRB Request for Tests. The system is extremely flexible, with available options for any LTE band currently scheduled for deployment, as well as easily changeable test parameters to enable testing of UE performance.

The LTE RF Conformance Test System (ME7873L) is a modular system to fit with user requirements, and can include 3GPP TS 36.521-1 tests for Chapter 6 (TX), Chapter 7 (RX), Chapter 8 (Performance), or Chapter 9 (UE Reporting) as well as 3GPP TS 36.521-3 (RRM). A user may compile a test sequence combining test cases from any of these chapters. In addition, support for both FDD, TDD and Inter-RAT tests including LTE to GSM/UMTS/CDMA2000, and UMTS to LTE. The most recent addition is support for LTE Release 10 LTE Advanced Carrier Aggregation with the most test case validations across a single platform type for LTE-Advanced Carrier Aggregation (CA).

ME7834L LTE Protocol Conformance and Carrier Acceptance Test System

The ME7834 is a single, comprehensive platform designed to address the needs of modern wireless terminal developers, test houses and network operators and to get LTE terminals into the market fast and efficiently. It is scalable allowing for customization of tools and features as needed based on releases of updated air interface physical layer as well as protocol layers. The platform provides support for LTE, UTRAN, GERAN, CDMA2000.

VECTOR SIGNAL

MG3710A Vector Signal Generator (VSG)

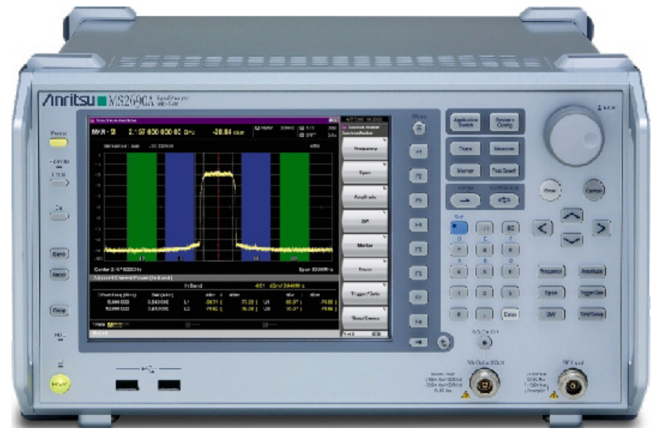
The MG3710A Vector Signal Generator is a best-in-class, high-function signal generator with excellent RF and baseband performance. Generates up to four independent signals.

- Fast switching speed (<600 uS)
- Supports Carrier Aggregation, Multipath Fading and MIMO testing
- Analog and digital modulation signal generation up to 160 MHz bandwidth
- Supports modulation analysis, including
  - – LTE/LTE-Advanced
  - – CDMA
  - – W-CDMA
  - – WiMAX
  - – GSM
  - – TD-SCDMA
  - – 802.11a/b/g/j/n/p/ac

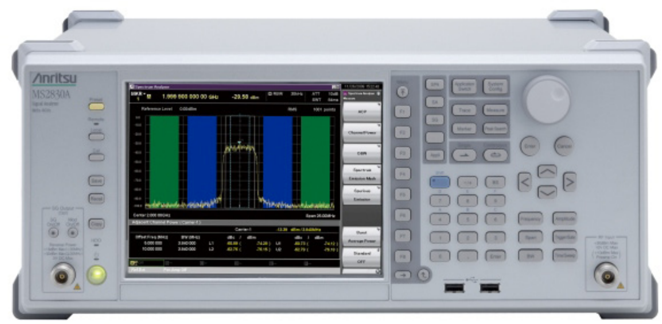
TESTERS & ANALYZERS

MS269xA and MS2830A Vector Signal Analyzers (VSA)

Anritsu's MS269xA and MS2830A-series high performance VSAs perform multi-format signal analysis, including LTE uplink and downlink analysis with optional signal generation. The MS269xA is focused on applications requiring high performance, while the MS2830A is focused on applications requiring high speed and low cost. The VSAs are ideal for the demanding requirements of LTE measurement, and include DSP-based modes for fast TX measurements as well as a digitizer that captures signals so they can be replayed on the instrument or removed from the analyzer for post-processing.



Both Vector Signal Analyzers (MS269xA and MS2830A) support one-button spectrum analysis including Channel Power, Occupied Bandwidth, Adjacent Channel Leakage Ratio, and Spectrum Emission Mask, all with wide dynamic range. In addition, vector analysis is available including EVM and power by symbol, subcarrier, RB, RE, and many other variations. Users can create a One-Box LTE tester (without signaling) by adding the optional signal generator to the base package. For eNB testing, built-in test model configurations allow rapid test setup.



SIGNAL ANALYZER

MS2690A/MS2691A/MS2692A Signal Analyzers

Anritsu's MS269xA series high performance Signal Analyzers perform LTE uplink and downlink signal analysis and signal generation. The MS269xA's are ideal for the demanding requirements of LTE measurement. The base package includes a spectrum analyzer for swept measurements, a signal analyzer that uses FFT to produce fast measurements, and a digitizer that captures signals so they can be replayed on the instrument or removed from the analyzer for post-processing. Users can create a One-Box LTE tester by adding the optional signal generator to the base package.

The MS269xA signal analyzer series offers low residual Error Vector Magnitude (EVM) of 1% (²0.5% typical) and total level accuracy of ±0.6 dB. It supports one-button spectrum analysis (Channel Power, OBW, ACLR, SEM) with wide dynamic range. Built-in test model configurations allow rapid test setup. The MS269xA's capture and replay up to 200 waveforms for troubleshooting faults and offers an EVM Window Length function for precise measurement of FFT timing.

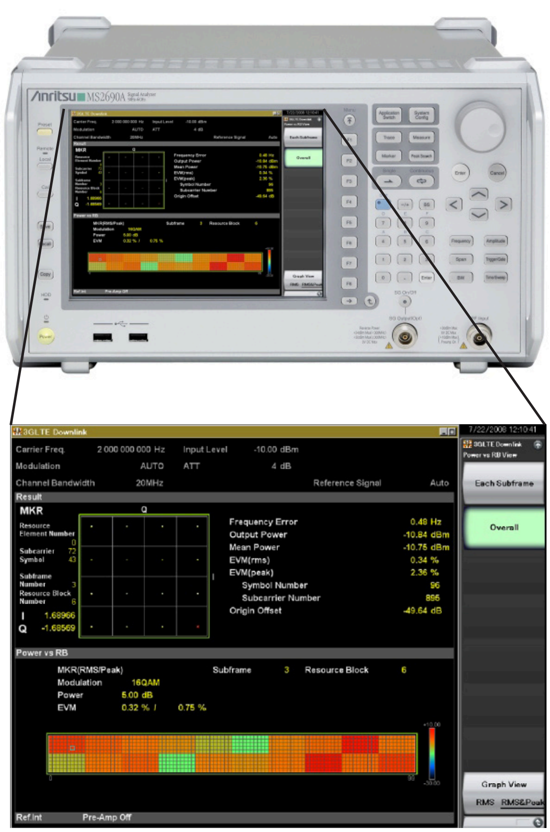


Figure 14: LTE analysis includes constellation analysis and graphical displays with resolutions of Subcarriers, Symbols, and Resource Blocks.

Spectrum Analyzer (SPA) Function	
World-Class Dynamic Range	Avg. noise level: -155 dBm/Hz (2 GHz)
	TOI: +22 dBm
	W-CDMA ACLR: -78 dBc @ 5 MHz
Vector Signal Analyzer (VSA) Function	
Wideband FFT Analysis	31.25 MHz standard
	125 MHz option available
Capture Digitized Waveforms	Replay for additional analysis
	Use data in post-process analysis
Vector Signal Generator (VSG) (option)	
Frequency Range	125 MHz to 6 GHz
RF Modulation Bandwidth	120 MHz
Built in BER Measurement Function	
Built-in AWGN Addition Function	
LTE Specific Analysis Software	
MX269020A LTE Downlink Measurement Software	
MX269021A LTE Uplink Measurement Software	

General LTE Specifications	
Operating Band	800 to 2700 MHz
Channel Bandwidth	1.4/3/5/10/15/20 MHz
PDSCH/PUSCH Mod Scheme	QPSK/16QAM/64QAM
Analysis Time Length	10 subframes max. (1 frame)
Text Display	Frequency Error, Output Power, Mean Power. EVM (Peak/rms), Origin Offset, Timing Offset (External Trigger)
Constellation Display	Constellation
Graphical Display	EVM vs Subcarrier, Symbol, Demod-Symbol (Uplink), or Resource Block (Downlink) Spectral Flatness, Power vs Resource Block (Downlink), Time Based EVM (Uplink)
Spectrum Display	Adjacent Channel Power, Channel Power, Occupied Bandwidth, Spectrum Emission Mask,
Downlink Summary Display	Total EVM PDSCH (ALL/QPSK/16QAM/64QAM) EVM PDCCH EVM, RS/SS/P-SS/S-SS EVM PBCH/PCFICH/PHICH EVM RS/P-SS/S-SS/PBCH/PDCCH/PCFICH/PHICH Power, Power vs Slot, Cell ID, Number of PDCCH Symbols, RS Power vs Subframe, OFDM Symbol Tx Power vs Subframe
Uplink Summary Display	Time-Based EVM: Total EVM, PUSCH QPSK, PUSCH 16-QAM, and PUSCH 64-QAM Total EVM, PUSCH QPSK/16-QAM/64-QAM EVM, RS EVM, Power vs Slot

BTS MASTER/CELL MASTER/SPECTRUM MASTER

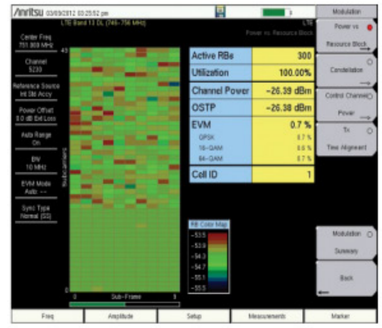
BTS Master™ MT8220T, Cell Master™ MT821xE and Spectrum Master™ MS2720T & MS271xE Features

LTE Signal Analyzers

The LTE Signal Analyzer features three measurement modes:

– RF Measurements
– Modulation Measurements
– Over-the Air Measurements (OTA)

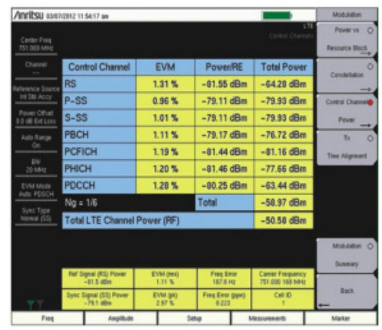
The goal of these measurements is to increase data rate and capacity by accurate power settings, ensuring low out-of-channel emissions, and good signal quality. These attributes help to create a low dropped call rate, a low blocked call rate, and a good customer experience. Cell site technicians or RF engineers can make measurements Over-the-Air (OTA) to spot-check a transmitter's coverage and signal quality without taking the cell site off-line. When the OTA test results are ambiguous one can directly connect to the base station to check the signal quality and transmitter power.



Modulation Quality – Power vs. Resource Block
A high utilization of the Resource Blocks would indicate a cell site in nearing overload and it may be appropriate to start planning for additional capacity.

Adjacent Channel Leakage Ratio (ACLR)

Adjacent Channel Leakage Ratio (ACLR) measures how much BTS signal gets into neighboring RF channels. ACLR checks the closest (adjacent) and the second closest (alternate) channels. Poor ACLR can lead to interference with adjacent carriers and legal liability. It also can indicate poor signal quality which leads to low throughput.



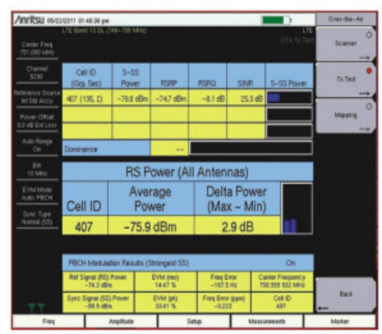
Modulation Quality – Control Channels
High values will create larger areas of cell-to-cell interference and create lower data rates near cell edges. Low values affect in-building coverage.

Cell ID (Sector ID, Group ID)

Cell ID indicates which base station is being measured OTA. The strongest base station at your current location is selected for measurement. Wrong value devices for Cell ID lead to inability to register. If the cause is excessive overlapping coverage, it also will lead to poor EVM and low data rates.

Pass/Fail Test

Set up common test limits, or sets of limits, for each instrument. Inconsistent settings between base stations leads to inconsistent network behavior.



Over-the-Air Measurements – Tx Test
By looking at the reference signals of MIMO antennas one can determine if MIMO is working properly. If the delta power is too large, there is an issue.

EVM

High values will create larger areas of cell-to-cell interference and create lower data rates near cell edges.

Mapping

On-screen mapping allows field technicians to quickly determine the downlink coverage quality in a given geographic location. Plot S-SS Power, RSRP, RSRQ or SINR with five user definable thresholds. All parameters are collected for the three strongest signals and can be saved as *.kml and *.mtd (tab delimited) for importing to third party mapping programs for further analysis.

Over-the-Air On-screen Mapping
Import map area on instrument screen to drive test downlink coverage of S-SS Power, RSRP, RSRQ, or SINR.

BTS MASTER/CELL MASTER/SPECTRUM MASTER

BTS Master™ MT8220T, Cell Master™ MT821xE and Spectrum Master™ MS2720T & MS271xE Specifications

GSM/EDGE Signal Analyzers (Options 0040, 0041)

Measurements

RF (Option 0040)	Modulation (Option 0041)	Over-the-Air (OTA)	Pass/Fail (User Editable)
Channel Spectrum Channel Power Occupied Bandwidth Burst Power Average Burst Power Frequency Error Modulation Type BSIC (NCC, BCC) Multi-channel Spectrum Power vs. Time (Frame/Slot) Channel Power Occupied Bandwidth Burst Power Average Burst Power Frequency Error Modulation Type BSIC (NCC, BCC)	Phase Error EVM Origin Offset C/I Modulation Type Magnitude Error BSIC (NCC, BCC)	RF Measurements and Demodulation can be made OTA. There are no additional OTA Measurements.	Measurements Channel Power Occupied Bandwidth Burst Power Average Burst power Frequency Error Phase Error EVM Origin Offset C/I Magnitude Error Script Master™

Setup Parameters	GSM/EDGE Select	Auto, GSM, EDGE
	Frequency	Center, Signal Standard, Channel #, Closest Channel, Decrement/Increment Channel
	Amplitude	Scale/Division, Power Offset, Auto Range, Adjust Range
	Sweep	Single/Continuous, Trigger Sweep
	Save/Recall	Setup, Measurement, Screen Shot (save only), to Internal/External Memory
	Measurement Summary Screen	Overall Measurements
RF Measurements (Option 0040)		
	Frequency Error	± 10 Hz + time base error, 99% confidence level
	Occupied Bandwidth	Bandwidth containing 99% of the total power transmitted on a single channel
	Burst Power Error	± 1.5 dB, ± 1 dB typical, (-50 dBm to +20 dBm)
Demodulation (Option 0041)		
	GSMK Modulation Quality (RMS Phase)	
	Measurement Accuracy	± 1 deg
	Residual Error (GSMK)	1 deg
	8 PSK Modulation Quality (EVM)	
	Measurement Accuracy	± 1.5%
	Residual Error (8 PSK)	2.5%

IQPRODUCER

LTE IQproducer

IQproducer is a PC-based application software with a graphical user interface (GUI) for generating I/Q waveform patterns in compliance with the 3GPP TS36.211, TS36.212, and TS25.814 standards. This Windows-based software creates waveforms for the MG3700A and the signal generator option for either the MS269xA or MS2830A VSA. The GUI allows a user to quickly set signal parameters for LTE waveforms and download them for replay at RF or baseband.

Anritsu offers 4 LTE IQ Producer software packages including the MX269908A and MX370108A FDD-LTE packages as well as the MX269910A and MX370110A TDLTE package, MX370108A FDD. These packages include built-in simulation tools and allow the user to examine these waveforms in the time domain, as a CCDF plot, or as an FFT spectrum. It's easy to generate test patterns by allocating the physical channels in the appropriate RBs.

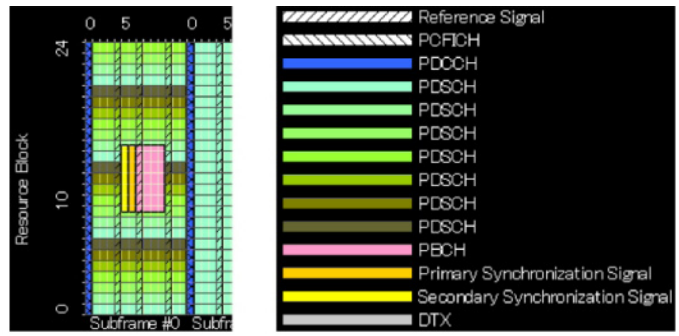


Figure 15: The Frame Structure Screen shows a downlink subframe configured with 25 PDSCH. The PDCCH is on the first symbol; the Primary and Secondary Synchronization Signals are on the sixth and fifth symbols respectively, and the Broadcast Channel ranges from the seventh to the tenth symbols. Both the Synchronization Signals and the Broadcast Channel are assigned to the center 72 subcarriers for all bandwidths. Reference Signals are shown by hash marks in the first and fifth symbols of the slot. The PCFICH is on the first symbol of each subframe.

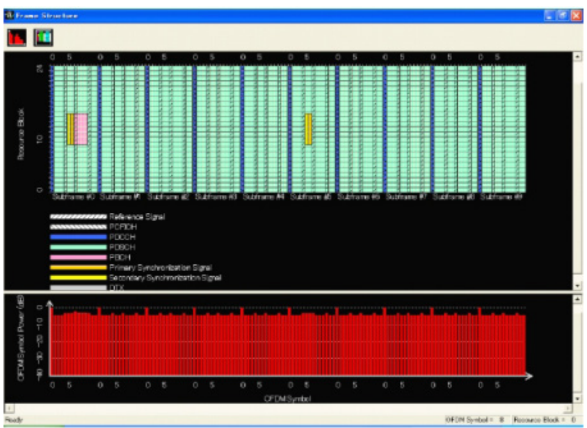


Figure 16: The Frame Structure Screen shows the layout of the physical layers in the upper section and the power profile of the symbols in the lower section. In the upper section, the physical channels map to the Y-axis as frequency in Resource Block units (12 subcarriers) and to the X-axis as time in OFDM symbol units.

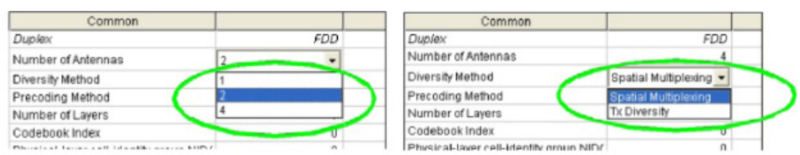


Figure 17: The LTE IQproducer supports Spatial Multiplexing and Transmit Diversity. When multiple antennas are selected, the appropriate files are created for each antenna for immediate MIMO testing.

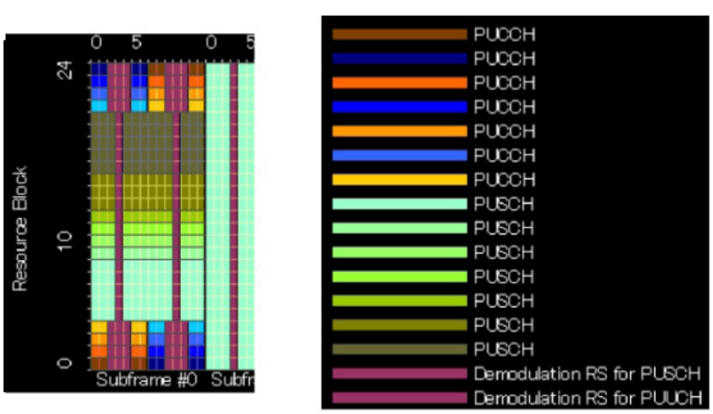


Figure 18: Here the Frame Structure Screen shows an uplink subframe with eight PUSCH and eight PUCCH. Easily configure test signals such as this one by changing parameters and get immediate feedback in the Frame Structure Screen.

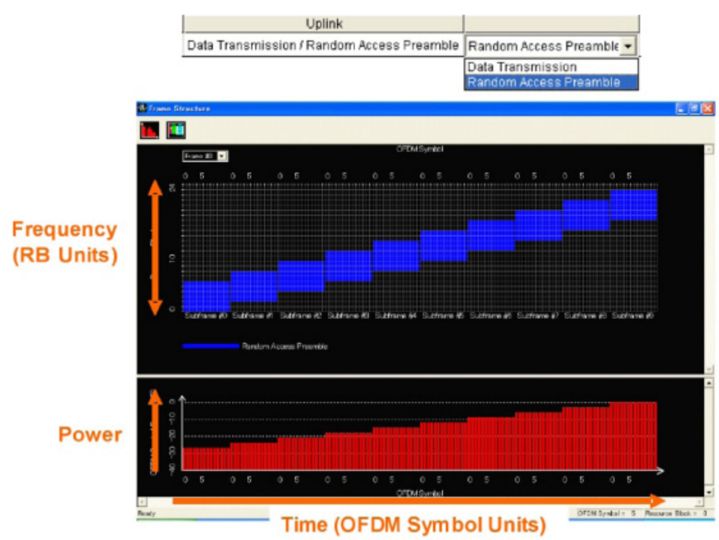


Figure 19: IQproducer also creates Random Access Preambles for uplink testing. Frequency hopping and power ramping can be quickly set from the parameter screen. Limits on all settings ensure that signals comply with the standards.

Specifications are subject to change without notice.

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