Leader in Converged IP Testing

Wireless Network Testing

915-2623-01 Rev A January, 2010


IXIA®

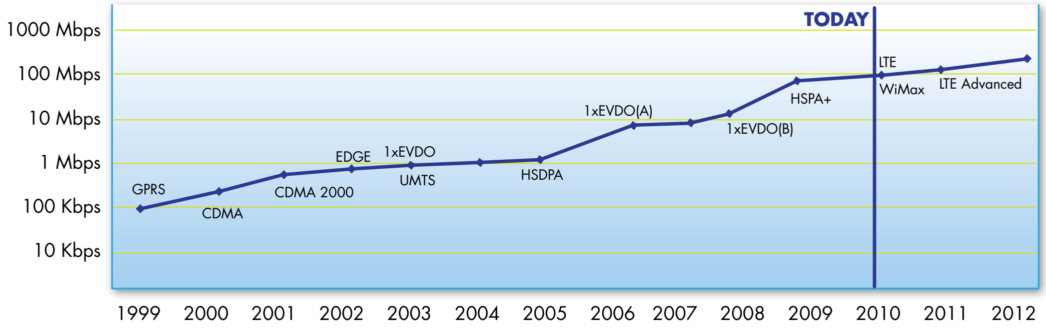
Contents

The Progression of Wireless Technologies

Cellular data speeds, beginning with GPRS in 1999, have increased over the last decade by a factor of 10 every 3-5 years. This growth has been driven by increased consumer demand for wireless data bandwidth. Reporterlink[1] has estimated that wireless data traffic will increase ten-fold between 2009 and 2017 – a 59% CAGR. Data traffic is expected to hit 1.8 exabytes/month[2], fueled by a rapid increase in interactive data and multiplay applications. Video is the largest bandwidth consumer today, a fact that will continue for the foreseeable future.

Long Term Evolution (LTE), as defined by the Third Generation Partnership Project (3GPP), is widely acknowledged as the next generation technology for both voice and data wireless transmission.

Figure 1. Wireless Bandwidth Trends



LTE

Long Term Evolution (LTE), as defined by the Third Generation Partnership Project (3GPP), is widely acknowledged as the next generation technology for both voice and data wireless transmission. LTE was first specified in the 3GPP Release 8 specification in December, 2008.

With the exception of the air interface, LTE is an all-IP network – taking advantage of and converging with IP network technology. LTE has some impressive capabilities:

- Support for multiple-input, multiple-output (MIMO) antenna technology, including 2x2 and 4x4 configurations.
- 300 Mbps downlink and 150 Mbps uplink bandwidth when using 4x4 MIMO.
- Latencies of less than 5 ms.
- Hundreds of users per cell.

Most major telecom equipment manufacturers (TEMs) and carriers have announced their intention to develop and provide LTE products and services. As of early 2010, 51 providers in 24 countries have made commitments[3]. Early deployments are expected in Asia and North America in 2010, with significant expansions in all major markets in 2012. 2013 will see some 85 million LTE subscribers[4] and nearly half a billion people will use LTE by 2015.[5]

The strategic LTE components consist of a new radio standard and the eNode B, which supports the LTE air interface and performs radio resource management. The eNode B

---

[1] Reporterlink, 9/09
[2] An Exabyte is 10^{18} - a billion, billion
[3] Global mobile Suppliers Association (GSA)
[4] Forward Concepts
[5] Analysys Mason

integrates the functions of the 3G node B and RNC, making the eNode B a complex element and flattening the network architecture.

Alongside LTE development is the evolution of the core architecture, called the evolved packet core (EPC), which maximizes data throughput while minimizing latency and network complexity.

The key functional elements of the EPC include:

Mobility Management Entity (MME) – The MME has a key role in the EPC in the handling of mobile users. It performs the signaling and control functions that manage the mobile users' access to LTE, assigns network resources, and manages mobility states that support roaming, paging, and handovers. The MME oversees all control plane functions related to subscriber and session management.

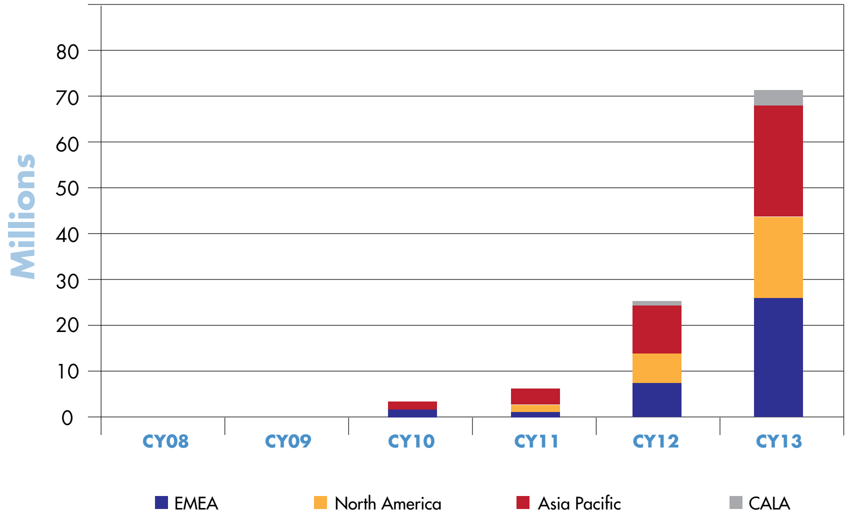
Serving Gateway (SGW) – the SGW is a node that provides data paths between eNode Bs and the PDN-GW. The essential capabilities of the SGW, aside from routing and forwarding packets, is that it acts as a local mobility anchor point for inter-eNode B handovers as well as managing mobility between LTE and 2G/GSM and 3G/UMTS networks. The SGW also provides charging services for user equipment, the PDN, and service classes.

Packet Data Network Gateway (PDN-GW) – The PDN-GW is the termination point of the packet data interface connecting to packet data networks, providing the anchoring function for sessions with external networks. A critical function of the PDN-GW is the ability to enforce per-user packet filtering, allowing gating and rate enforcement policies as well as service level charging.

The EPC is the all IP-mobile core network for LTE, allowing the convergence of packet-based real-time and non-real-time services. These elements, along with radio and network technology from earlier wireless technologies, are shown in Figure 3.

Alongside LTE development is the evolution of the core architecture, called the evolved packet core (EPC), which maximizes data throughput while minimizing latency and network complexity.

Figure 2. Worldwide LTE Revenue Forecast



Other Wireless Technologies

As with existing deployments, LTE networks need to interoperate with a variety of existing wireless edge and core technologies. Principal among these are Universal Mobile Telecommunications System (UMTS) and IP Multimedia Subsystem (IMS).

UMTS, which uses W-CDMA as the underlying air interface, is one of the 3G mobile telecommunications technologies. UMTS also covers the core radio access network (UTRAN). Two common technologies associated with UMTS are high speed downlink packet access (HSDPA) and high speed uplink packet access (HSUPA), together referred to as HSPA and sometimes called 3.5G. HSPA+ is a further evolution of HSPA that uses the same equipment. HSPA+ networks can expect a downlink transfer rate of up to 44 Mbps when using HSDPA+ handsets. As of 2010, over 300 networks in 142 countries offer HSPA; a total of 66 operators have committed to HSPA+.[6]

LTE networks need to interoperate with a variety of existing wireless edge and core technologies.

IMS is an architectural framework for delivering IP multimedia to fixed and mobile users. IMS facilitates the blending of triple-play in interactive, personalized ways. Delivery of a triple-play bundle is a highly desirable objective for service providers of all types. IMS creates a network where new applications can be plugged in like Lego™ blocks. More competition is fostered, allowing operators to choose the most cost-effective equipment for each function.

Wireless Core and Internet Core Networks

Increased usage of HSPA+ and LTE networks will place increased bandwidth requirements on wireless core and Internet core networks. As more people simultaneously use multiple wireless technologies, the complexity of the core networking control plane signaling and the volume of bearer traffic will rise. The data requirements associated with multiplay applications will have two dramatic effects on the core networks: a need for increased capacity and a need for more intelligence. Wireless frequency bandwidth is an inherently limited resource. That bandwidth must be carefully balanced to provide all users with an acceptable quality of experience (QoE). Techniques such as deep packet inspection (DPI) must be used to properly identify information flows so as to provide them with the proper QoS.

---

[6] Global Mobile Suppliers Association (GSA)

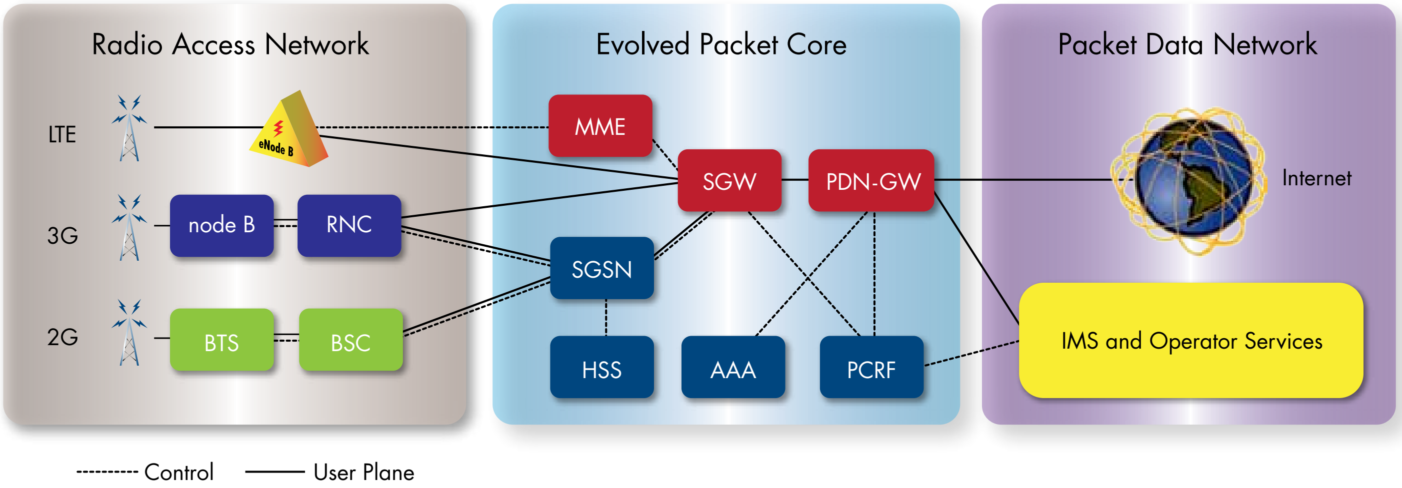


Figure 3. End-to-End Wireless Network Testing

Wireless Testing Requirements

The major components of an end-to-end wireless network solution are shown in Figure 3. Complete testing of a wireless service must separately test the components in each of the radio access network, wireless core network and Internet core networks, test each of the three subsystems independently, and test the entire system end-to-end, from the wireless edge through the Internet core.

Proper testing occurs at multiple levels, usually in a sequential manner:

- **Compliance testing** is an essential first step in ensuring correct operation and interoperability. Compliance tests are built from RFC and other standards, and are designed to perform positive and negative tests that ensure devices properly implement the standards.
- **Functional testing** further exercises device capabilities with combinations of options, multiple connections, differing types of traffic, and many sequences of operations. Full protocol stacks are tested at this level, along with further negative tests.
- **Performance testing** measures raw capacity, such as the maximum number of connections, maximum rate of connection establishment, and maximum uplink and downlink throughput.
- **Scalability testing** measures real-world effectiveness and the ability to handle a complete user community. This type of testing requires realistic traffic loads that meet and exceed network capacity, coupled with quality of experience measurements.

Comprehensive quality assurance requires compliance, functional, performance and scalability testing.

LTE Testing

Testing of LTE components and networks is especially challenging due to their complexity and operational scale.

Radio Access Network (eNode B)

The eNode B is the key element of the LTE radio access network, as shown in Figure 3. It is the most complex part of the LTE access network, and is more complex than the UMTS node B or GSM base transceiver station (BTS) since it operates without a controller (RNC – radio network controller or BSC – base station controller). The functions of the central controller are performed by the eNode B, making it a critical component of the new LTE network architecture.

The complexity of the eNode B is manifest in its complete stack implementations. The *Uu* interface, shown in Figure 4, embodies a number of previously distributed protocols. It is essential that testing explore all stack layers, not merely the top layers.

Radio access testing for earlier wireless generations was often accomplished through the use of banks of modified handsets.

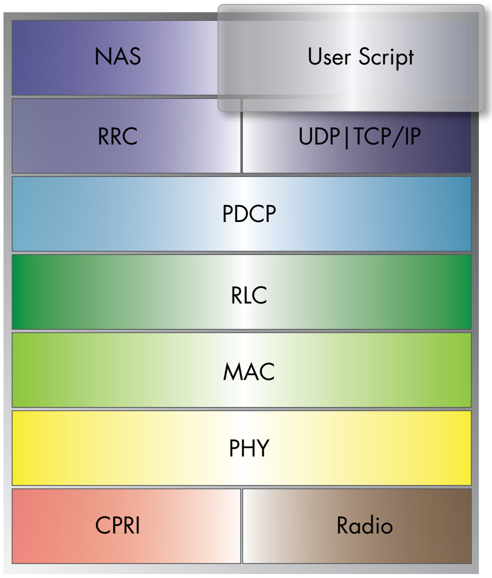


Figure 4. Uu Interface Stack

Radio access testing for earlier wireless generations was often accomplished through the use of banks of modified handsets. The scale of modern eNode Bs makes this approach no longer viable. Similarly, low to moderate bandwidth testing used in earlier technologies cannot be used to stress a network that will transport 300 Gbps of download traffic.

Both network and air interfaces must be simulated to fully test the eNode B. Coordinated testing using *Uu*, *X2* and *S1* interfaces is required – emulating the operation of other eNode Bs, MMEs and SGWs. Many eNode B functions and procedures can only be verified through emulation of all surrounding components. For example, signaling between the user equipment (UE) and eNode B on the *Uu* interface is tightly coupled with intra-E-UTRAN signaling on the *X2* interface and signaling between the eNode B and the EPC on the *S1* interface. This tight coupling makes testing any one interface in isolation difficult, if not impossible. Testing through all of the eNode B's interfaces verifies all eNode B user plane connections by:

- Applying a variety of realistic user plane traffic flows.
- Coordinating each user plane flow according to the signaling exchanged with the eNode B.
- Verifying the content of user plane traffic flows transmitted by the eNode B.
- Exercising control of user plane frames at both the source and sink.
- Measuring the QoE delivered for each traffic flow.

Evolved Packet Core (EPC) Testing

The EPC components – MME, SGW, and PDN-GW – together with the eNode B handle user mobility, unique bandwidth, and quality requirements of multiplay applications and error situations. Testing of these components must use multiple connection scenarios and real-world combinations of voice, video, and data traffic to ensure proper, scaled operation. EPC-specific testing challenges include:

- **Capacity and performance** – with thousands of eNode Bs, potentially carrying from 1 to 300 Gbps of traffic each, the capacity in the EPC could quickly become an issue in terms of high availability, validation, and network configuration.

- **Media** – a typical LTE mobile user will concurrently run many types of applications, including voice, texting, video viewing, and e-mail updates. Real-world traffic is required to fully validate QoE enforcement and the effect of gating and policy control on the network.

- **Quality of service** – expressed in jitter, latency, packets dropped, and other measurements are key performance indicators in an all-IP network.

- **Interoperability with 2G/3G networks** – LTE will likely be deployed in small islands in a sea of existing 2G/3G networks.

- **Multiple architectures** – MMEs, SGWs, and PDN-GWs may be combined into single hardware units. Different combinations and network structures are possible.

- **End-to-end data and control plane security** – IPSec, TLS, and other security is required in some EPC components and optional in others.

As with eNode B testing, coordination of control and user plane traffic from all interfaces is essential, utilizing the *S11, S1, S8* and *S5* interfaces that emulate eNode B, MME, SGW, and PDN-GW operation. With different combinations of these interfaces it is possible to test the functionality, performance, and scale of the MME, SGW, and PDN-GW.

The EPC components – MME, SGW, and PDN-GW – together with the eNode B handle user mobility, unique bandwidth, and quality requirements of multiplay applications and error situations.

UMTS Testing

Wireless providers have invested heavily in UMTS/HSPA/HSPA+ technology, and will push their deployment in favor of LTE for several years. The testing of these components and sub-systems requires the same types of techniques used in LTE testing: coordinated use of all individual device and sub-system interfaces. As shown in Figure 5, the essential HSPA components are the node B, RNC, serving GPRS support node (SGSN), and mobile service switching center (MSC), using *Iub, Iu-CS,* and *Iu-PS* interfaces.

Though not as much as with LTE, HSPA+ still requires a significant amount of multiplay data traffic to measure capacity – up to 44 Mbps on the download link and 11 Mbps on the upload link.

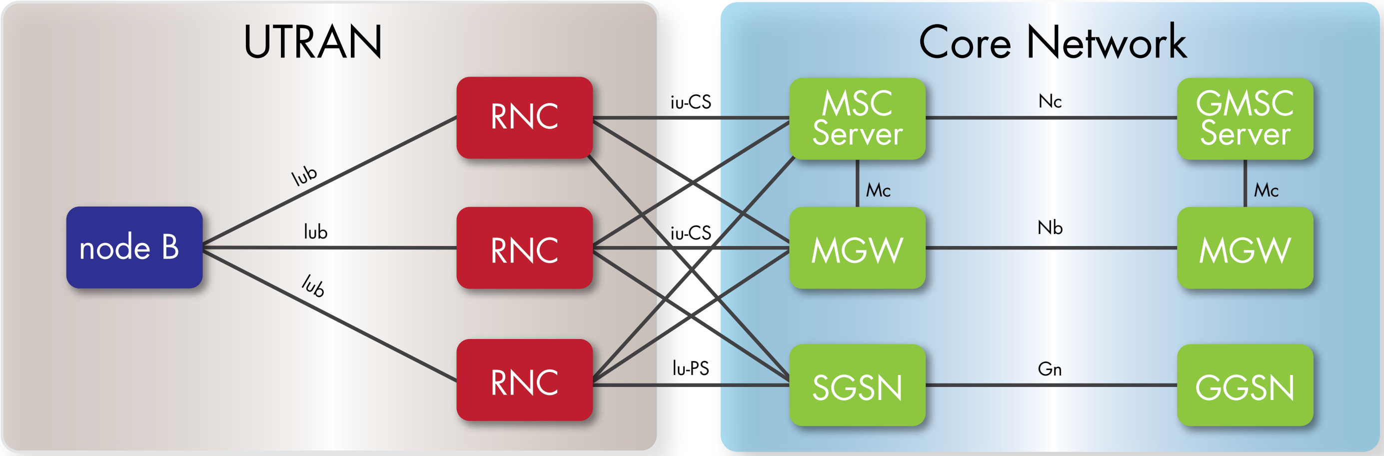


Figure 5. UMTS Edge and Core Network

IMS Testing

IMS promises to be a key component of LTE deployments – serving as the unifying mechanism for delivering voice and other services. As shown in Figure 6, IMS is a complex system encompassing many possible components that are linked by multiple protocols. Several base protocols, especially session initiation protocol (SIP), are being extended to support IMS functionality. As shown in Figure 6, testing can be performed for the major categories:

- **Core Network** – using protocols for testing call session control functions in the P-CSCF, interrogating CSCF (I-CSCF), and serving CSCF (S-CSCF).
- **Interworking Elements** – using protocols for media and signaling gateways in the IP multimedia media gateway (IM-MGW), signaling gateway (SGW), media gateway controller function (MGCF), and breakout gateway control function (BGCF).
- **Application Servers** – using protocols, including SIP, for application servers, home subscriber service (HSS), and subscriber location function (SLF).

Service providers will continue to support multiple wireless technologies. It is essential that the wireless core network be tested under conditions in which UEs from different sources share the network – and that their relative quality and bandwidth requirements be met.

IMS promises to be a key component of LTE deployments – serving as the unifying mechanism for delivering voice and other services.

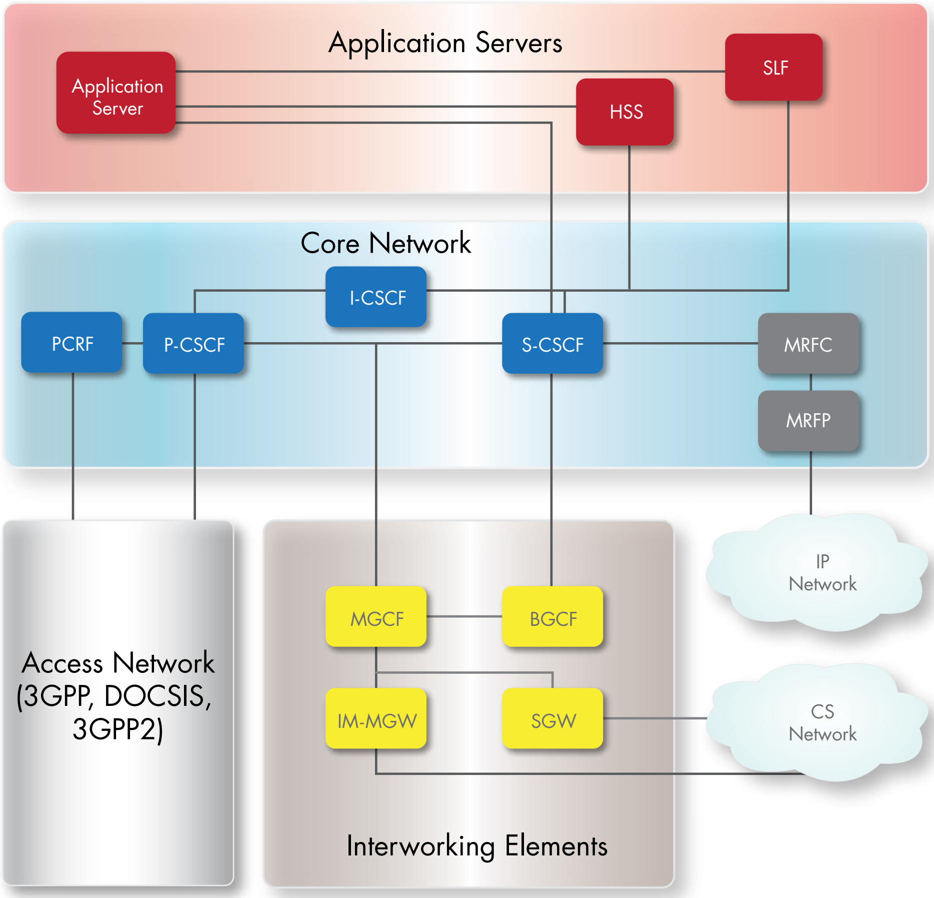


Figure 6. IMS Network Components

Ixia Test Solutions

Ixia provides a complete set of test solutions for use in wireless testing. Ixia's test solutions are end-to-end from the wireless edge to the Internet core. Ixia's platforms and test applications, including IxCatapult, IxLoad, IxNetwork, and IxANVL are used to test individual devices, subsystems or entire networks.

LTE Network Testing

Ixia tests LTE radio access and EPC network components both independently and in combination. Figure 7 depicts the emulation environment used to test eNode B elements.

Ixia's physical network interfaces emulate all of the components that surround an eNode B in a live network.

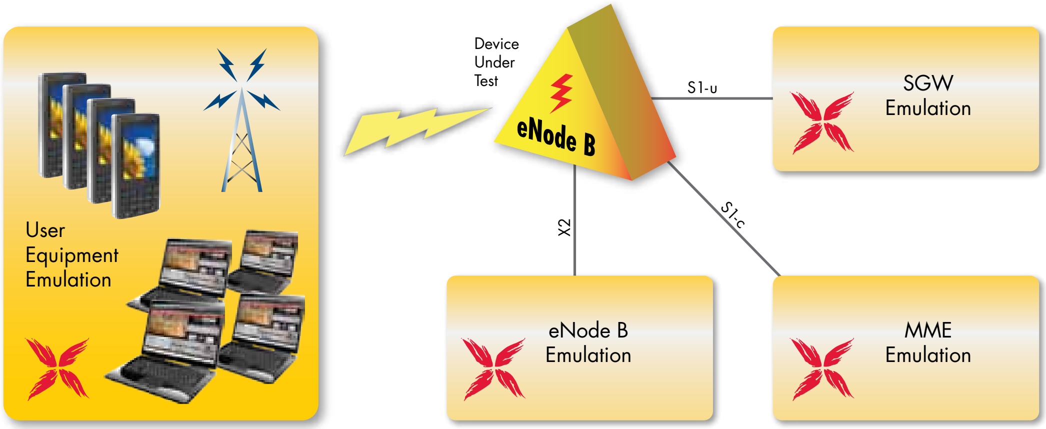


Figure 7. Ixia eNode B Testing

Ixia's UE emulation includes:

- **Multi-UE emulation**. Hundreds of emulated users per sector, with 6-sector support test any eNode B at its maximum capacity and complexity. With 2x2 MIMO, up to 125 Mbps of download traffic can be generated and verified.
- **Full Uu interface support with associated protocols**. PHY, MAC, RLC, PDCP, RRD and NAS protocols through available encoders and decoders, state machines and procedure libraries.
- **Uu simulation**. Includes support for 5, 10 and 20 MHz channels, 2x2 MIMO, in-cable CPRI v3.0/4.0, and RF over LTE frequency bands I-XIV.
- **Simulation of real-world scenarios**. Register and de-register, handover with inter-eNode B, intra-eNode B and IRAT, as well as interoperability with UTRAN, GERAN, CDMA2000 and IMS.

The three key devices in the EPC – the MME, SGW, and PDN-GW – are similarly tested by emulating all interconnected devices.

Device	Simulations
eNode B	eNode B, MME, SGW, UE
MME	HSS, eNode B, SGW, MME
SGW	MME, eNode B, PDN-GW
PDN-GW	SGW, PCRF, SGW, Network
Network	UE, IP Core

Table 1. IxCatapult Wireless Device Simulations

UMTS and IMS

Ixia offers a complete UMTS functional and load testing portfolio using high speed downlink/uplink packet access (HSDPA/HSUPA). Full protocol stack testing of the *Iub* interface with HSDPA and HSUPA is available for functional testing, with additional flexibility for lower layer protocol analysis. Ixia test systems deliver the industry's highest load test capacity systems, enhanced with advanced traffic generators that effectively stress and verify UMTS terrestrial radio access network (UTRAN) and core network components. The network components that can be tested include the node B, UE, radio network controller (RNC), and GPRS support nodes.

Ixia's IMS test solutions offer the protocol breadth, stack depth, and traffic/signaling capacity required to stress and verify IMS network elements. Test cases and configurations can be constructed for any of the primary IMS functional areas: core network, interworking elements, and application servers.

Extensive protocol support is included to test all key IMS areas, including authentication, call session control, security, charging, and quality of service. Complex lower layer protocol analysis, essential for IMS testing, is likewise supported. PESQ support is provided for voice analysis. Ixia's multi-user, multi-protocol, multi-technology platform facilitates simultaneous testing of mobile users, application servers and their services, and the PSTN. High performance load testing is easily accomplished.

Realistic Subscriber Modeling

Control and user plane testing facilities must stress test components to ensure proper operation under load, and determine realistic capacities.

Bit and block error rate testing (BERT/BLERT) are used for bit level data pattern testing of all interfaces. For higher layer testing, a wide variety of protocols are available:

- Multiple media streams per UE – RTP, UDP, and TCP.
- Multiple voice and audio encoders – AMR NB/WB, G.711, G.726, G.729, H.261, H.263, MPEG-2, and MPEG-4.
- IPv4 and IPv6 with IPSec, TLS, and ROHC.
- SIP and SDP simulation and analysis.

All types of traffic are available on a per-call basis. Ixia offers the highest flexibility and volume of triple-play traffic in the industry. A wide variety of protocols are emulated, both from the client and server side. These are described in Table 2. Device and network measurements are performed on a per-call or aggregated basis, and include:

- Network characterization: packet loss, jitter, latency, and throughput
- Audio: PESQ
- Video: Telchemy VQmon®, VQA
- Quality of service and quality of experience

Conclusion

Comprehensive quality assurance requires compliance, functional, performance and scalability testing. Wireless network components must be tested under stress, with realistic user data to mimic real-world loads. In addition to packet-based metrics, it is imperative to measure QoE for voice, video and data services.

LTE as a technology opens a new realm of opportunity for high-bandwidth services, but brings with it a number of new complexities to challenge testers.

Ixia has the essential tools that allow telecommunication equipment manufacturers and mobile service providers to ensure that they have designed, built, and deployed the correct devices and networks. Ixia's solutions ensure that the appropriate components have been selected and that their networks have been provisioned with sufficient performance. Ixia's wireless testing hardware and software enables full capacity testing with real-world user counts and realistic triple-play traffic, measuring QoE. The flexibility of the tools makes it straightforward to test individual components, sub-systems and entire end-to-end networks. Ixia's protocol coverage runs the complete gamut – from the wireless edge through the Internet core.

Acronym Soup

2G	Second generation (wireless networks)
3G	Third generation (wireless networks)
AAA	Authentication, authorization and accounting
BGCF	Breakout gateway control function
BSC	Base station controller
BTS	Base transceiver station
3GPP	Third Generation Partnership Project
BERT	Bit error rate testing
BGCF	Breakout control function
BLERT	Block error rate testing
BSC	Base station controller
BTS	Base transceiver station
CDMA	Code division multiple access
CDMA2000	Hybrid 2.5G / 3G CDMA
CPRI	Common public radio interface
CS	Circuit switched
DHCP	Dynamic host control protocol
DNS	Dynamic naming system
DPI	Deep packet inspection
DUT	Device under test
eNode B	Evolved node B
EPC	Evolved packet core
E-UTRAN	Evolved UMTS terrestrial radio access network
GERAN	GSM EDGE radio access network
GGSN	Gateway GRPS support node
GMSC	Gateway mobile switching center
GPRS	General packet radio service
GSM	Global system for mobile communications
HSDPA	High speed downlink packet access
HSPA	High-speed packet access
HSPA+	Evolved high-speed packet access
HSS	Home subscriber service
HSUPA	High speed uplink packet access
I-CSCF	Interrogating call session control function
IM-MGW	IP multimedia media gateway
IMS	IP multimedia subsystem
IPSec	IP security
IRAT	Inter-radio access technology
LTE	Long term evolution
MAP	Mobile application part

MGCF	Media gateway controller function
MGW	Media gateway
MIMO	Multiple-input, multiple-output
MME	Mobility management entity
MRFC	Multimedia resource function controller
MRFP	Multimedia resource function processor
MSC	Mobile switching center
P-CSCF	Proxy call session control function
PCRF	Policy and charging rules function
PDF	Policy decision function
PESQ	Perceptual evaluation of speech quality
PDN	Packet data network
PDN-GW	Packet data network gateway
PHY	Physical layer
QoE	Quality of experience
QoS	Quality of service
RF	Radio frequency
RLC	Radio link control
ROHC	Robust header compression
RNC	Radio network controller
RTP	Real-time transport protocol
S-CSCF	Serving call session control function
SDP	Session description protocol
SGSN	GPRS support node
SGW	Serving gateway (EPC) or signaling gateway (IMS)
SIP	Session initiation protocol
SLF	Subscriber location function
TCP	Transmission control protocol
TEM	Telecommunications equipment manufacturers
TLS	Transport layer security
UMTS	Universal mobile telecommunications system
VQA	Voice quality assessment
W-CDMA	Wideband code division multiple access
UDP	User datagram protocol
UE	User equipment
UTRAN	UMTS terrestrial radio access network

Ixia Worldwide Headquarters
26601 Agoura Rd.
Calabasas, CA 91302

(Toll Free North America)
1.877.367.4942

(Outside North America)
+1.818.871.1800

(Fax) 818.871.1805
www.ixiacom.com

Other Ixia Contacts
Info: info@ixiacom.com
Investors: ir@ixiacom.com
Public Relations: pr@ixiacom.com
Renewals: renewals@ixiacom.com
Sales: sales@ixiacom.com
Support: support@ixiacom.com
Training: training@ixiacom.com