Drive Testing LTE

Do we need drive test in LTE?

In Long Term Evolution (LTE), as with other cellular technologies, drive testing is a part of the network deployment and management life cycle from the early onset. Drive testing provides an accurate real-world capture of the RF environment under a particular set of network and environmental conditions. The main benefit of drive testing is that it measures the actual network coverage and performance that a user on the actual drive route would experience. It is argued that in today's networks with modern simulations, network engineers can mathematically model how a network will perform. While this is true to a certain extent, it is also essential to conduct drive testing as network parameter settings alter how the user equipment (UE) interacts and deals with the network environment. Such interactions cannot be wholly predicted through mathematical modeling. Figure 1 shows how drive test is used in the network planning life cycle.

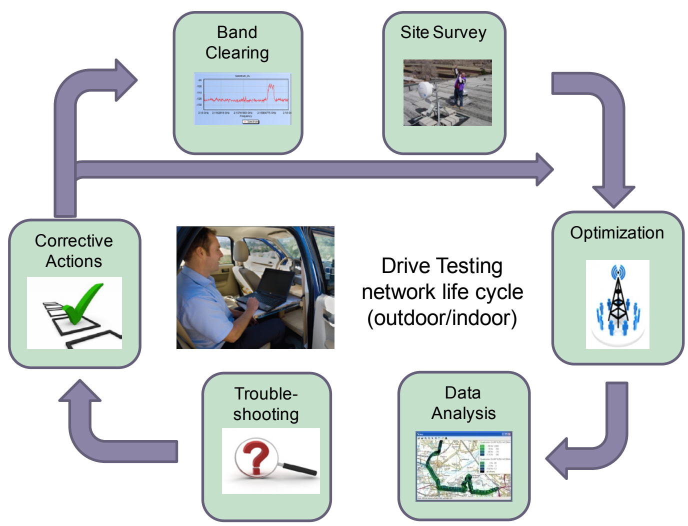

Figure 1. Network planning cycle

Components of a Drive Test System

Drive test systems are generally built around two measurement components, instrumented mobile phones (test engineering phones) and measurement receivers. Each component has its own characteristics with associated benefits and drawbacks. Phone-based systems can respond to problems within network-controlled constraints. Receiver-based systems give a complete overview of RF activity but cannot duplicate network-related problems. These measurement devices are controlled with data-logging software on a laptop PC together with a global positioning system (GPS) to provide geo-location of the collected data. The collected data can be analyzed using software that allows for plotting the results on digital maps enabling visualization of the RF environment.

The measurements carried out during drive testing have evolved over time — from the early days when the focus was purely on parametric RF measurements to the wide variety of application-based data performance measurements integrated into modern drive test systems. Many of these changes have been driven by the change in services provided from a simple voice carrier to the multi-service, data-centric wireless networks that LTE intends to enable. Network operators have shifted their focus from purely measuring RF performance to measuring customer experience, and this has driven the integration of many data application tests such as video streaming and voice over IP (VoIP) into drive test systems so that engineers can correlate end-user application performance with detailed RF measurements. With LTE, many of the measurements themselves have had to adjust to take into account the much higher data rates that LTE provides.

Another evolution is the move from single-band single-technology networks to multi-band multi-technology networks. LTE is not going to exist as an island technology, but will be overlaid and integrated with the existing universal mobile telecommunications system/high-speed packet access (UMTS/HSPA) and third-generation code-division multiple access (cdma2000) 1xRTT and high-rate packet data (HRPD) 1x Evolution-Data Only (1xEV-DO) networks. Drive test tools need to embrace this multi-technology multi-band environment. An area of key interest to cellular operators will be the interaction of LTE with their existing infrastructure and, in particular, the crossover points where handovers take place.

Importance of Drive Test for LTE

Many different strategies and methods to monitor network performance have been described. Network "probing" in which the signaling traffic is monitored at control points and then centrally analyzed can provide valuable insights into the overall network health. This strategy works well where, as in Global System for Mobile Communications (GSM) and UMTS networks, much of the control traffic is consolidated through radio network controllers (RNCs) or base station controllers (BSCs) so that by monitoring relatively few major interfaces, a good view of a wide range of base station end-points can be obtained.

As the industry has moved ahead with HSPA and now LTE technologies, more and more of the network intelligence has moved out from the core to the edge of the network and into the E-UTRAN Node Bs (eNBs), also taking the traffic management toward the network edge (see Figure 2). This means that much of the control and decision making is now deployed within the eNBs, and interaction between the UE and base stations can be most effectively monitored by instrumented phones involved in the actual transactions. This move of the decision point in traffic management has been needed to realize the reduced latency requirements for LTE performance — signaling control traffic no longer has to traverse multiple network nodes when a change is made for a UE.

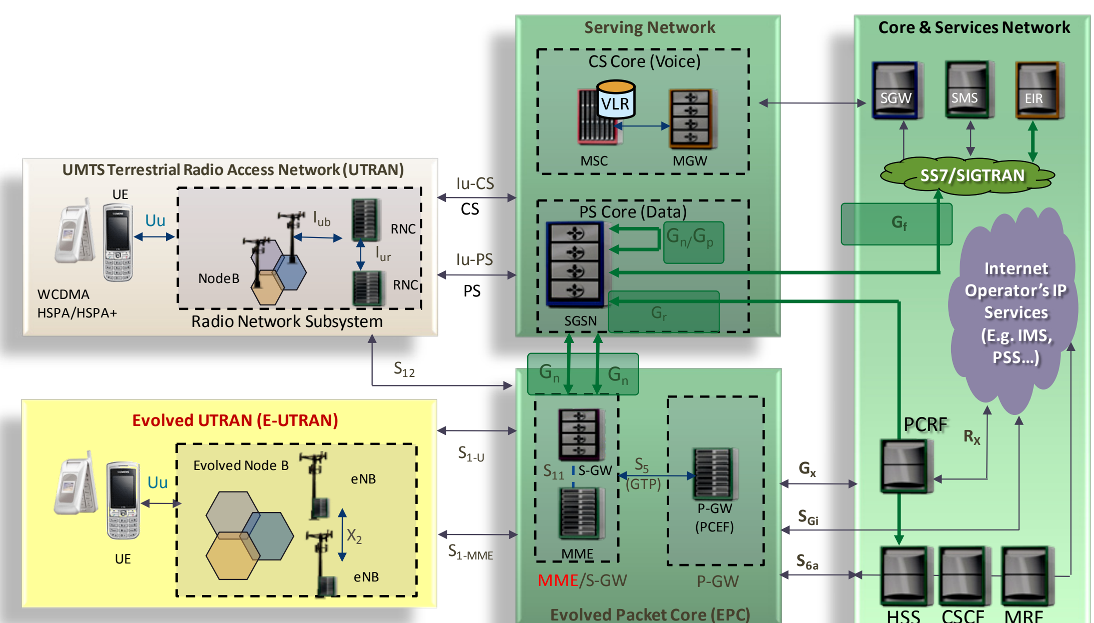

Figure 2. Control functions of the RNC have moved into the eNodeB

While the name “drive test” comes from the fact that the measurement equipment is generally “driven” in a vehicle, we should also mention that measuring indoor coverage is becoming increasingly important. Indoor performance measurements do not rely on views of the sky nor GPS for positional information. Instead, users indicate their measurement location on a scanned floor plan of the building using a point-and-click navigation method. The logging software allows for true geo-location of a corner of the floor plan so that the indoor results can be combined with the outdoor results in the final overall analysis. The considerable increase in the processing power available on smartphones has led to the creation of handheld drive test devices that can be used when extreme portability takes priority over depth of functionality. Handheld devices lend themselves very well to indoor measurement environments where discretion of collection is also a factor. The range of measurements on a handheld device is as extensive as on a full drive test system and data may be analyzed and amalgamated in post-processing.

Phone-Based Drive Test for LTE

Phone-based drive test systems are useful for evaluating basic network performance and are essential to characterizing the end-user experience while using the network. Phone-based systems address the need to verify network settings such as cell selection and re-selection boundaries and to measure the voice and data application performance in the live network. Most modern mobile phones chipsets have engineering measurement capabilities built into them, which were used during the mobile phone’s design process. These same parameters are exploited in drive test software to provide new value to the RF engineers rolling out the final network.

With radio resource management taking place in the eNB, suitably instrumented phones can be used to monitor the performance of the physical layer including modulation schemes, access procedures, synchronization, and power control.

The same types of parameters are measured for LTE as for other cellular technologies. Beyond the essential protocol log, which provides visibility of the fundamental interaction with the network, the initial focus is on RF coverage and quality. Figure 3 identifies the main measurements that are made. In LTE, these equate to reference signal received power (RSRP) and reference signal received quality (RSRQ), which are measures of the strength and quality of reference signals. These two results are the major components of network-based decisions to keep a UE on its current cell or hand it over to an adjacent cell. Additional measurements used to assess the link quality include call quality index (CQI) and block error rates (BLER). While RSRQ is the 3rd Generation Partnership Project (3GPP)-defined measure of signal-to-noise ratio (S/N), which all mobiles must make and report, many LTE UEs are also making custom carrier-to-noise ratio (C/N) measurements, which they use internally to assess channel quality. These additional carrier-to-interference (C/I) measurements are not reported back to the network, but they are available within the drive test logs and can be used by RF engineering teams to get extra insight as to how the mobiles perceive the RF environment.

Instrumented phones can also report the measured channel state information (CQI, pre-matrix indicator [PMI], and rank indicator [RI]) and hybrid automatic repeat request (HARQ) statistics. The number of resource blocks assigned to a device at a particular time, together with the modulation and coding scheme applied, can be used to evaluate the eNB scheduler performance. These types of tests are of particular interest during early stages of deployment of a new network but also must be monitored as network loading increases and true end-user traffic patterns establish.

One of the most interesting LTE network features to RF optimization engineers is the impact that multiple input multiple output (MIMO) with spatial multiplexing and antenna diversity brings to the end-user performance. Drive-test-enabled devices can log the current rank, number of transmit and receive paths in active use, together with the reported availability of antennas. They can also individually report the signal strength and quality from each of the device's antennas. This information can be correlated with the measured data application performance to establish the impact MIMO has on network performance. Because full MIMO is a feedback system, an instrumented mobile that is part of the active channel is the only way to evaluate the true impact that this technology can make.

As LTE networks are deployed alongside existing cellular networks, cellular operators are particularly interested in the efficient use of each network resource and the transition between the network technologies. Drive testing is used extensively to monitor the handover points between LTE and legacy technologies. The signal strength, quality, cell ID, and neighbor information both before and after a handover are analyzed and optimized. The length of time it takes to complete an initiated handover, success rates, and the end-user data-interruption time (during the actual transition between technologies) are key performance indicators that are closely monitored.

End-user data throughput performance and latency are the two key measures of a network's optimization. If the network is not achieving the expected data performance, it is important to be able to analyze the signaling performance and settings at each signaling layer, including the radio resource control (RRC), radio link control (RLC), and media access control (MAC). Monitoring the resources allocated to a UE together with the measured network conditions, available neighbor cells. and power levels will allow troubleshooting and optimization of network settings.

Measurement	Description	Use
Protocol Log	RRC and NAS protocol log	Capturing cell broadcast and system information Performing calculation on timing of events Troubleshooting failures
Cell-ID / E-ARFCN	Physical cell identity/E-ARFCN	Confirmation of the carrier in use; identifying the cell sector and base station in use
RSRP	Reference signal received power	Measure cell site received signal coverage in dBm (3GPP)
RSRQ	Reference signal received quality	Measure of cell site received signal quality in dB (3GPP)
SINR/CINR/SNR	Channel quality measure	Supplemental to RSRQ; mobile-manufacturer-specific implementations; not 3GPP
DL-SCH/UL-SCH Throughput	DL/UL shared channel throughput	Measure of throughput the mobile unit is achieving on shared UL or DL channels
DL-SCH/UL-SCH BLER	DL/UL shared channel BLER	Measure of error rate mobile unit is experiencing on the UL or DL shared channels
#DL RB UL RB	DL/UL resource blocks allocated	Measure of how much of the shared channels are allocated to the mobile by the scheduler.
#DL MCS/UL MCS	DL/UL modulation and coding	Indication of the efficiency of the transport channel under current network conditions; range is BPSK/QPSK/16QAM/64QAM
Wideband/Narrow Band CQI	WB / NB channel quality information	Measures the channel quality across the allocated frequencies; used for link adaption
Rank	Number of TX/RX paths in use.	Determines where MIMO is active
UE TX Power	Mobile transmit power	Monitors how much power the mobile needs to use to reach the eNodeB; used for link adaption.
Application Throughput	Performance of the end-user application	Measure of the end-user experience; making both UDP and TCP measures
Ping	Length of time to reach a specific IP address	Measures network latency

Figure 3. Top 14 phone-based measurements for LTE drive testing

As LTE evolves, not only is data transmission of interest, but voice remains the key service that many end users rely upon. In the initial stages of roll out for LTE, circuit switched fallback (CSFB) is the technology being deployed ahead of full IP voice over LTE (VoLTE.) Phone-based drive test systems are used to ensure that these services operate as designed. The length of time to set-up voice calls is monitored through the recorded protocol signaling as well as its affects on the users' data activity in process while a call is made and how it is resumed afterwards.

As network technologies advance and move toward IP service delivery mechanisms, drive test systems are used increasingly in combination with other test instruments. For signaling analysis, this includes protocol testers which monitor the signaling between the core and the eNB. The drive test system provides the last link in the chain to the end user, so combining the measurements made with the drive test system and core network protocol analyzers can give a full end-to-end picture of network performance.

Receiver-Based Drive Test for LTE

Receiver-based systems are used to obtain a "raw" view of the RF environment. They can measure the entire spectrum and are not constrained by network operator settings. These systems are useful for activities such as band clearing and general coverage estimation, but they cannot give a true measure of customer experience because they do not physically interact with the network under test. With new network technologies, receivers are generally available before fully fledged mobile devices which means that propagation models can be validated very early in the network life cycle.

In many regions, LTE is being deployed in re-farmed spectrum, for example, the "digital dividend" in Europe. This deployment has led to a renewed interest in spectrum clearing activities to ensure that no rogue interfering signals are left from other technologies prior to deploying LTE. Drive test is used extensively in this activity where the entire band can be monitored using a receiver as shown in Figure 4 that can be set to trigger if a signal is detected above a user-defined threshold. A waterfall-type spectrograph is used, giving a visual indication of transient potential interfering signals.

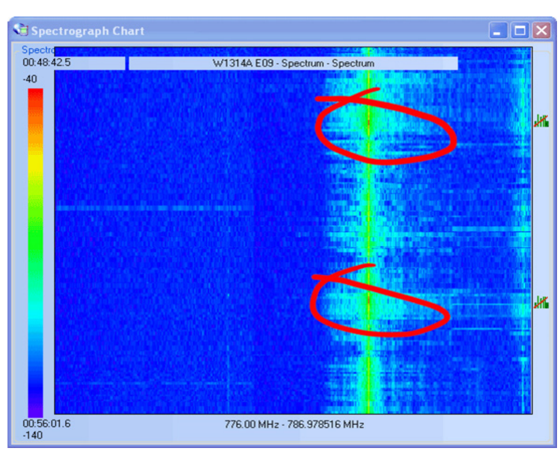

Figure 4. Drive test spectrograph for identifying interfering signals

Modern drive test receivers include specialist measurements targeted at specific technologies. To be useful, it is necessary to identify which signals are contributing positively to the mobile environment and which are negative influences. For LTE, identification of the reference signals that the UEs use to lock onto the network are key measurements. The RSRP, RSRQ, and physical cell identity (PCI) are the key measurements required. Some receivers also report custom C/I measurements, much in the way that UEs do. The ability to extract the LTE PCI allows the next level of identification of the cell similar to how the scrambling code can be used to identify a UMTS cell or similar to how a base station identity code (BSIC) would identify a GSM cell. Receivers also play a role in assessing MIMO deployment in the network. A receiver must be able to report the RF characteristics received from each eNB transmission antennae.

As mentioned, LTE is being deployed in harmony with existing technologies and in multiple bands both indoors and outdoors. Therefore, it is essential that a receiver used for drive test can measure both LTE and any co-residing legacy technologies. Low power consumption and careful hardware cooling design ensure their utilization in indoor environments where battery power is typical and equipment is usually enclosed in a back-pack.

A receiver is independent of the network and can, therefore, be used to monitor both the network of interest as well as other, perhaps competing, networks without direct interaction with either. Therefore, receivers are often employed in RF coverage benchmarking where we seek to plot the coverage of one network/technology combination versus another.

Benefits of Combining Phone- and Receiver-Based Tests

While both phone-based and receiver-based systems have their place, the real advantages come when the measurements from both systems are combined to allow troubleshooting that either cannot be conducted or is difficult to conduct when only using one system type. A solution such as the JDSU E6474A Drive Test System Software creates links between the test engineering phones and receivers in the system so that the receivers can dynamically track and measure the channels being used by the UE.

In all network technologies, identifying missing neighbor cells is a classic problem that can be addressed by the use of a combined phone- and receiver-based system. The phone reports and measures how the network has set the neighbor list while the receiver reports the actual impartial neighbor list. Combining the results of these two independent measures allows optimization of the network settings for the current RF environment.

In LTE, where that harmonizes a new network technology with an existing technology, optimizing traffic loading and handover points is another area where receivers can be used to provide insight into the complete RF environment. A multi-band multi-technology receiver can monitor both the LTE and legacy network simultaneously. Often, expanding network capacity requires the ability to do this on multiple carrier frequencies at the same time.

Identifying interference where it matters is also facilitated using a combined receiver and phone solution. The phone part of the system can establish the network connection and report application performance, and the receiver part of the system can monitor any external RF sources that may be adversely affecting the ongoing connection. Thus, network-dependent application performance and independent RF measurements are combined to provide information used to solve customer application problems.

Verifying LTE Application Performance Using Drive Test

Delivering user data rates of 100 M and above is one of the key challenges for LTE. Therefore, in addition to RF measurements, data application testing is a critical activity during network deployment. LTE moves wireless communications to an all-IP network. Bridging the gap between RF performance and end-user IP services, such as VoIP, video telephony, and video streaming, is a challenge for network operators who must ensure that these new offerings can be added to their infrastructure without affecting the quality of existing services.

Drive test solutions need to include a broad portfolio of instrumented data test applications including video streaming, video telephony, hypertext transfer protocol (HTTP), file transfer protocol (FTP), e-mail, short message service (SMS), multimedia messaging service (MMS), and wireless access protocol (WAP). These test applications are essential for network engineering departments to measure the performance of the applications in conjunction with the RF environment. Many of these applications have been used when previous technologies have been deployed but required making changes due to the higher data rates involved with LTE. An example of this is the simple FTP test that has long been a favorite of RF engineering departments to measure the end-user transmission control protocol (TCP) throughput. The massive increase in available data bandwidth in LTE has resulted in a single FTP connection being insufficient for fully exercising the channel capacity. For this reason, multi-segment FTP testing has been introduced, where multiple simultaneous socket connections are established between the drive test UE and the network-based FTP server. Figure 5 shows that as the number of simultaneous connections increases, so does the network delivered throughput. If just testing a single FTP session, the user may believe that the network was only delivering a fraction of its capability.

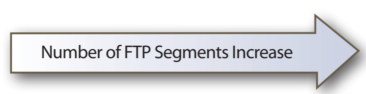

Figure 5. Multi-segment FTP test showing increasing throughput as segments increase

Note that download time duration decreases and throughput increases with more segments.

A new test introduced to the cellular testing environment with LTE is the Internet Performance Working Group (iPERF) test traditionally used in wireline testing. It is a client/server application capable of measuring network bandwidth and throughput. The main attraction of iPERF for LTE deployments is its ability to measure both user datagram protocol (UDP) as well as TCP throughput, and users can specify the test bandwidth.

If a service is not performing as expected, the RF performance and network configuration information is available alongside application performance data. A GPS provides precise geographic location to allow troubleshooting and problems to be identified. Figure 6 shows a typical network optimization and troubleshooting cycle involving analysis of data.

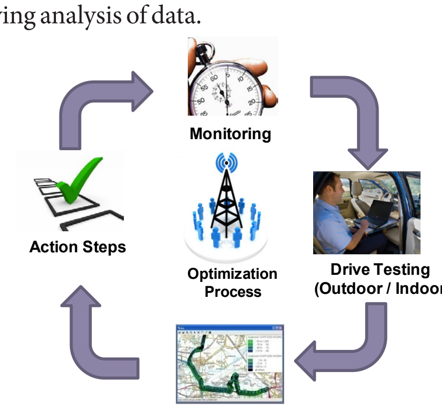

Figure 6. RF network optimization/troubleshooting cycle

Drive Test Solutions for LTE

Comprehensive drive test systems such as the JDSU E6474A Wireless Network Optimization Platform address the challenges of optimizing LTE network performance by quickly and accurately identifying problems. The E6474A system shown in Figure 7 can be used in spectrum clearing, site evaluation, cluster and initial optimization, system acceptance, and ongoing optimization and troubleshooting. The system can be scaled from a single phone-based solution to a multi-phone, multi-technology receiver and phone combined system covering all the major technologies that are deployed in wireless networks worldwide: LTE, HSPA, UMTS, GSM, general packet radio service (GPRS), enhanced data rates for global evolution (EDGE), 1xEV DO, cdma2000, time-division synchronous code-division multiple access (TD-SCDMA), integrated digital enhanced network (iDEN), and worldwide interoperability for mobile access (WiMAX). The system also encompasses a wide range of application tests including TCP/UDP, messaging, analog and VoIP testing, web-oriented, and video streaming components and is designed for both indoor and outdoor use.

Figure 7. JDSU E6474A Drive Test System for network planning, deployment, and maintenance

With the flexibility to combine multiple phones and the JDSU multi-band multi-technology receiver, this drive test system lets users measure multiple technologies simultaneously with a single computer. The unique graphical data test sequencer facilitates construction of a range of end-user scenarios to simplify network optimization and to determine a customer's quality of service.

To simplify configuration and reduce costs, the JDSU W1314A Measurement Receiver used in the E6474A Drive Test System can measure up to eight frequency bands in a single drive, allowing verification of multi-band multi-technology coverage using a single piece of measurement hardware. Powerful digital signal processing (DSP) technology allows for software upgrades to keep the measurements current as the technology evolves.

JDSU has a range of smartphone-based drive test solutions that seamlessly integrate with the full laptop solution for in-depth analysis where extreme portability and ease of use are paramount considerations.

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