PROTOCOL STACK TESTING for LTE

EFFECTIVE TEST STRATEGIES CAN HELP TRANSFORM UMTS INTO A CELLULAR WIDEBAND SYSTEM.

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Producers of mobile phones and mobile infrastructure are working on the next big step in the development of the universal mobile telecommunications system (UMTS): UMTS long term evolution (LTE). The new standard will ensure that UMTS remains competitive while giving users enhanced mobile Internet access. The first commercial LTE networks could be in place by 2010, and LTE standardization is progressing as part of Release 8 from the 3rd Generation Partnership Project (3GPP). Manufacturers, therefore, will soon need suitable test capability to verify their LTE products.

LTE networks must provide downlink data rates of higher than 100 Mbps and uplink rates of higher than 50 Mbps. They must also significantly reduce the latency times for packet transmissions so users won’t experience unacceptable delays. To achieve these goals, the 3GPP is defining new air-interface transmission methods and is also revamping the protocol and network architecture of UMTS.

Where UMTS used wideband code-division multiple access (WCDMA) for transmitting signals, the LTE downlink uses orthogonal frequency-division multiple access (OFDMA), which is particularly robust when handling the varying propagation conditions seen in mobile radio. The LTE uplink will employ single-carrier frequency-division multiple access (SC-FDMA), which can be considered a precoded OFDMA.

Another significant feature of LTE is its high bandwidth—up to 20 MHz. Because the usable bandwidth is scalable, LTE can also operate in the existing 5-MHz UMTS frequency bands, or in even smaller bands. Developers of LTE base stations and wireless devices must also account for a very short latency time; LTE has a transmission time interval of only 1 ms between data packets.

LTE systems can also employ multiple-input multiple-output (MIMO) antenna systems. In one MIMO technique, multiple antennas can transmit the same data stream to improve data-transmission reliability, resulting in diversity gain. In another, the different antennas can transmit different data streams simultaneously to increase throughput; this method is called spatial multiplexing and results in multiplexing gain. Spatial multiplexing is necessary to achieve the greater
than 100-Mbps data rates in the down-
link direction.
An LTE base station can have up to
four transmit antennas, and an LTE
wireless device will have up to four re-
ceive antennas. Initial implementa-
tions will probably consist of 2x2 systems—
that is, two antennas on the transmit end
and two on the receive end.

The protocol architecture of LTE
The 3GPP is completely reworking the
network and protocol architecture of
UMTS so LTE can support high data
rates and short latency times. LTE is a
purely packet-oriented technology de-
veloped in accordance with the 3GPP’s
System Architecture Evolution (SAE) ef-
fort. LTE uses a minimal network archi-
tecture to reduce latency time. Figure 1
provides an overview of the LTE net-
work elements and their interfaces. The
LTE base station, or eNodeB (eNB), initi-
ates connections on the air interface. It
also assigns air-interface resources and
performs scheduling.

Each LTE base station connects to the
core network through the 3GPP-defined
S1 interface. The base stations themselves
are interconnected via the X2 interface
so they can initiate and complete actions
such as handovers. As a result, the radio
network controller (RNC) previously
used in UMTS is no longer needed,
which significantly reduces the number
of internal interfaces in the network.

The eNB basically assumes the
functions previously handled by the
RNC.

Figure 2 shows the protocol
architecture for the user plane

and control plane. The layer-1 and layer-
2 protocols of the air interface terminate
in the wireless device and in the eNB.
The layer-2 protocols include the me-
dium access control (MAC) protocol,
the radio link control (RLC) protocol,
and the packet data convergence proto-
col (PDCP). The layer-3 radio resource
control (RRC) protocol also terminates
in both the wireless device and the base
station. The protocols of the non-access
stratum (NAS) in the control plane ter-
minate in the wireless device and in the
mobility management entity (MME) of
the core network.

Many of the procedures used for
UMTS have been simplified for LTE.
For example, LTE employs the shared-
channel principle, which provides mul-
tiple users with dynamic access to the air
interface. In contrast to the con-
ventional circuit-switched oper-
ation, the packet-oriented LTE
network does not assign re-
sources to a user for the entire
duration of a connection. In-
stead, the base station gives the
user a resource on the shared
channel only when a data packet
is to be transmitted. During
transmission pauses, the resource
can be assigned to other sub-
scribers. The dedicated channels
used in GSM and UMTS are
thus no longer needed, greatly
simplifying the LTE protocol ar-
chitecture and ensuring efficient
use of the resources on the air
interface.

The addition of procedures
for link adaptation further im-
proves the performance of the
shared channels. With link adaptation, the base station selects the optimum modulation and coding scheme based on the connection quality. The base station also makes frequency-dependent scheduling decisions, such as whether a user would have better connection quality in a specific range of bandwidths.

The scheduling mechanism is therefore complex and if not properly implemented can significantly degrade the performance of the LTE system. The stringent timing requirements are of particular importance because the base station makes a scheduling decision every millisecond.

LTE differs from UMTS in dispensing with the compressed mode of WCDMA, which allows a wireless device to take measurements on other frequencies or radio technologies to optimize call quality and to facilitate handovers. For this purpose, data transmission is compressed so that the wireless device can find gaps for performing measurements. This method is relatively complex to implement. Because LTE doesn’t use compressed WCDMA, the base station is responsible for providing individual subscribers with the necessary pauses for these measurements.

An important aspect, particularly from the point of view of network operators, is the integration of LTE into established mobile radio networks. In addition to GSM/GPRS and the existing UMTS networks, these include networks that are based on WiMAX and CDMA2000. To ensure the successful handover of calls from LTE networks to ones based on other technologies, the 3GPP specifies suitable handover mechanisms.

Protocol tests for LTE devices
During the early stages of development of LTE-capable chipsets and wireless devices, engineers should perform protocol tests as well as a functional test to ensure that the functioning of the protocols on the air interface complies with the 3GPP LTE specifications. Engineers should also address performance aspects, such as whether the product can handle the high-data-rate requirements of LTE.

Depending on the degree of integration, you can use various approaches for performing protocol tests. Several test-equipment manufacturers offer test instruments that include software-based LTE protocol testers. If a layer-1 implementation is not yet available, or integration has not yet taken place, you can use this software to perform a virtual test of the protocol software. In the R&S CMW500 for LTE, for example, the test software emulates the behavior of the protocols on the network end. Develop-

![FIGURE 3](image.png)

FIGURE 3. A message composer can help you specify the contents of layer-3 messages that are used in a test scenario. These messages can perform functions such as setting up a connection.
ers can connect the protocol stack to be tested to a virtual tester via an IP connection. LTE test scenarios then verify the behavior of the protocol stack on the wireless device end. These scenarios can include a simple connection setup or more complex reconfigurations. All important functions of the layer-2 and layer-3 protocols can be verified in the virtual test environment of the CMW500, for example.

After layer-1 integration, you can connect the wireless device or chipset to a bench protocol tester for further testing. The connection can take place via RF or in the baseband—for example, over a digital I/Q interface. You can then subject the device under test (DUT) to the LTE test cases to study the behavior of the device and detect possible errors.

When moving to the hardware version of a protocol tester, developers can reuse the scenarios from the virtual-test environment. The R&S CMW500 for LTE also provides test cases that include layer-1 functionality. Of particular interest are the test cases that require an interaction between the downlink and uplink, such as MIMO or the hybrid automatic repeat request (ARQ) protocol.

For throughput measurements, connection to the user plane—for example, to a video streaming server—is important. Actual user data can thus be processed in the protocol test scenario. LTE devices must be able to work with other technologies, as LTE services will not be rolled out everywhere simultaneously.

**Test scenarios for development**

When testing LTE devices in R&D, engineers should use a flexible programming language like C++ so they can develop numerous complex test scenarios. A distinction is made between the low-level application programming interface (LLAPI) and the medium-level application programming interface (MLAPI), depending on whether the interface accesses layer 2 or layer 3.

The LLAPI offers users particular flexibility for programming layer 2 of the network simulator. Plus, the LLAPI is available early on as it does not require a layer-3 implementation. (The 3GPP is still working on the specification of LTE layer 3.)

On the other hand, the MLAPI is a particularly efficient method because the user does not have to configure layers 1 and 2 on the tester end; layer 3 handles that automatically. The user only needs to specify the desired sequence of the protocol test scenario, plus the contents of the layer-3 mes-
sages, for example, for setting up the connection.

Figure 3 illustrates the use of the R&S CMW500 for LTE instrument for editing messages. State machines allow the scenarios to be set up modularly, so that individual components can easily be reused. Figure 4, generated by the CMW500 message-analyzer function, shows every message exchanged between a tester and a DUT.

Interoperability scenarios
The first LTE-capable wireless devices will soon be tested in real networks. To comprehensively prepare for these field trials, producers of chipsets and wireless devices will need to perform interoperability tests to completely test a wireless device in the lab and prepare for all test cases in the field. As a result, implementation errors can be detected early on and surprises avoided. If problems do still occur during the field trial, the scenarios can be reproduced in the lab by using the protocol tester, and the implementation error can then be eliminated from the chipset or wireless device.

3GPP is currently working on test specifications for LTE. In addition to test cases for RF and radio resource management, the 3GPP will develop numerous signaling test cases. These will include layer-2 and layer-3 test cases, as well as NAS test cases. The 3GPP will describe these test cases in testing and test control notation version 3 (TTCN-3). The conformance test cases specified in 3GPP will form the foundation for the certification of wireless devices, ensuring that all wireless devices worldwide comply with the same standards.

LTE involves many technical changes for UMTS. Developers of LTE-capable chipsets and wireless devices must therefore carry out numerous protocol tests to detect errors in the implementation early on, thus saving time and money. The interworking between LTE and other radio technologies will be a particularly important task in protocol testing. T&MW

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