LTE protocol tests for IO(D)T and R&D using the R&S®CMW500

The standardization of layer 3 signaling for the new UMTS long term evolution (LTE) standard is almost complete, and Rohde & Schwarz is ready with test scenario packages for the R&S®CMW500 test platform as well as with a powerful programming interface for creating customized tests. The LSTI-defined IODT tests play a significant role here.

The LTE/SAE Trial Initiative

The LTE/SAE Trial Initiative (LSTI) is a group of network operators and manufacturers whose goal it is to drive the implementation of the 3GPP LTE/SAE standard. The particular focus is on demonstrating the performance of LTE and SAE. LSTI has agreed on a selection of essential LTE functions that are being verified as part of the interoperability development testing (IODT) and interoperability testing (IOT). IODT represents early testing of a subset of LTE/SAE functions on the air interface and is a preparatory step for interoperability testing between manufacturers of network infrastructure and of wireless devices. The individual tests are defined in the LSTI common test descriptions. Rohde & Schwarz became a member of LSTI in February 2008 and has contributed significantly toward the definition of these descriptions.

LSTI IODT test scenarios

Rohde & Schwarz offers the LTE IO(D)T and field trial test scenario package for the R&S®CMW500 test platform. The availability of IODT tests in a lab environment makes it possible to prepare fully for testing in trial networks of an LTE/SAE infrastructure implementation. Additional advantages of the IODT test scenarios on the R&S®CMW500 include:

- Convenient setting of network parameters
- Detailed analysis of test results
- Simple reproducibility of results
- Availability of test scenarios' source code to allow users to modify and expand test scenarios as required

Of particular interest is that the test scenarios in this package can be run on both the R&S®CMW500 hardware protocol tester (FIG 1) and the R&S®CMW-KP502 virtual LTE test environment as pure protocol stack software tests.

FIG 1 The universal R&S®CMW500 wideband radio communication tester addresses the complete test scenario from development through to production. It covers all layers and all relevant standards.

R&S®CMW500: multistandard platform for measurement tasks of the wireless future

The R&S®CMW500 wideband radio communication tester is the first all-in-one solution on the market that covers all phases of development and production. It unifies unique advantages, making it a secure investment for many years to come.

Multistandard platform for development and production

As a true one-box tester, the R&S®CMW500 meets the increasing requirements in the development and production of chipsets and mobile UEs. This is why it supports all production-relevant cellular and noncellular standards. And in development, it offers the advantage of being able to test all the functional layers of a mobile UE, from RF parameters and protocols to the actual applications. Featuring a frequency range up to 6 GHz, it is also fully ready to handle future technology developments.

Compared to existing technologies such as WCDMA or GSM, standards such as LTE and HSPA+ place more stringent requirements on T&M equipment, due to more complex modulation methods (64QAM), multi-antenna systems (MIMO), and expanded layer 1 configuration capabilities. Processes are becoming more complicated in the protocols as well. As a result, Rohde&Schwarz has tailored the R&S®CMW500 specifically to meet these requirements, in close cooperation with wireless device manufacturers and chipset designers. The R&S®CMW500 combines RF generator and RF analyzer functionality and, by means of signaling, can control the interplay of downlink and uplink signals.

In production, time and cost savings are paramount. Rohde&Schwarz has developed special approaches to this: By utilizing the R&S®Smart Alignment test concept, the R&S®CMW500 makes alignment up to ten times faster than with conventional methods. Plus, the tester is optionally equipped with two channels, which allows parallel measurement of two DUTs using different standards. Since a maximum first pass yield is necessary in order to achieve minimum production costs, high standards were placed on absolute accuracy, repeatability, and linearity during the development of the tester.

Consistent test concepts from development to production

One advantage that has been given hardly any attention to up to now is the use of consistent test concepts in all phases involved in the creation of a product. Since the R&S®CMW500 can be used from development to production, it provides consistent, comparable results throughout. Errors that occur in production can be easily reproduced in development. Conversely, test scripts or alignment routines that were written during development can be used again later for the integration phase or in production.

From RF to protocol to end-to-end application testing

The transmission of high data rates via the (less than ideal) radio interface channel involves highly complex processes at the protocol layers of the mobile station. Errored data packets must be corrected and parallel data streams processed. These extremely fast processes such as hybrid automatic repeat request (HARQ) and MIMO run on layer 1. Since the R&S®CMW500 performs protocol analysis as well as hardware-oriented RF measurements simultaneously, it makes troubleshooting much simpler.

The R&S®CMW500 at a glance

- Scalable wideband radio communication tester for development and production
- Multistandard tester
- Supports all layers (RF, protocol, application)
- Future-oriented hardware (frequency range optionally up to 6 GHz, MIMO-capable)
- Reduced test times and costs (alignment up to 10 times faster than with conventional methods)
- High precision and reproducibility

Supported standards

- GSM/(E)GPRS
- WCDMA/HSPA
- LTE
- TD-SCDMA
- CDMA2000® 1xRTT/CDMA2000® 1xEV-DO
- Mobile WiMAX™
- WLAN
- Bluetooth®
- DVB-T
- GPS

Already in the early phases of development, the test plans of manufacturers include RF parameter measurements of the layer 1 unit and protocol analysis. To achieve test scenarios as realistic and practice-oriented as possible, solutions are required that allow end-to-end performance measurements across all layers. The high test depth provided by the R&S®CMW500 – achieved through the combination of RF, protocol, and application tests – is ideal for this purpose.

Summary

The R&S®CMW500 provides chipset and mobile phone manufacturers as well as network operators with a flexible, scalable platform for performing all of the relevant tests. Its modular concept yields minimum test costs plus high investment safety. The tester is a single-box solution that performs all tasks that usually require multiple test instruments. It is thus a cost-efficient and space-saving solution that promises a high return on investment for many years to come.

Additional articles on the R&S®CMW500:

- Breakthrough in scalability and speed in production. NEWS (2008) No. 195, pp. 4–9
- UMTS LTE protocol tests for all phases of development. NEWS (2008) No. 196, pp. 10–15
- Versatile and precise signals for the production of wireless devices. NEWS (2008) No. 197, pp. 15–17

LTE R&D test scenario framework for the R&S®CMW500

The R&S®CMW500 provides two programming interfaces for implementing LTE R&D protocol tests:

- Low-level application programming interface – LLAPI (R&S®CMW-KP501)
  LLAPI-based test scenarios directly control the lower layers of the network end LTE protocol stack. Some layers, like the RLC, can be switched to be transparent. This allows precise testing of the lower protocol layers as well as negative testing, making it possible to verify layers 1 and 2 in a UE early on in development, even before signaling functionality is available.
- Medium-level application programming interface – MLAPI (R&S®CMW-KP500)
  An MLAPI test scenario utilizes a single service access point (SAP) in the RRC implementation of the R&S®CMW500 for signaling. This SAP is mainly used for exchanging the peer-to-peer messages transmitted via the air interface. The RRC configurator automatically configures the lower protocol layers and keeps them consistent with the signaling messages exchanged between the LTE UE and the network end. The use of MLAPI is recommended when testing the entire protocol stack in the UE. The spectrum of applications extends from higher-layer signaling (including handover and inter-RAT procedures) to end-to-end testing of IP applications.

FIG 2 shows a comparison of the two programming interfaces. MLAPI scenarios interface with the RRC configurator implemented in the LTE protocol stack, while LLAPI scenarios directly control the individual protocol layers.

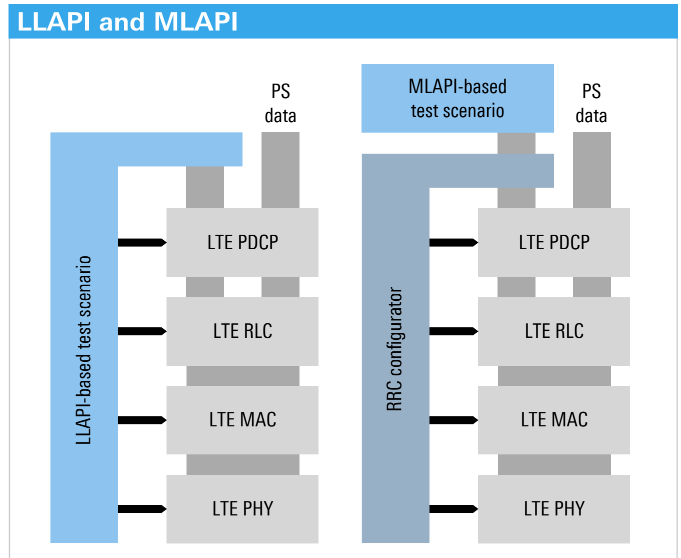

FIG 2 Comparison of the LLAPI and MLAPI interfaces.

MLAPI – automatic protocol stack configuration

The RRC configurator helps ensure consistent configuration of the LTE protocol stack and also evaluates the protocol messages exchanged between the MLAPI test scenario and the UE. While the MLAPI test scenario includes only the transmission of and response to layer 3 messages, the RRC configurator in the protocol stack – which is the base of the MLAPI – controls the lower protocol layers. The R&S®CMW-KT012 message composer allows convenient editing of the layer 3 signaling message contents. Only a single file needs to be edited to keep both the message itself and the configuration of the protocol stack consistent.

Since the protocol message contents are saved as XML files and not interpreted until the MLAPI test scenario runs, the configuration can be modified without recompilation. As long as the dynamic response of the test scenario – i.e. the sequence of the various message types – remains constant, new test scenarios can be created without modifying the C++ source code. This makes it easy for new users to begin working with MLAPI, even without any knowledge of C++ (FIG 3).

The LTE MLAPI state machine library: building blocks for LTE test scenarios

To simplify the generation of layer 3 signaling scenarios, a C++ class library is supplied together with the LTE example test scenarios (R&S®CMW-KF500). The C++ class library contains the building blocks in which the RRC and NAS procedures are implemented as state machine classes. FIG 4 illustrates how a test scenario can be implemented simply by calling four of these MLAPI state machine classes. During these tests, the UE registers, activates, and deactivates a packet data connection, and at the end of the tests initiates a detach procedure. The MLAPI state machines are constructed in a modular way, i.e. procedures that are used in multiple MLAPI state machines are encapsulated in separate state machines.

MLAPI users benefit because complex signaling tests can be implemented very quickly without having to re-implement all of the procedure components. Object-oriented programming helps ensure that the C++ source code remains clearly structured. The source code is provided for all of the state machines supplied, and advanced users can take these as basic classes for their own state machines. Both the MLAPI state machines and the protocol messages used in them are provided in the form of XML files.

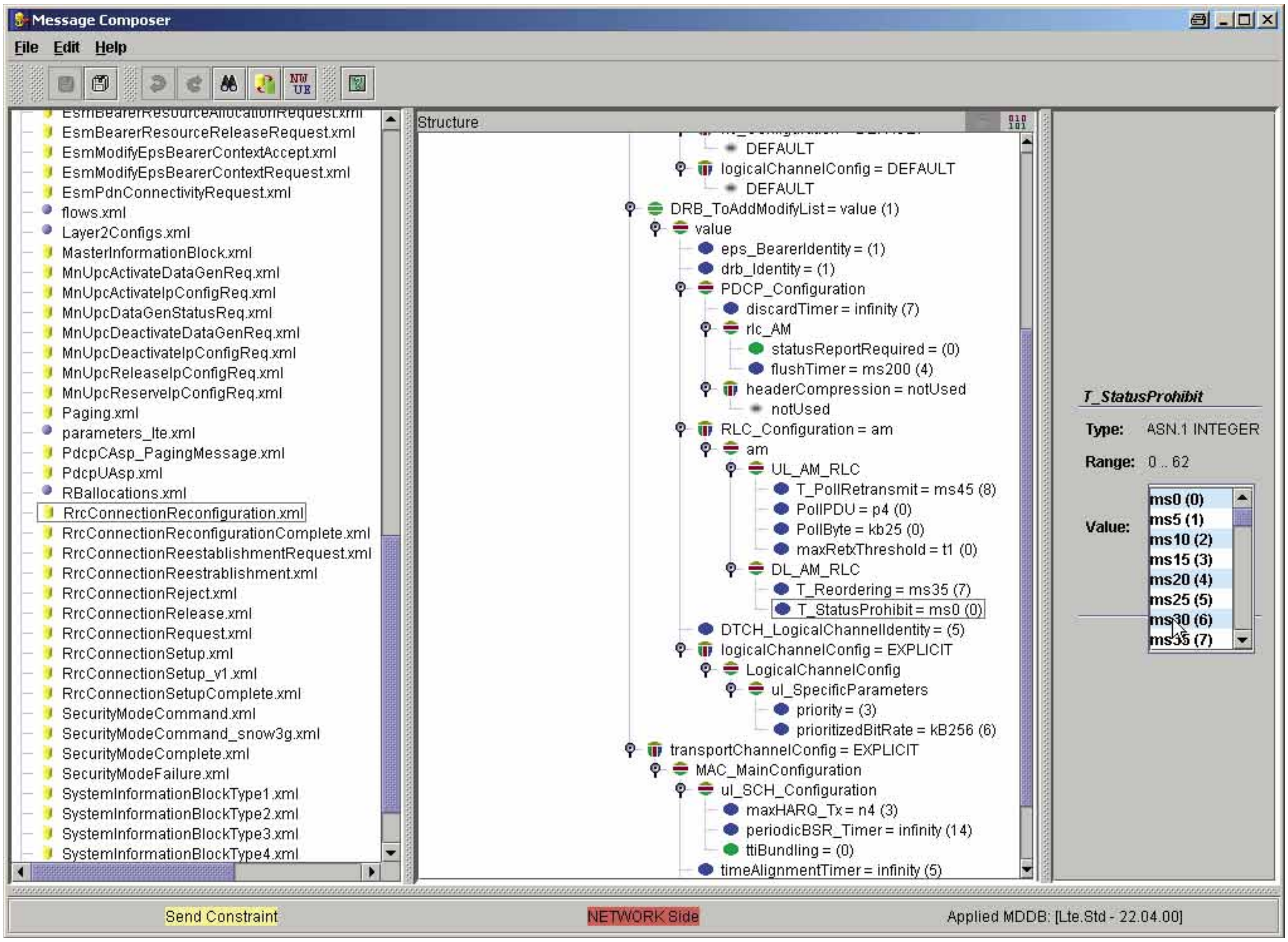

FIG 3 Simple editing of signaling messages in the message composer.

Combining LLAPI and MLAPI in one test scenario

LLAPI and MLAPI are components of a consistent test scenario framework for the R&S®CMW 500 that allows users to combine both worlds in a single test, and thus profit equally from the strengths of the respective interface. For example, the MLAPI state machines described in the previous section can serve to register a UE on the network and perform the signaling for activating a packet data service. In a second test step, the LLAPI functionality can then be used to manipulate the RLC and MAC in a targeted manner. FIG 5 shows how this type of scenario is organized in an MLAPI preamble, LLAPI body, and MLAPI postamble. This approach saves time when implementing signaling that might already have been verified during other tests, and allows focus on the implementation of the actual layer 1 or layer 2 oriented test purpose.

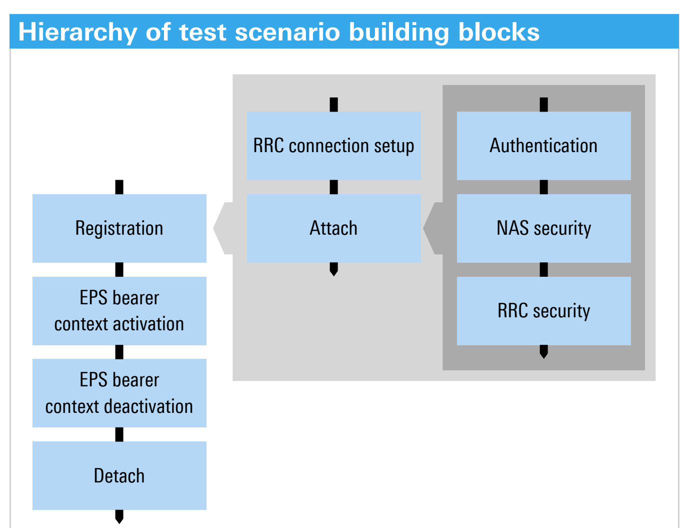

FIG 4 The substeps of the RRC connection setup and the actual attach procedure are organized in separate state machines. The state machine attach is subdivided into further state machines for authentication and for security procedures.

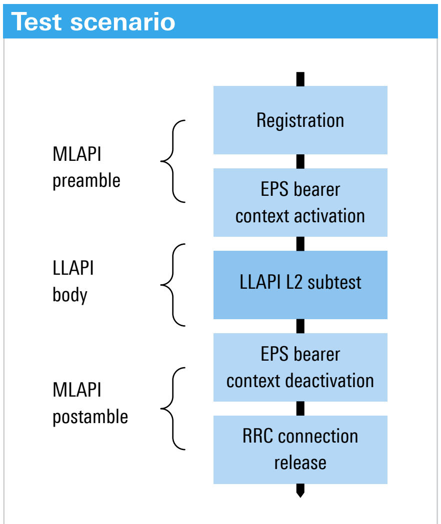

FIG 5 A combined LLAPI/MLAPI test scenario.

R&D test scenario packages for the R&S®CMW500

As the base for more than 1000 commercially available R&D and IOT test scenarios on the R&S®CRTU-W protocol tester for 3G WCDMA, MLAPI has proven its worth. In addition to the R&S®CMW-KF505 IODT test scenario packet discussed, four additional product options are now available for LTE protocol testing:

- R&S®CMW-KF500 – LTE sample scenarios
  LLAPI and MLAPI example scenarios for visualizing the use of the MLAPI framework and the state machine classes
- R&S®CMW-KF502 – basic LTE procedures
  Basic LTE RRC and NAS procedures, including attach, detach, EPS bearer connection setup, GUTI reallocation, and tracking area update
- R&S®CMW-KF503 – EPS bearer verification
  Activation and verification of various radio bearer configurations
- R&S®CMW-KF504 – intra-LTE mobility and handover
  Handover and mobility within LTE, intrafrequency and inter-frequency handover, adjacent cell measurements

Applications include integrating and verifying protocol stack functionality, as well as UE regression tests that permit a comparison of various UE software versions. The close cooperation with key customers ensures the selection of relevant test purposes and the practical applicability of the different test scenario packages from Rohde&Schwarz.

Summary

By using the R&S®CMW500 wideband radio communication tester, the powerful LLAPI/MLAPI programming interfaces, and customized LSTI IODT test scenario packages, Rohde&Schwarz makes a perfect combination of test equipment and test cases available to mobile phone manufacturers to ensure that their LTE signaling tests are performed quickly, efficiently, and cost-effectively.

Michael Dreimann

Abbreviations

EPS	Evolved packet system
GUTI	Globally unique temporary identifier
IODT	Interoperability development testing
IOT	Interoperability testing
LLAPI	Low-level application programming interface
LSTI	LTE/SAE Trial Initiative
LTE	Long term evolution
MLAPI	Medium-level application programming interface
PHY	Physical layer
RAT	Radio access technology
RLC	Radio link control
RRC	Radio resource control
SAE	System architecture evolution
SAP	Service access point
UE	User equipment