Reference Guide

LTE OTDOA

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LTE OTDOA

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INTRODUCTION

Demand for mobile services is exploding and one of the fastest growing segments is Location Based Services (LBS), primarily driven by two major requirements: emergency services and commercial applications. For emergency services, the most significant driver is the FCC's E911 mandate in the US, which requires location (with certain accuracy limits) of emergency callers to be provided. A wide variety of commercial applications, such as maps and location based advertising, also need fast and accurate positioning performance. It is important to note that both E911 and commercial uses require accurate positioning both in outdoors and indoors.

With the rollout of LTE comes a new focus on enabling E911 and LBS. Current LTE standards support three independent handset based positioning techniques: Assisted Global Navigation Satellite Systems (A-GNSS), Observed Time Difference of Arrival (OTDOA), and Enhanced Cell ID (ECID). OTDOA is a key technology for positioning when A-GNSS is limited or unavailable, and is extremely important for enabling E911 and other LBS applications indoors.

Because OTDOA technology is so important and testing is so complex, this reference guide provides an overview of the downlink OTDOA technology, important test areas, and Spirent coverage for conformance and R&D performance testing.

CORRESPONDING LITERATURE

WHITE PAPERS

An Overview of LTE Positioning

LTE Positioning Technology
for Moble Devices:
Test Challenges and Solutions

POSTER

LTE and the Mobile Internet

WHAT YOU CAN LEARN IN THIS REFERENCE GUIDE

1. Downlink OTDOA Technology Overview
2. Key OTDOA Test Areas
3. Spirent Solutions for OTDOA
4. Spirent Test Coverage

TECHNOLOGY OVERVIEW

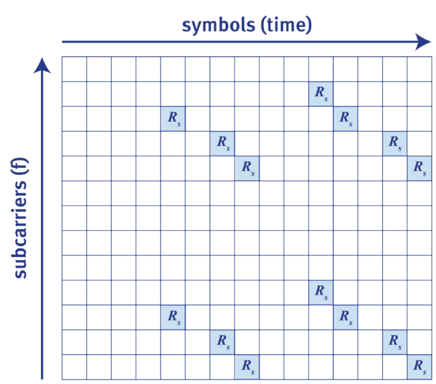
Handset-based OTDOA positioning consists of two aspects – the actual positioning technology, which is called downlink OTDOA, and the protocol necessary to enable the technology. In addition, downlink OTDOA can be combined with A-GNSS in a "hybrid" mode to achieve better positioning performance.

Downlink OTDOA Positioning

The basic downlink OTDOA (hereafter referred to simply as OTDOA) principle involves the User Equipment (UE) measuring time differences in downlink signals from two or more base stations. These measurements are sent back to the network. Using the known position of the base stations and these time differences, it is then possible to calculate the position of the UE. In LTE[1], an additional cell-specific reference signal has been defined for positioning, called the Positioning Reference Signal (PRS). The PRS occupies specific consecutive sub frames, which are known as positioning sub frames. The measured time difference of arrival of the PRS from a serving cell and one or more neighboring cells is known as the Reference Signal Time Difference (RSTD) – this value is reported back to the network. Using the RSTD, the known position of the eNodeB transmit antennas and the transmission timing of each cell, the network can calculate the UE's position.

OTDOA Diagram

PRS Structure



1 LTE 3GPP Release 9.

Cell-Specific Reference Signals?

In LTE, cell-specific Reference Signals (RS) are physical-layer transmissions that are scheduled in specific downlink sub frames in specific known resource blocks. These signals are critical for the UE to acquire cell information and perform downlink synchronization. Reference signals, in a group of cells, are unique for each cell.

Why PRS?

Using a PRS instead of standard cell-specific reference signal has advantages, such as:

- Improved "hearability" of transmissions from neighboring cells compared to the RS – the PRS reuse factor is 6 compared to 3 for the RS.
- PRS sub frames are designed to be low-interference: they either don't transmit on the data channels or are with low transmission activity.

Uplink OTDOA?

Downlink OTDOA is a handset-based method, where the UE is primarily responsible for the time difference measurements. A technology called Uplink OTDOA (or UTDOA) is also defined, where the base stations measure UE uplink transmissions and determine the time differences of arrival. This is a purely network based location method that requires no UE interaction.

Key OTDOA Terms

PRS – Positioning Reference Signal – Special Reference Signals defined enabling OTDOA positioning.

RSTD – Received Signal Time Difference – the time difference of arrival between the PRS from a serving cell and neighboring cells.

N_{PRS} – Number of consecutive subframes containing PRS

Muting – If PRS patterns between cells overlap, the network can turn off a regularly scheduled PRS transmission to aid acquisition.

PRS Bandwidth – the PRS can occupy a certain amount of bandwidth, generally less than the signal bandwidth.

Location Protocols for OTDOA

The network can provide assistance data to the UE to speed up the process of PRS acquisition. This data generally consists of relative eNodeB transmit timing differences (in the case of asynchronous networks), search window length, and expected PRS patterns of surrounding cells. The UE reports RSTD measurements back to the network for final position calculation. This data exchange is done by means of the LTE Positioning Protocol (LPP) over the control plane and the Secure User Plane Location (SUPL 2.0) protocol over the user plane.

OTDOA + A-GNSS Hybrid Mode

In LTE, OTDOA and A-GNSS may be used together in a “hybrid” mode - a combination of satellites and base station locations can be used in the position calculation function. In this technique, the UE measures the RSTD for at least one pair of cells and satellite signals and returns the measurements to the network, which is responsible for analyzing the measurements and calculating a position. This hybrid mode can be expected to provide better accuracy than OTDOA positioning alone, and is a key enabler for improving positioning accuracy in challenging environments.

OTDOA is a complex technology. However, it has a big part to play in the enabling of overall positioning availability. Good OTDOA performance will assist in meeting E911 location requirements indoors, as well as enable a host of commercial applications. The following section provides an overview of the key test areas that are required to characterize the performance of a handset supporting OTDOA.

KEY OTDOA TEST AREAS

Making accurate time difference measurements under a variety of conditions is critical for overall OTDOA positioning performance. Key OTDOA test areas can be categorized as:

RECEIVER PERFORMANCE

How **accurately** can the UE **measure** the RSTD value?

The key quantity enabling OTDOA positioning is the RSTD value. This is directly related to Positioning Reference Signal (PRS) acquisition, which can be difficult under challenging conditions such as fading, variable bandwidth (BW), cell timing offsets, and varying numbers of neighbor cells. To work well in the real world, PRS acquisition and RSTD measurements must be both accurate and reliable.

PROTOCOL RELIABILTY

How **robust** are the UE's LPP and SUPL 2.0 **protocol stacks**?

Assistance data transfer to the UE and RSTD reporting to the network are enabled by LPP or SUPL 2.0 (which wraps around an LPP payload). Both LPP and SUPL 2.0 are complex protocols, with complicated call flows and advanced new features. Both protocols are being supported by LTE network operators – implying that both need to be tested exhaustively.

HYBRID OTDOA + A-GNSS

How accurately can the UE **measure and report** OTDOA and GNSS information **simultaneously**?

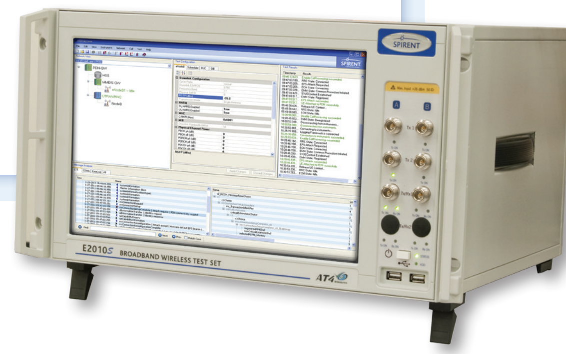
Some devices will support hybrid A-GNSS/OTDOA positioning to improve the performance of positioning when only 1 to 3 GNSS satellites can be received. By combining OTDOA and A-GNSS measurements, a "hybrid" position fix can be calculated. For this to work, the receiver must be able to acquire both PRS and satellite signals (Multi-GNSS) simultaneously and accurately.

SPIRENT ENABLES OTDOA TESTING

The Spirent Location Tecnology Solution (LTS) provides coverage for both conformance and R&D testing of LTE OTDOA. The figures below provide an overview of the hardware and software required to enable OTDOA testing.

SPIRENT E2010S LTE NETWORK EMULATOR

- Up to 4 2x2 MIMO enabled cells (2 cells per instrument)
- Define PRS and Muting patterns
- Configure all major LTE network elements
- 16 3GPP-defined fading models

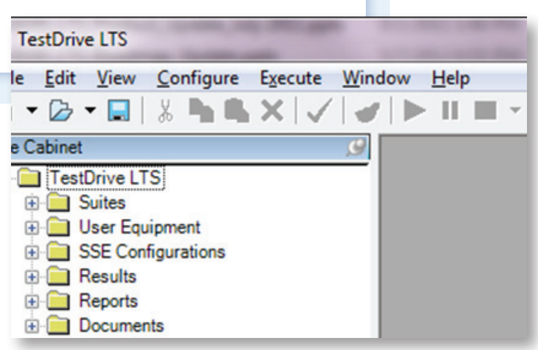


GSS6700 GNSS SIMULATOR

- Industry leading multi-GNSS simulator
- Support for multipath, obscuration, real time assistance data generation
- 12 channels per constellation (GPS L1 and GLONASS L1)

TESTDRIVE LTS TEST EXECUTIVE

- Easy-to-use test execution and results analysis
- Both 37.571 conformance and R&D scenarios
- Support for SUPL 2.0 and LP



Spirent supports OTDOA testing on a variety of LTS test platforms – starting from the entry level, low cost B750 system, to the fully featured one-stop-shop B500 covering UMTS, CDMA and LTE location testing. For an overview of the possibilities, please refer to the figures below.

Getting Started: 8100-B750

- Two cells
- MIMO and Fading
- LTS configured controller PC
- Add another E2010S for **4-cell** OTDOA
- Add **GSS6700** for hybrid scenarios

Upgrading From Spirent UMTS or CDMA Location Test System? 8100 B500

- Add E2010S
- SR8068 TCU replaces SR5048 – **no cable switching**
- Add another E2010S for **4-cell** OTDOA
- One system for both 2G, 3G and 4G testing

Already have a Spirent LTE-LBS system?

- Add additional cells (2, 3, or 4)
- OTDOA software license
- Add SUPL 2.0, LPP license (if needed)
- Start testing!

SPIRENT OTDOA TEST COVERAGE

Test coverage of LTE OTDOA is divided into two areas: Conformance and R&D Performance. The sections below provide details of the test offerings in each area. For information on when these features are available, please refer to the Spirent OTDOA Roadmap section.

OTDOA Conformance Tests

This area refers to the tests defined in 3GPP TS 37.571 Section 9 – E-UTRA OTDOA Measurement Requirements. These tests support 2-cell and 3-cell scenarios where the key measurements of importance are RSTD values and timing delay. Table 1 shows coverage of specific test cases from 37.571 section 9 (FDD Only).

Conformance cases are supported in TestDrive LTS over both control plane[2] and user plane[3]. Control plane tests involve the usage of LPP over NAS downlink transfer messages to provide assistance data and receive RSTD measurements. While the standards have defined the tests for control plane, TestDrive LTS also makes them available over the user plane by means of the SUPL 2.0 protocol.

Test Title	Channel BW	Cell ID	Expected RSTD (μs)	Expected RSTD Uncertainty (μs)
37.571-9.1.1 FDD Measurement Reporting Time Delay: 3 LTE Cells required (1 serving + 2 neighbor)	10 MHz	0	3	5
37.571-9.1.3 FDD RSTD Measurement Accuracy 2 LTE Cells required (1+1)	1.4MHz	0	3	5
37.571-9.1.3 FDD RSTD Measurement Accuracy 2 LTE Cells required (1+1)	1.4MHz	1	0	5
37.571-9.1.3 FDD RSTD Measurement Accuracy 2 LTE Cells required (1+1)	10MHz	0	0	5
37.571-9.1.3 FDD RSTD Measurement Accuracy 2 LTE Cells required (1+1)	10MHz	3	-3	5

Table 1 - Current Spirent Test Coverage for 37.571 Section 9 (FDD cases only)
Note: Spirent Coverage for 37.571 A-GNSS test cases are not shown in this table.

2 Coverage for control plane cases is available Sep 2012
3 Coverage for user plane test cases is available July 2012

R&D PERFORMANCE TESTS

Conformance tests are useful in ensuring basic, minimum performance of the OTDOA technology. However, they do not cover all types of important test scenarios, such as:

- Varying PRS bandwidths (only two bandwidth types are supported)
- Varying muting patterns
- 4-cell scenarios
- Hybrid OTDOA + A-GNSS scenarios

Spirent LTS provides the means to create these scenarios to better characterize device performance. The OTDOA conformance test pack features an "R&D" mode which unlocks select parameters to enable building of an initial set of R&D scenarios. Tests are configured by using a parameter-based GUI which enables quick building of scenarios with no scripting required. The OTDOA R&D test pack (Sep 2012) significantly expands this flexibility and enables building of many different types of R&D scenarios.

Creating R&D Scenarios with Spirent Conformance Test Pack

The conformance tests provided by Spirent are in complete compliance with the test standards. However, they feature a "parameter customizable" mode where customization of key parameters that affect OTDOA positioning is possible (Figure 1). Changes are applied by means of an easy-to-use, parameter-based GUI, and are tracked in the final test report. The tests can be reverted back to default conformance settings quickly and simply.

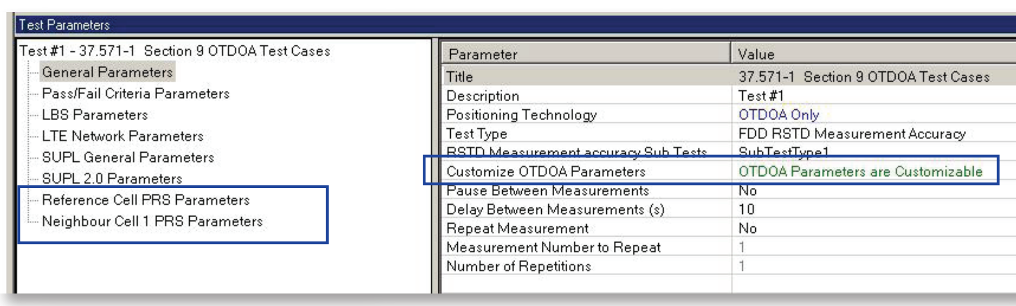


Figure 1 – Customizing OTDOA parameters using the conformance test pack

Setting the conformance tests to the customizable mode makes a variety of parameters available to configure the PRS transmissions – both at serving cells and at neighbor cells. Up to three cells are available for tests that measure the RSTD reporting delay, and 2 cells are available for tests that measure the RSTD measurement accuracy. Table 2 lists the parameters, their purpose and allowed values.

Expected RSTD	Defines the expected RSTD corresponding to the cell delay
Expected RSTD uncertainty	Allows the definition of the uncertainty expected from the UE when the RSTD is measured.
Reported RSTD lower range	Represents the lower range of the allowed values of the UE-reported RSTD.

Table 2 – Configurable parameters relating to LTE cells and the PRS

In addition to the above general parameters, the neighboring cells allow configuration of the following parameters:

Parameter Name	Description
PRS Configuration Index	Defines the periodicity of the PRS and the starting subframe of transmission. The value changes depending on whether 3-cell or 2-cell scenarios are chosen.
PRS Bandwidth	Configures the bandwidth of the PRS signal. Values are: 1.5, 3, 5, 10, 15 and 20 Mhz.
Number of consecutive downlink subframes with PRS	Represents N_{PRS}
PRS muting pattern length	Allows configuration of the length of muting patterns - one of 2,4,8,16 bits or none.
PRS muting pattern	Allows specification of the actual muting pattern (depends on the selection for the muting pattern length parameter setting). For example, a 2-bit PRS muting pattern could be 10, where 1 represents PRS presence and 0 represents absence.
Cell Timing Delay (Ts)	The cell timing delay is the difference in timing in the downlink transmissions with respect to the neighboring cells. This parameter is to be configured for each cell, and is in Ts.
Antenna Port config	Represents which port the PRS is transmitted from - Primary, Diversity or 4x4 MIMO (not currently supported).
Response Time OTDOA	Represents the desired response time interval in which the network receives RSTD measurements.
Reported RSTD upper range	Respresents the upper range of the allowed values of the UE-reported RSTD.

Table 3 – Additional configurable parameters applicable to neighboring cells

NOTE: Some of the parameters for neighboring cells are limited by choices made for the serving cell. For example, the bandwidth chosen in the parameter for the serving cell will apply to the neighbors as well.

Example R&D Performance Test Case:
RSTD Measurement Accuracy with Varying Bandwidth

By changing the channel bandwidth power and inserting multiple test cases with different values, a BW "sweep" for RSTD Measurement Accuracy can be performed.

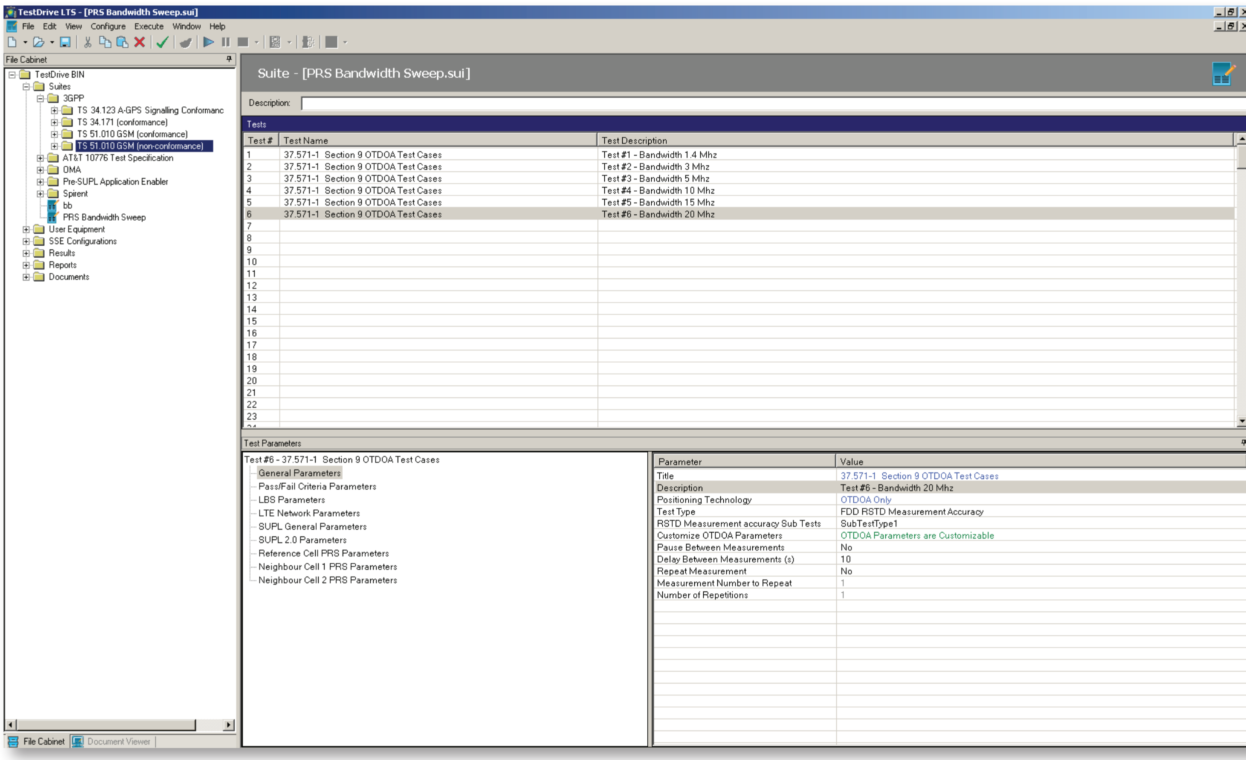


Figure 2 - RSTD measurement accuracy with varying bandwidth

Creating R&D Scenarios with Spirent OTDOA Test Pack

The conformance test cases mentioned above (along with the configurability) are available July 2012 in the LTS 6.30 software release. The September 2012 release (LTS 6.40) will feature the Spirent OTDOA test pack, specifically aimed at R&D testing and enabling Operator Acceptance scenarios.

The Spirent OTDOA test pack expands upon the configurability detailed in the section above, providing powerful tools to perform measurement analysis and characterize receiver performance. Table 4 lists some key R&D scenarios enabled by the OTDOA test pack.

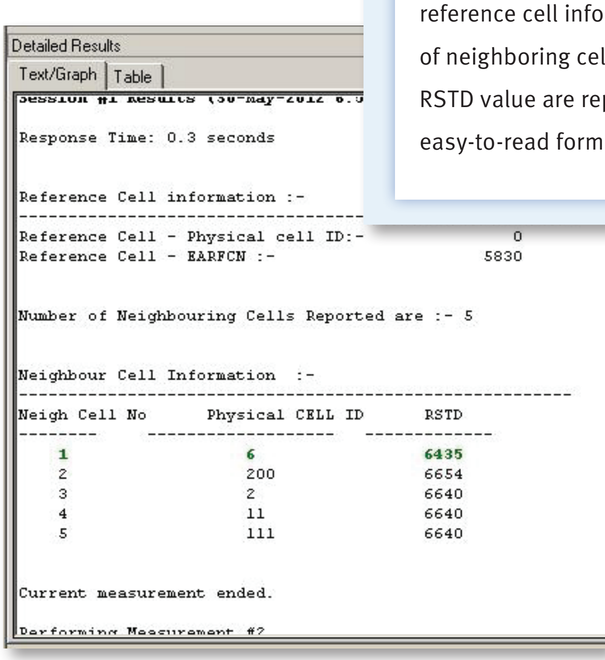
Test Area	Abstract	Test Detail
Receiver Performance	4-cell scenarios	Having four cells provides a clearer idea of RSTD measurement accuracy and Reporting Delay, especially when variable muting patterns are used in difference cells.
Receiver Performance, Protocol Reliability	GNSS and OTDOA	This allows testing of the "hybrid" mode, where the UE returns both GNSS satellite measurements and OTDOA cell network measurements to the network.
Protocol Reliability, Hybrid Mode	E911 over control plane	E911 call establishment over VoLTE and positioning using OTDOA + A-GNSS (or hybrid mode) can be tested under a variety of challenging conditions (such as IP impairments, noise, etc).
Receiver Performance	Multiple fading options	The network emulator supports up to 16 different 3GPP based fading models. Trying different fading models is important to characterize OTDOA performance in varying conditions.
Receiver Performance	Antenna configuration and multipath	The E2010 network emulator can operate under several different types of antenna modes. These include SISO, 2x2 MIMO and 4x4 MIMO – characterizing OTDOA performance under varying antenna conditions is important.

Table 4 - R&D scenarios enabled by the OTDOA test pack

RESULTS ANALYSIS

TestDrive LTS provides an easy way to review all results. The raw measurements as well as protocol messages are logged and presented with a full decode of the ASN.1 payloads. Results are automatically saved, and can be exported into PDF for sharing.

The detailed results view presents information per positioning session. Key data such as reference cell information, number of neighboring cells, and per cell RSTD value are reported in an easy-to-read format.



All protocol messages exchanged between the UE and the network are logged, with full ASN.1 decode of payloads made available. This figure shows the LPP payload of a SUPL POS message sent by the network to the UE requesting a location.

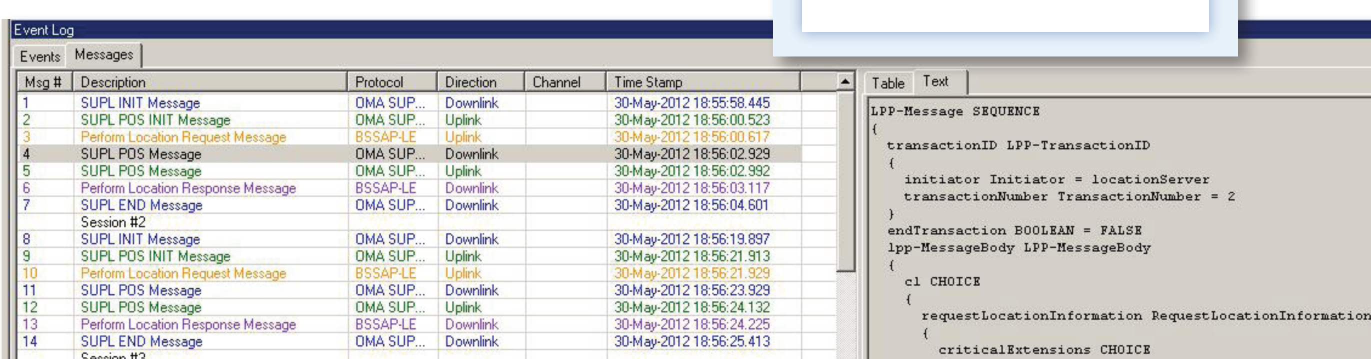


Figure 3 - Results analysis

SPIRENT OTDOA ROADMAP

OTDOA test offerings are split across three major LTS software releases. Note: the information presented below is subject to change based on market requirements.

LTS 6.3/July 2012

TS37.571-1 LPP User Plane Minimum Performance (OTDOA + A-GNSS)

- Features supported for 2 and 3-cell conformance scenarios
- Conformance tests are customizable to create R&D scenarios

LTS 6.4/October 2012

TS37.571 LPP Control Plane Minimum Performance (OTDOA + A-GNSS)

- Conformance tests are customizable to create R&D scenarios

Spirent OTDOA test pack

- Create a variety of R&D scenarios (antenna configuration, fading models and 4-cell OTDOA)

LTS 6.5/January 2013

E911 VoLTE OTDOA + A-GNSS Minimum Performance

- E911 scenarios
- OTDOA + A-GNSS hybrid scenarios

NOTES