ANALYZE LTE-ADVANCED NETWORK PERFORMANCE IN THE PALM OF YOUR HAND

The benefits of XCAL-Solo and XCAL-Harmony when it comes to quantifying LTE and LTE-Advanced network performance

March 2015

Prepared for
Accuver Americas

500 N. Central Expressway #210
Plano, TX 75074, USA
Phone: +1-469-241-6100 option 3
Email: sales.usa@accuver.com

Prepared by
Signals Research Group

www.signalsresearch.com

In appreciation for Accuver's invaluable support over the last five years we've put together a short paper that highlights a couple of the company's drive test tools and how we've used them to analyze the performance of next-generation networks.

In addition to providing consulting services on wireless-related topics, including performance benchmark studies, Signals Research Group is the publisher of the *Signals Ahead* research newsletter (www.signalsresearch.com). Many of the figures used in this paper were previously published in this publication.

Table of Contents

Index of Figures and Tables

1.0 Introduction

For the last five years, Signals Research Group (SRG) has leveraged several of the drive test solutions in the family of drive test products that Accuver provides to its global subscriber base. We first teamed up with Accuver when we used its PC-based XCAL-M LTE drive test solution to evaluate the world's first commercial LTE network – literally weeks after the launch. Just recently, we used a combination of XCAL-Solo and XCAL-Harmony to analyze LTE-Advanced network performance in one of the very first networks in the world that supports carrier aggregation with three inter-frequency carriers.

Over the years we've used a host of Accuver's products to conduct other time-critical studies, including:

- The world's first DC-HSDPA network (Dec 2010)
- The world's first commercial LTE network (Feb 2010)
- Multi-operator/vendor/technology, including EV-DO Rev A, Mobile WiMAX, HSPA+, DC-HSDPA and LTE (Summer 2011)
- In-building LTE performance, including a comparison of Band 7 and Band 4 (Dec 2012)
- LTE TDD and LTE FDD performance comparison (Aug 2013)
- The world's first LTE-Advanced network, including user experience tests (Aug 2013)
- Comparisons of 2x2 MIMO, SISO, and 4x2 MIMO (Jan 2014)
- The world's first commercial LTE-Advanced (225 Mbps) network (Aug 2014)
- One of the world's first commercial LTE-Advanced (300 Mbps) networks (Feb 2015)

For us, it is critical that we are first-to-market with a study of the latest and greatest LTE feature or service offering. We need a partner that not only provides the analytical tools and software that we need for our research, but a partner that can provide what we need almost as soon as the feature has been commercially launched and across a vast array of LTE chipset suppliers. For this reason, we've teamed up with Accuver to provide our clientele with very timely and in-depth network performance analysis.

In large part, the company's time-to-market success stems from its R&D center being located just outside of Seoul, South Korea and its very close relationship with the vendor and operator community in the country. In addition to being the home of two leading, and very aggressive handset manufacturers, South Korean operators have generally been first to market with VoLTE and LTE-Advanced, and they will likely lead the charge toward 5G. Accuver is able to leverage these close relationships to bring its products to market in a rapid fashion throughout the rest of the world, and generally in advance of when they are needed.

We'd like to highlight a couple of the company's solutions that we've just started using and why we believe they would make a great addition into any arsenal of network performance tools.

2.0 XCAL-Solo – LTE Performance Analysis in the Palm of Your Hand

LTE Network performance is now based on the intricate dynamics of two or more radio carriers operating together, yet spanning nearly 2 GHz of spectrum.

Although commercial LTE networks have existed for the last five years, the technology and the market dynamics continue to evolve at an extremely rapid pace. From a technology perspective, LTE Release 8 has given rise to LTE-Advanced with a host of new features that require a greater understanding of network performance. Carrier Aggregation tops the list since network performance is no longer based on the performance of a single radio carrier but on the intricate dynamics of two or more radio carriers operating together.

In a span of just over six months, the industry has seen the launch of the world's first 225 Mbps network and just recently the launch of the world's first 300 Mbps with three unique radio carriers spanning nearly 2 GHz of spectrum. Later this year, there could even be carrier aggregation configurations used in commercial LTE networks that include the simultaneous assignment of both FDD and TDD duplex schemes to a single mobile device. As we know from firsthand experience, Accuver supports Carrier Aggregation with two or three carriers and we have no doubt that they will be there when the world's first FDD-TDD LTE-Advanced Carrier Aggregation network becomes a reality.

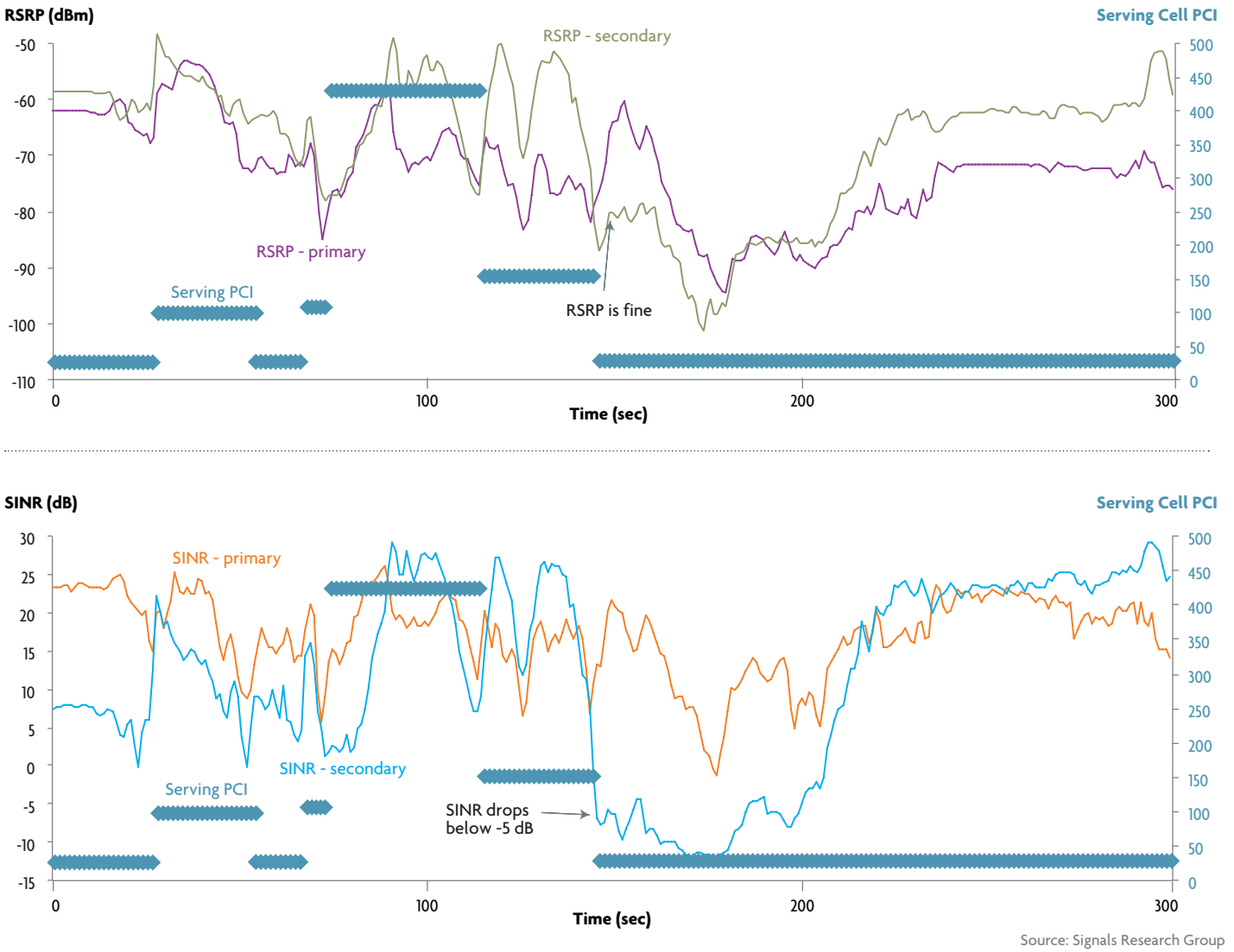
It is critical to use a drive test solution that supports a large number of chipset suppliers versus limiting itself to only a couple of chipset suppliers.

Separate from the technology advancements that have occurred in the last few years, one needs to take into consideration the rapidly changing market landscape. At the moment we are aware of at least four chipset suppliers that currently have an LTE-Advanced chipset with carrier aggregation support (Cat 4 or Cat 6) shipping into commercially-available smartphones and we know of several other LTE chipset suppliers that are shipping LTE Release 8 chipsets. Since network performance and the user experience are strongly influenced by device/chipset performance, it is critical to use a drive test solution that supports a large number of chipset suppliers versus limiting itself to only a couple of chipset suppliers. Accuver currently supports LTE FDD/TDD chipsets from ten suppliers and LTE-Advanced chipsets from Qualcomm and Samsung, with support for additional LTE-Advanced chipsets coming later this year.

We focus a lot of attention in our studies on many of the innumerable RF parameters that the Accuver tools capture – the list of captured RF parameters depends on the chipset supplier. For example, the wide separation of the individual radio carriers presents a number of challenges which require a sophisticated drive test solution to help analyze. First and foremost, these networks likely have hidden coverage gaps where the higher frequency does not reach or where it delivers sub-par performance. We've also observed the exact opposite, where one of the radio carriers has great coverage (i.e., signal strength) but also high interference levels. Both situations result in an inefficient use of network resources.

Figure 1 shows an area in the network where the signal strength was great (top figure) but the interference was high (bottom figure). Consequently, the secondary carrier was not used and the overall throughput dropped. In addition to analyzing signal strength and signal quality, it is important to understand how the network is scheduling resources. One example of where we've applied this principle is work that we've done on MIMO utilization. With the Accuver tools it is possible to look at the underlying network conditions when MIMO was used and the degree to which MIMO actually improved user throughput. As we discovered in our use of the tools, vendors have different philosophies when it comes to when to use MIMO and in some cases MIMO gets over-used, ultimately resulting in reduced throughput versus throughput gains.

Figure 1. Poor Carrier Aggregation Performance due to High Interference Levels



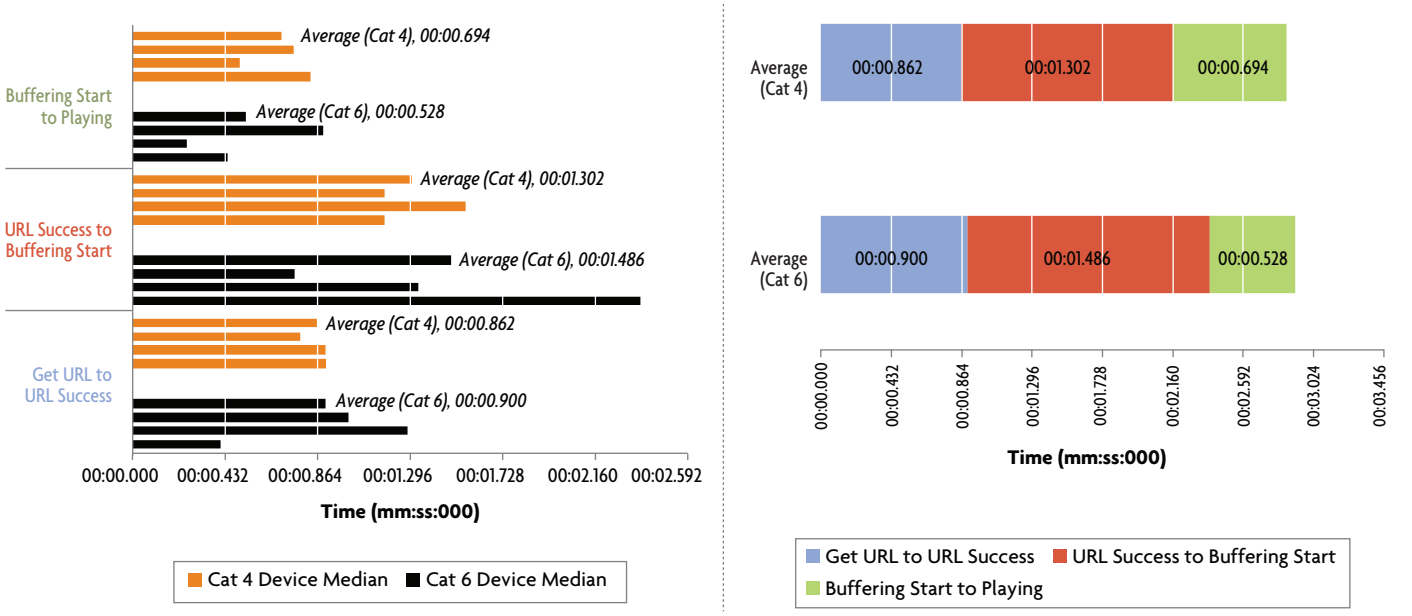
Source: Signals Research Group

The Accuver tools make it possible to bring together higher protocol layer messages and the Physical Layer attributes to determine how the Physical Layer impacts the user experience.

Separate from the Physical Layer performance characteristics of LTE-Advanced, one must understand how, or even if, carrier aggregation impacts the real user experience. After all, many user applications, such as web browsing and even watching YouTube videos, do not generate a huge amount of data traffic so the benefits of carrier aggregation are not obvious. The full suite of Accuver tools supports an Auto Call feature that supports pre-programmed web browsing and YouTube streaming. This feature, along with the XCAP post-processing software makes it possible to bring together higher protocol layer messages and the Physical Layer attributes to determine the relationships (if any) between the capabilities and actual performance of the Physical Layer and the end user experience.

As we have observed, the benefits of Carrier Aggregation are far from obvious with many applications, even though the overall benefits of Carrier Aggregation are immense. Figure 2 shows our analysis of a user experience study involving the playing of a YouTube video. Using the Auto Call feature in XCAL-Solo, the same video was played back multiple times on two smartphones – one smartphone supported Cat 6 capabilities and the other smartphone only supported Cat 4. Although the observed peak data rates were higher with the Cat 6 smartphone (not shown), the impact on the user experience was negligible since other transactions (Get URL, etc.) took a relatively long time to complete and these transactions do not benefit from a faster air interface.

Figure 2. YouTube Analysis



Source: Signals Research Group

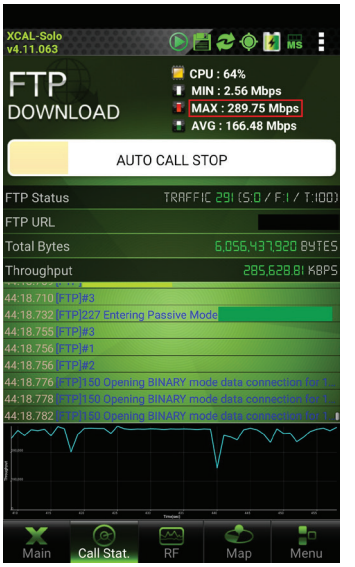
XCAL-Solo offers the same rich functionality and comparable user interface/GUI as Accuver's PC-based products.

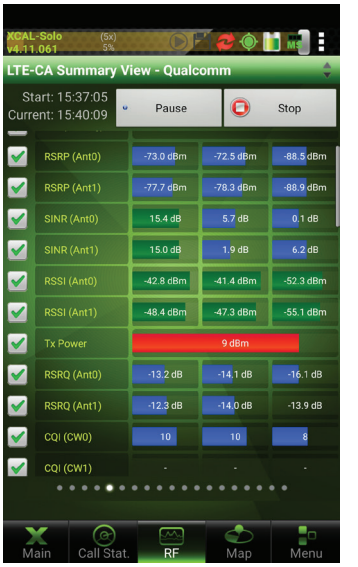
In our last two carrier aggregation studies, we had the opportunity to use XCAL-Solo. XCAL-Solo offers the same rich functionality and comparable user interface/GUI as Accuver's PC-based products, not to mention XCAL-Mobile, which is integrated into the smartphone. The key difference is that XCAL-Solo does not require any customization or rooting of the smartphone to work on a specific smartphone model. This highly differentiated attribute makes it easy to rapidly test with a new smartphone model or to test a new LTE feature – much like we did when we tested some of the industry's first two-carrier and three-carrier LTE-Advanced Carrier Aggregation networks.

The form factor of XCAL-Solo – roughly the size of a breath mint box – makes it ideal for pedestrian or in-building testing.

The form factor of XCAL-Solo – roughly the size of a breath mint box – makes it ideal for pedestrian or in-building testing since the analysis of LTE performance can literally be done from the palm of your hand. XCAL-Solo attaches to the smartphone through the smartphone' USB port. As we know from personal experience, with XCAL-Solo it is extremely easy to conduct an extensive test of an LTE network anywhere and everywhere without anyone knowing. Figure 3 shows a picture of XCAL-Solo in action along with two screen shots of the GUI from a recent 3-carrier carrier aggregation study that we conducted in South Korea.

Figure 3. XCAL Solo in Action





3.0 XCAL-Harmony – When One XCAL-Solo Solution Just Isn't Enough

Although XCAL-Solo provides us with the full capabilities of the PC-based XCAL-M, for some test situations it is beneficial to complement XCAL-Solo with XCAL-Harmony. In essence, XCAL-Harmony is a software-based control mechanism that runs on any standard Android OS tablet. XCAL-Harmony controls up to six smartphones using XCAL-Solo via Bluetooth, thus moving the Auto Call feature and the monitoring of each XCAL-Solo session from the smartphones to the tablet. It is one thing to operate two XCAL-Solo smartphones but it can be logistically challenging to control and monitor multiple XCAL-Solo sessions running in parallel.

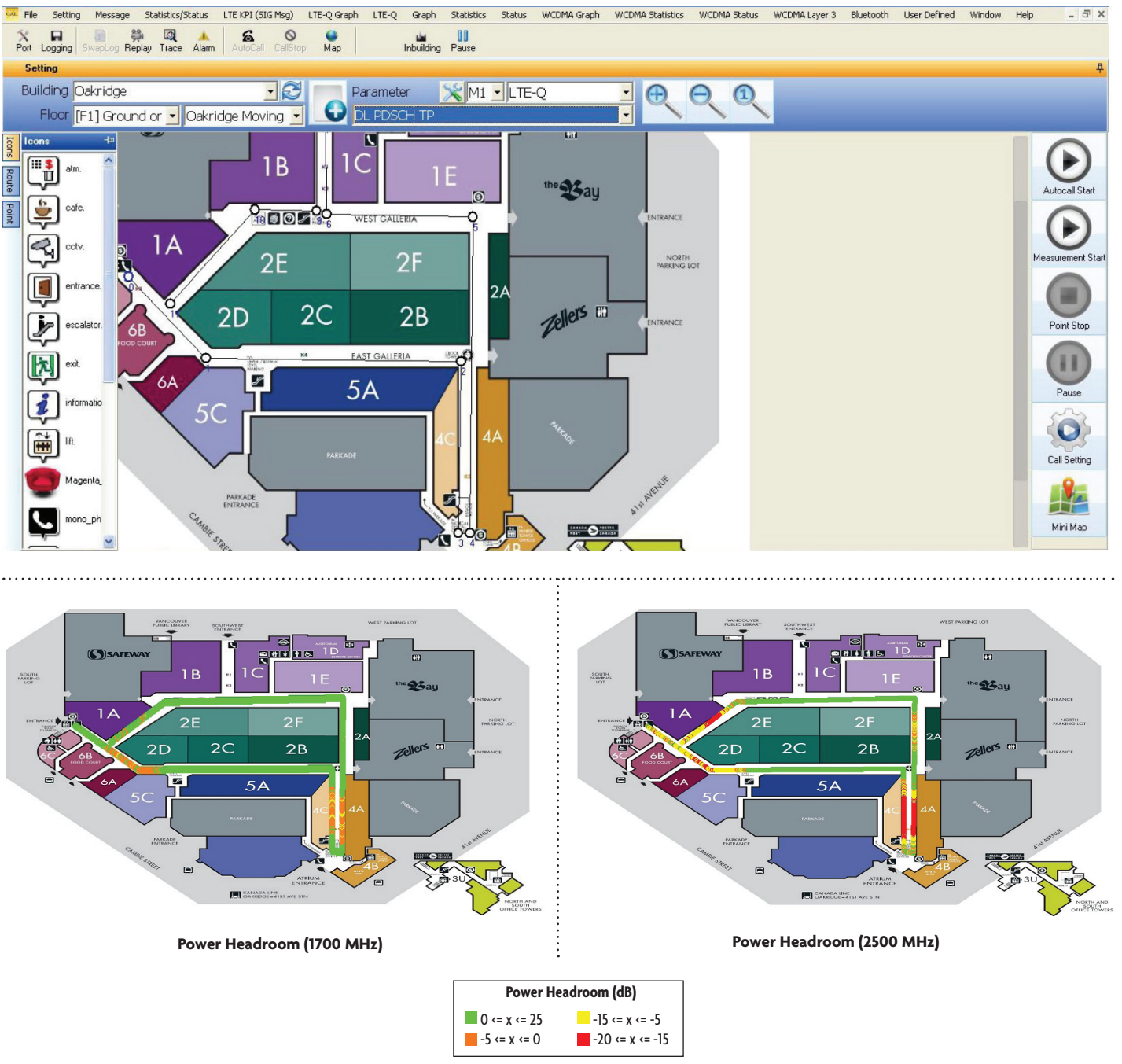
In addition to making it far easier to test with three or more smartphones at the same time, XCAL-Harmony is ideal for in-building testing and VoLTE. We've used XCAL-M for in-building testing but XCAL-Harmony provides the identical functionality with a very similar GUI. Further, as we know from personal experience, it is much easier to walk around with a light-weight tablet and the test phone(s) hidden in a backpack than it is to walk around carrying a laptop computer.

The in-building test methodology is simple:

- Find a suitable JPEG of the building or create one on your own (for our tests we used building maps that we readily found on the Internet)
- Load the map into XCAL-Harmony and create a "drive route" with event trigger points
- Start Auto Call
- Walk the "drive route" and simply click on a button each time you reach one of the event trigger points on the map – XCAL-Harmony will then uniformly spread all of the collected data between the new event trigger point and the previous event trigger point.

Figure 4 shows a pre-loaded map of a shopping mall along with our test path and event trigger points (done with XCAL-M). Below this figure we've included some captured data – in this case the Power Headroom for a dual-band LTE network at 1700 MHz and 2500 MHz. Although the measured throughput was excellent when we did our tests the underlying KPIs showed that there were some uplink coverage limitations at 2500 MHz. This shortcoming wasn't a problem at since the network was lightly loaded. However, when network resources become more limited due to network loading the problem will be very apparent.

Figure 4. In-building Testing Made Easy



Power Headroom (1700 MHz)

Power Headroom (2500 MHz)

In many respects, operators had an easy time launching commercial LTE networks since the only service being offered was best effort data. If the call dropped momentarily or even handed off to 3G the user may not have noticed the difference. Launching voice services on an LTE network (i.e., VoLTE) is entirely different. Network optimization is paramount since users will know when a call drops. They will also be able to detect handovers to 3G (SRVCC) in the event that the operator does not support HD Voice (WB-AMR) on its 3G network.

It is not good enough to merely know the perceived voice quality (i.e. MOS value) when doing VoLTE drive testing.

When it comes to VoLTE drive testing it is not good enough to merely know the perceived voice quality (i.e. MOS value). Likewise, information about the underlying Physical Layer attributes of the network, including the signaling information for call set-up times is critical, but it doesn't suffice by itself. Instead, both metrics are important when it comes to determining why the perceived call quality is not satisfactory, or why a voice call drops or does an SRVCC handover to 3G. XCAL-Harmony, with support for VoLTE testing, brings together these two discrete sets of information and it makes the data analysis far more simplistic since all of the data is contained in a single log file and analyzed by a single post-processing solution, or XCAP. And as previously mentioned, XCAL-Harmony is not limited to a single chipset supplier, thereby making it possible to test with a number of LTE chipset suppliers that have already implemented their own VoLTE solution. In the final figure we have intentionally masked some of the information in order to not disclose confidential or personal information.

Figure 5. XCAL-Harmony and VoLTE Testing

This page left intentionally left blank.

Accuver

Paper prepared by

SIGNALS
Research Group

www.signalsresearch.com