# ANALYZE GIGABIT LTE NETWORK PERFORMANCE IN THE PALM OF YOUR HAND

## THE BENEFITS OF XCAL-SOLO AND XCAL-HARMONY WHEN IT COMES TO QUANTIFYING THE PERFORMANCE OF SMALL CELLS WITH LAA

*September 2018*

**Accuver**

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## Introduction

For nearly the last decade, 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 customer 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. More recently, in 2017 and 2018, we used XCAL-Solo to analyze the incremental benefits of small cells deployed in an LTE-Advanced network. The form factor and ease of use proved invaluable during the walk tests, which included sub-zero temperatures.

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)

➤ FDD and TDD Carrier Aggregation (Mar 2016)

➤ The first commercial deployment of 256-QAM (May 2016)

➤ Uplink 64-QAM (Sept 2016)

➤ 4x4 MIMO (Jan 2017)

➤ Four-carrier aggregation in a 1 Gbps-capable LTE network (Apr 2017)

➤ High-Power UE benchmark study in an LTE-TDD network (Dec 2017)

➤ A three-part series of reports on the incremental benefits of small cells with LAA functionality in a commercial LTE-Advanced network (2017-Jan 2018)

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, operator and handset manufacturer community in the country. Accuver leverages 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. In the coming months, we anticipate using the company's suite of tools to evaluate the world's first commercial network which uses millimeter wave spectrum.

In 2015, we provided Accuver with an initial whitepaper which shared highlights on how we've used their tools. We are now updating that paper to feature more recent work, specifically the series of small cell studies that we conducted in 2017 through early 2018. For these studies, we didn't need to use XCAL-Harmony, so we retained our initial write-up of XCAL-Harmony in this paper.

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

*The LTE standard continues to evolve with commercial 5G networks right around the corner.*

Although commercial LTE networks have existed since late 2009 and commercial 5G networks are right around the corner, the LTE standard continues to evolve. Commercial LTE networks now include several advanced carrier aggregation features, including simultaneous support for FDD and TDD radio channels, aggregation of licensed and unlicensed radio channels in the 5.8 GHz band (LAA - Licensed Assisted Access), uplink carrier aggregation with 64-QAM modulation, and support in the downlink direction for up to five radio channels and 2 Gbps data speeds. We have tested them all (and more) with various Accuver products, but as of late it has primarily been with XCAL-Solo.
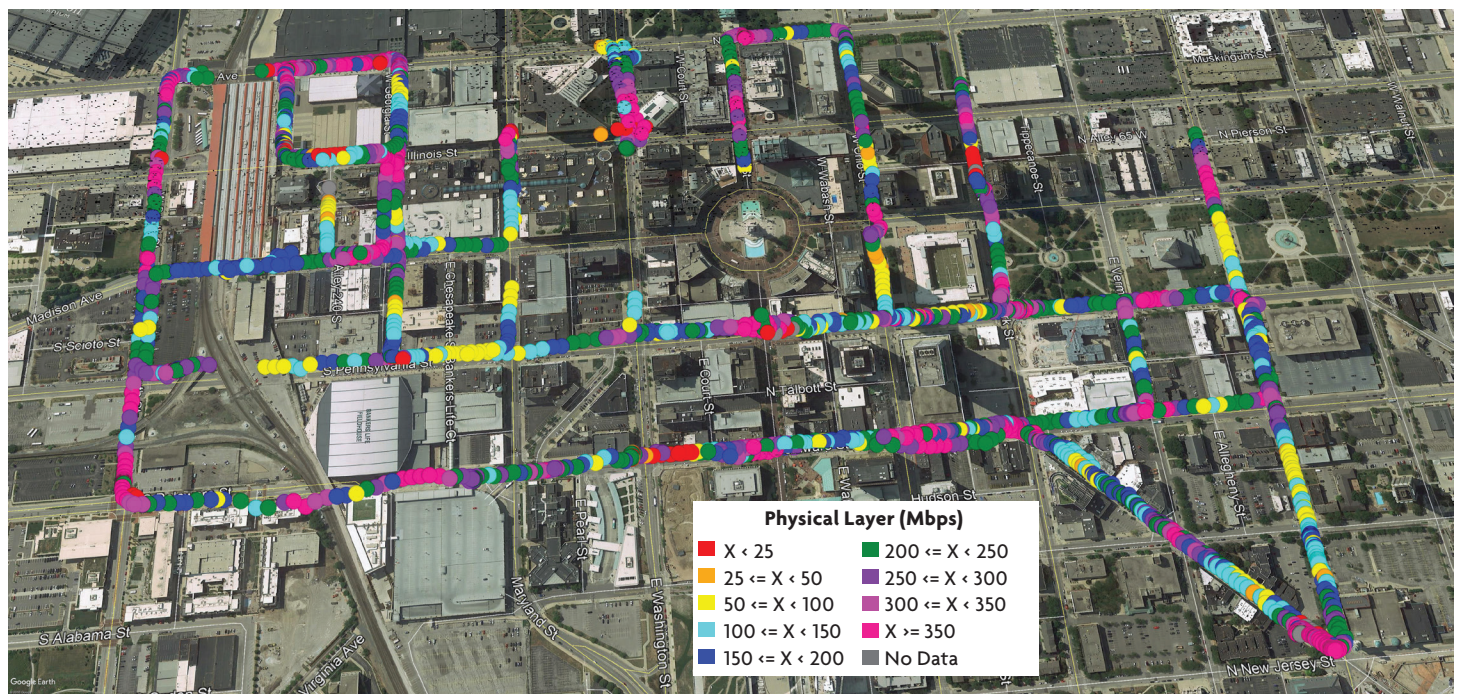
*We used XCAL-Solo to conduct a multi-part evaluation of small cells, deployed in an LTE-Advanced network.*

Starting in mid-2017, we conducted a series of benchmark studies to quantify the incremental benefits of small cells in a commercial LTE-Advanced network. For this study, we tested the same area of a major US city on three separate occasions. The first test occurred prior to the operator deploying small cells. The second test occurred shortly after the operator had deployed a limited number of small cells, and prior to the operator upgrading the small cells to include LAA functionality. Finally, the third test occurred after the operator had deployed additional small cells and upgraded all small cells with LAA functionality. In this case, the small cells supported three LAA radio carriers in addition to a licensed radio carrier in Band 2 (1900 MHz).

To conduct this study, we needed test equipment with several attributes. First and foremost, we needed a logging tool that supported LAA functionality. This requirement was by no means a given, since the US operator was perhaps the first operator in the world to launch LAA. At the time there was also only a single smartphone that supported LAA. Second, we needed a lightweight, portable and nonobtrusive test tool to conduct the tests since most of the testing occurred while walking along the city streets. For these tests, we placed the smartphone and XCAL-Solo in our backpack, at which point we only had to take a leisurely stroll along the city streets to conduct the tests. This strategy proved to be especially valuable when we tested in early January when there were sub-zero temperatures. Finally, we needed a credible means of comparing results between three sets of tests that spanned several months. To meet this last criterion, we used the XCAP post processing software to geo bin the data while also filtering the data by radio channel and using Resource Block (RB) normalization of the measured data speeds to account for other mobile data users in the network.

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As one might imagine, we collected and analyzed a considerable amount of data, so it isn't practical so show all the results in this whitepaper. We can, however, share some data that we collected with XCAL-Solo and analyzed with XCAP before jumping to one of the primary conclusions from the study. To start things off, Figure 1 shows a geo plot of the physical layer throughput while connected to the small cells in the operator's network. One important observation is that it is evident we walked a considerable distance while collecting the data, making it almost impractical to lug around a notebook computer or other large test equipment. A less obvious observation is that there was a fair amount of analysis required to produce the figure since the data speeds are exclusive to the small cells in the network. Although not provided in this paper, we also created a geo plot that only showed the contribution from the small cell LAA radio channels.

## Figure 1. Small Cell (Band 2 + LAA) Physical Layer Throughput Geo Plot



**Physical Layer (Mbps)**

| | |
|---|---|
| X < 25 | 200 <= X < 250 |
| 25 <= X < 50 | 250 <= X < 300 |
| 50 <= X < 100 | 300 <= X < 350 |
| 100 <= X < 150 | X >= 350 |
| 150 <= X < 200 | No Data |

Source: Signals Research Group

*We used the XCAP post-processing software to geo bin the data and make other adjustments to account for differences in network loading.*

The information in Figure 1 stems from our January tests, but to really quantify the incremental benefits of small cells, it is important to compare results from two different tests (before and after small cells with LAA), which in our case spanned several months. Simply comparing results between the two sets of tests isn't appropriate because there is a proximity component to network performance, not to mention likely differences in network loading. For example, simply spending more time standing in one place (e.g., waiting for the walk sign) can skew the results, especially if there happened to be a small cell on an adjacent street light. Therefore, we used the XCAP post processing software to geo bin the data for all tests and then compared results for each geo binned set of data points. In the case of throughput, we also used RB normalization to account for the presence of other mobile data users in the network. In essence, we grossed up the observed data speeds to reflect the network allocating all resource blocks to the smartphone. For example, in a 20 MHz radio channel, where there are up to 100 RBs available, an observed data speed of 25 Mbps with 50 RBs would become an RB-normalized data speed of 50 Mbps with an allocation of 100 RBs. Our assumption in this example is network loading resulted in the network only allocating the smartphone 50 RBs and that with a full allocation of 100 RBs, the smartphone would have achieved the higher data speed.

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Figure 2 and Figure 3 illustrate how we used XCAL-Solo and XCAP to quantify the incremental benefits of small cells. For this analysis, we analyzed geo binned SINR values in Band 2 for a geographic area with a high concentration of small cells that we dubbed "Area 2." In our full study, we included three small areas in addition to the total area that we tested. Visually, it is apparent the quality of the network improved substantially with the introduction of the small cells. Although it isn't evident in the two figures, the median SINR (geo binned) in Area 2 improved from 5.4 dB to 13 dB.

**Figure 2. "Area 2" Binned SINR Values – minimal small cells (September)**



Source: Signals Research Group

**Figure 3. "Area 2" Binned SINR Values – with small cells (January)**



Source: Signals Research Group

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Finally, Figure 4 and Figure 5 show the culmination of our small cell study. In Figure 4, we provide the calculated improvement in Band 2 spectral efficiency with the presence of small cells, based on the estimated median transport block size (TBS) values obtained in the three tests. In this figure, the median TBS values stem from mapping geo binned MCS values to their implied TBS values for a given RB allocation. We leveraged the 3GPP specification, TS 36.213, for this analysis.

We obtained the information in Figure 5 by calculating the RB normalized median data speeds with small cells in Area 3. Both the median RB and median observed data speeds are specific to the small cells and, most importantly, they are based on geo-binned values. Without LAA and with a limited number of small cells, the spectral efficiency was 4.2 bps/Hz. With LAA and an increased number of small cells, the spectral efficiency jumped to 13.35 bps/Hz. For this latter calculation, we included the throughput contribution from the unlicensed radio carriers – total median throughput = 267 Mbps – to achieve the abnormally high spectral efficiency. We believe this approach is appropriate since the operator didn't own the unlicensed spectrum, yet it was able to use the spectrum to boost the end user data speeds and the overall efficiency of the network.

**Figure 4. "Area 2" and "Area 3" Band 2 Spectral Efficiency Comparison – with and without small cells and LAA**
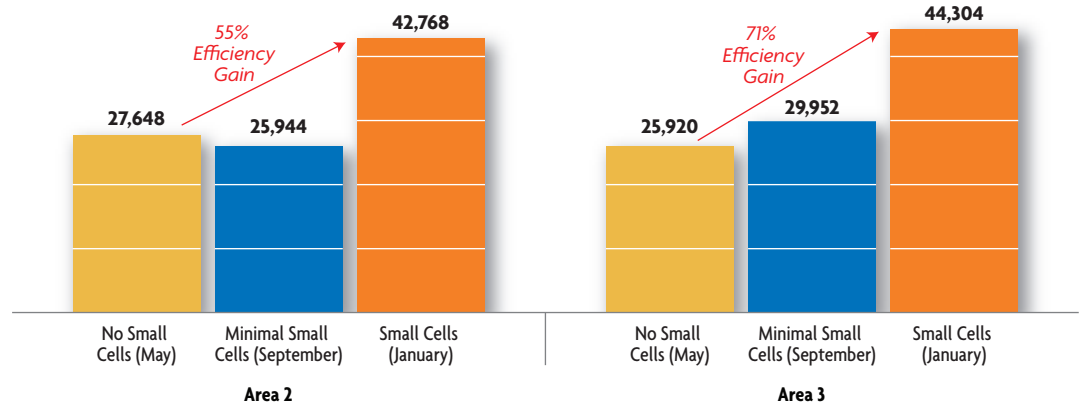


Source: Signals Research Group

**Figure 5. "Area 3" Band 2 Spectral Efficiency Comparison – with and without small cells and LAA**



Source: Signals Research Group
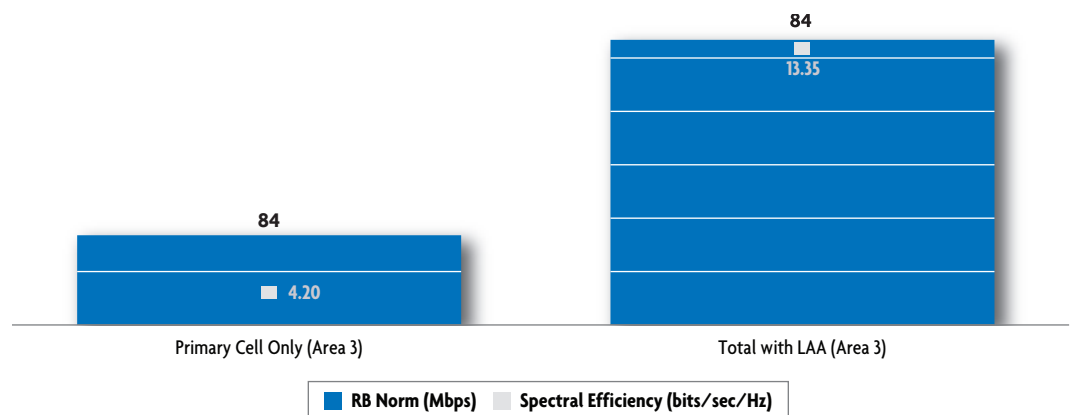
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Evaluating the incremental benefits of small cells isn't a straight-forward process, but the information is critical to operators who are determining their small cell strategies. A portable and lightweight test tool, such as XCAL-Solo, along with sophisticated post-processing software (i.e., XCAP) are critical to this process.

We conclude this section, with a picture of XCAL-Solo in action., along with a couple of screen shots showing the XCAL-Solo GUI. These pictures stem from testing that we conducted in South Korea, but the configuration and GUI identical to what we used when we conducted the small cell study.

**Figure 6. XCAL-Solo in Action**



Source: Signals Research Group

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## 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 6 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 the time since the network was lightly loaded. However, when network resources become more limited due to network loading the problem will be very apparent.

**Figure 6. In-building Testing Made Easy**
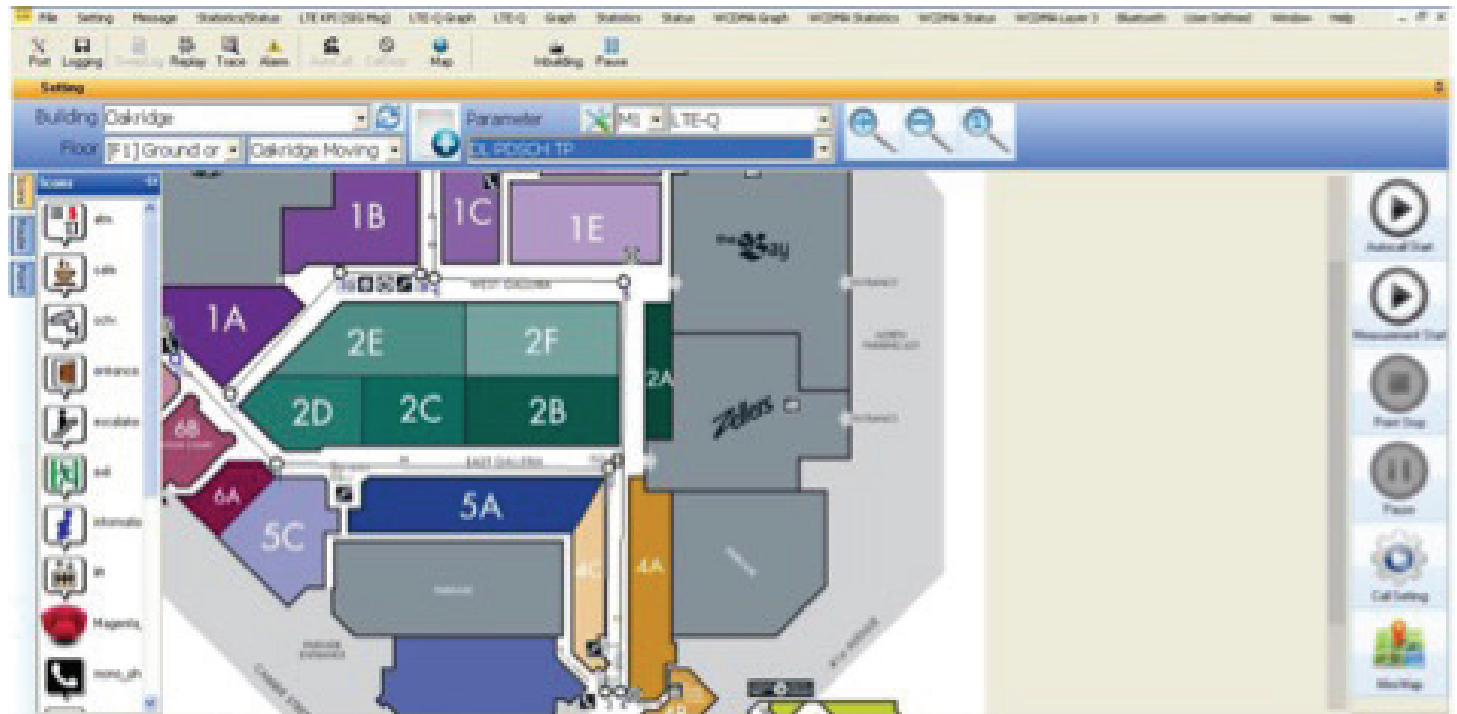




*Power Headroom (1700 MHz)*

*Power Headroom (2500 MHz)*

Source: Signals Research Group

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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.

**Figure 7. XCAL-Harmony and VoLTE Testing**



Source: Signals Research Group