February 21, 2013

SiGNALS Flash!

Dispatches from the frontier of wireless research

ADDRESSING A HUGE OPPORTUNITY AND A CRITICAL MARKET REQUIREMENT...

...while extending its tentacles into uncharted territories

SiGNALS Research Group
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KEY HIGHLIGHTS

- Qualcomm announced its entry into the RF front-end (RFFE) market with a suite of new [CMOS] products and a new manufacturing/packaging process called RF POP™.
- In their totality, the products can bring the industry much closer to a single SKU smartphone that supports global LTE roaming. The RF front-end, we note, has always been the bottleneck and not the baseband or transceiver, although some limitations still exist with all transceivers. Then again, there isn't a compelling need to have a smartphone that supports LTE in the approximately 18 different bands that have been deployed today, let alone the 34 bands that have been standardized as part of Release 10.
- The combination of the new transceiver and the innovative RFFE design gives the handset OEM greater flexibility in the number of bands that a handset supports. Additionally, there is more flexibility in the mix of low-, mid-, and high-bands, which has historically led to SKU fragmentation. From a handset manufacturer's perspective this flexibility can translate into meaningful cost savings since each new SKU has its own development cost. Much still depends on the incremental cost of the RF front-end components and pricing information isn't available. RF POP™ helps in this regard since it allows handset manufacturers to swap in/out new band-specific components without impacting the PCB footprint and the layout within the handset.
- By itself, each component isn't necessarily revolutionary as products with similar functionality already exist or are being promoted by other companies. However, these components allow Qualcomm to compete in a new multi-billion dollar market opportunity and it could make it more difficult for others to compete in Qualcomm's traditional market. Note that in the context of LTE, some of the new technologies Qualcomm is embracing are still a bit futuristic, although they have been used with legacy technologies (e.g., a CMOS power amplifier).
- All newly-announced products could be in commercial products by the end of 2013, with some of them commercial in Q3/2013. We're a bit skeptical about the timing of the CMOS PA with ET but recognize someday it will come. USB data sticks and comparable products probably represent an easier entry point with smartphones to follow.
- No single company currently offers such a near complete portfolio of products that span the baseband modem to the antenna. Qualcomm's initial foray into this new market could force others to follow or to be more aggressive in working with their RF front-end suppliers, some of whom we believe have compelling [albeit standalone] components.
- Which approach wins the day – a system-based solution based on technology from a single supplier or discrete-based approach from multiple suppliers? Historically, a system-based solution wins since there are efficiencies that can't otherwise be realized. Conversely, there is a single point of failure and it can be difficult to be a Jack of all Trades without being a Master of None. Fortunately, it isn't in our job description to have to take this bet.

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INTRODUCTION

Last May we published a self-help guide for the industry that discussed how the industry could address one of the biggest challenges that it faces. In that report (*SA* 05/23/2012, "Improve your [RF] front-end in seven easy steps!") we analyzed the innumerable RF-related challenges that currently exist and which will only get worse with the passing of time. In summary, the introduction of the LTE standard has resulted in the industry consolidating on a single air interface, but it is also an air interface that is highly fragmented due to the large number of frequency bands and combinations of frequency bands where it must operate. Further, many of these bands or band combinations (e.g., carrier aggregation) introduce additional complexity that isn't easily solved by traditional means.

Qualcomm just announced a suite of new products that specifically address the new complexities associated with the LTE air interface. With a couple of potential exceptions, these products are not necessarily revolutionary since there are other companies promoting solutions that are, for the most part, functionally comparable. However, the announcement is important because it signifies Qualcomm's attempt to further expand its traditional footprint – potentially at the expense of its peers and of the traditional RF front-end suppliers. Further, this announcement provides some credibility and validation that "new age" technologies can become mainstream long before Jonny Quest reaches manhood.

Qualcomm just announced a suite of new products that specifically address the new complexities associated with the LTE air interface.

In this issue of *Signals Flash!* we summarize the announcement and discuss two potential implications.

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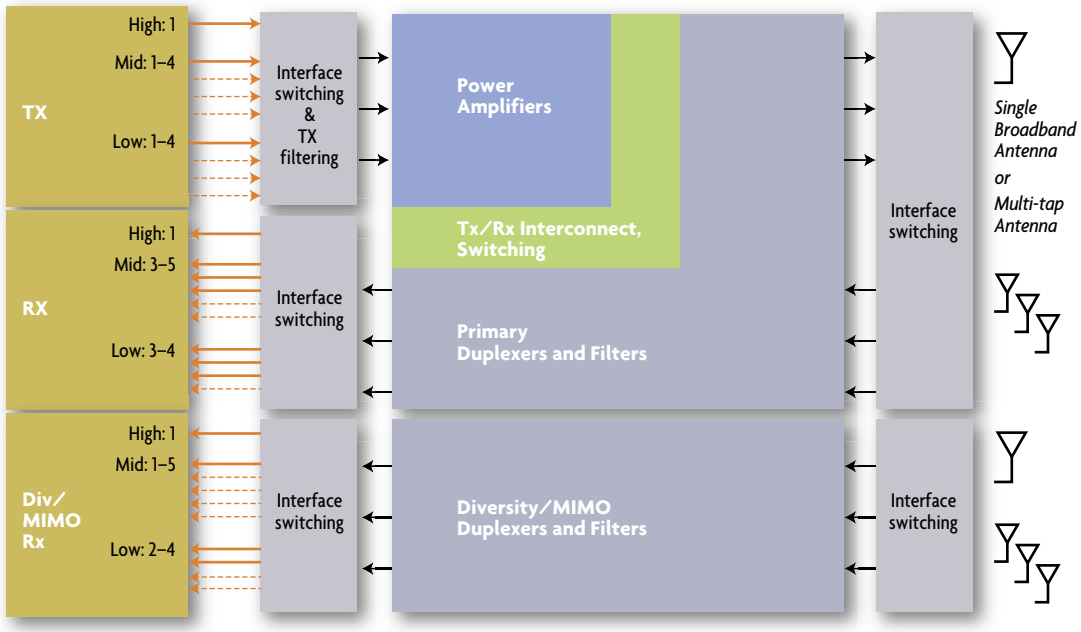
THE ANNOUNCEMENT

Qualcomm announced five new products – one traditional product and four nontraditional products. Its new RF transceiver, the WTR1625L, is a next-generation transceiver that essentially doubles the number of supported RF bands in a smaller footprint, compared to its early generation transceiver. It also supports features, such as carrier aggregation which is a critical component of LTE-Advanced, and LTE TDD. Like virtually all of its peers, Qualcomm has been doing its own RF design since the very early days of its existence, and given Qualcomm's early entry into the LTE chipset market the time is about right for a next-generation RF chipset. At MWC there could be additional transceiver announcements from other companies in the space, but generally a next-generation platform comes after the company has found at least some market traction for its first generation platform, not before.

The other product announcements are more interesting because traditionally Qualcomm has not participated in this market segment – the RF front-end or the portion of the transmit and receive paths that fall between the transceiver and the antenna (reference Figure 1). For that matter, none of the traditional baseband suppliers have done much, if anything, to offer their own RF front-end products, although various companies have tried over the years to gain traction with certain components – the power amplifier was the most popular.

Figure 1. The RF Front End



Source: NGMN Alliance presentation, recreated by SRG

Qualcomm's expanded product portfolio includes an antenna matching tuner, a multi-band power amplifier, including an integrated antenna switch, that also supports envelope tracking (another new product), and a new manufacturing process called RF POP that essentially allows band-specific components, such as third-party duplexers and filters, to be layered like a sandwich on top of the power amplifier and antenna switch module. All of these new components, including the power amplifier, are based on CMOS technology. Given that we covered in great

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IN CASE YOU MISSED IT: SIGNALS AHEAD BACK ISSUES

- **01/23/13 "The Mother of all Network Benchmark Tests - On the Inside Looking Out: evaluating the in-building performance capabilities of commercial LTE networks (Band 4, Band 7, Band 13, and Band 17)"** With the continued support of Accuver, we leveraged its XCAL-M drive test solution and its enhanced support for in-building testing to evaluate the performance of four LTE networks at Band 4, Band 7, Band 13 and Band 17. In this report we quantify the amount of LTE network traffic that we observed in the outdoor macro network and how it compares with our in-building testing. We also demonstrate that 700 MHz isn't a panacea for in-building coverage, that potential coverage problems are being masked by ample capacity, and that some in-building networks may not scale to support future traffic demands. Finally, we compare and contrast the performance of the VZW and AT&T LTE networks.

- **12/5/12 "LTE Band 7 versus LTE Band 4 - GAME ON!"** With the support of Accuver, we used its XCAL-M and XCAP drive test solutions to conduct a network benchmark study of LTE Band 7 and LTE Band 4. This benchmark study leveraged the Rogers Wireless network in Vancouver, Canada where they have deployed both frequency bands in virtually every single cell site. In addition to looking at basic throughput, we include a host of other device-reported KPIs to analyze the downlink and uplink performance characteristics of the two frequency bands under identical network conditions, including edge-of-of cell and in-building.

- **11/6/12 "M2M – toward the Internet of things"** We analyze the M2M landscape and some of the key players involved in realizing this vision. The business models for M2M are still in flux and eventually multiple business models will have to be implemented. We look at the new business models being explored by mobile operators and MVNOs. The global connectivity requirements of M2M services make it natural fit for cloud services so there will need to be new cloud platforms in both the operator networks and enterprises to support M2M services. We also analyze the requirements and vendors for such platforms. More importantly, the radio and core networks will require enhancements to support the deluge of new M2M connections. We discuss some of the major issues and how the 3GPP standards body and operators are planning to address these issues.

- **10/15/12 "Lost and Found"** As a follow-on report to Chips and Salsa XV, we examine the real world A-GNSS performance capabilities of leading smartphones. We also evaluate the performance attributes of the most popular navigation applications, including the amount of data traffic they generate, the length of time the smartphones remain connected to the network, and the amount of signaling traffic that they generate. Ultimately, we conclude that there are fairly dramatic performance differences for both the A-GNSS platforms and the navigation applications that have user experience and network implications.

- **9/13/12 "Chips and Salsa XV - Disparately Seeking Satellites"** In collaboration with Spirent Communications, we provide the industry's first independent analysis of A-GNSS platforms. The study includes conducted tests of vendor supplied A-GPS and A-GNSS (A-GPS + GLONASS) solutions and over-the-air testing of several leading smartphones. We demonstrate that while the performance across the platforms is largely comparable, there are significant differences in the performance of the solutions once they are implemented in the smartphone.

- **8/20/12 "The B Side of LTE - when your 'A Game' just isn't good enough"** We take a look at many of the proposed features being considered for 3GPP Release 12 and beyond, including advancements in the use of small cells, higher order MIMO and modulation schemes, 3D beamforming, network optimization, machine type communication, and device to device discovery and communication.

- **7/2/12 "Mobile Core Network 2.0 - the new reality or a fly-by-night catch phrase?"** Moving to an all-IP core network presents fresh challenges for operators. The EPC provides operators with the platform for the delivery of basic data services. However, operators need to prepare the EPC to deliver enhanced services beyond basic data services. Areas addressed include the centralized or decentralized approach, the Diameter protocol, network offload and optimization, the Content Delivery Network (CDN), and policy control.

- **6/8/12 "Debbie Downer Does Barcelona"** We provide highlights from this year's LTE World Summit, which was held in Barcelona, Spain. Unlike years past where the issue was on technical issues and challenges, the focus of this year's event was on the business case for LTE. To the extent technology issues were discussed, they were more futuristic, including network optimization, Cloud RAN, and small cells.

- **5/23/12 "Improve your [RF] Front-End in Seven Easy Steps!"** LTE, either directly or indirectly, poses several challenges for mobile devices, in particular for the RF front end. In addition to band fragmentation, LTE introduces MIMO and carrier aggregation, while its characteristics, such as a higher PAPR, can be problematic to support. In addition to exploring these technical challenges in detail, we examine seven potential solutions, all involving the RF front-end design, that should be considered.

- **4/16/12 "LTE Advanced and CoMP: what goes around, comes around"** CoMP is a Release 11 feature that leverages the simultaneous support of multiple transmission points to serve mobile devices in the high interference areas that occur between cells (inter-cell) and between sectors within a given cell (intra-cell). In theory it can provide stellar gains on the order of high double-digit percentages for edge of cell user throughput while also providing at least some increase in overall network efficiency. In practical terms, the benefits of CoMP are less clear and there is at least some justified reservations regarding its potential impact on an operator's network. In addition to explaining the technical details of the various CoMP implementations, we examine the potential benefits, key challenges, potential alternatives, and the likely rollout strategies.

- **3/28/12 "Cellular and Wi-Fi: A match made in Heaven?"** Based on interviews with leading stakeholders and a thorough analysis of the standardization processes, we discuss how and why Wi-Fi networks will become more closely integrated with cellular networks.

detail the functionality of these components, not to mention their importance when it comes to LTE, in our earlier Signals Ahead report, we are not going to reinvent the wheel and do it again. However, in the context of discussing the market implications, we may interject an important point or two.

IMPLICATIONS

We've identified two implications worth considering.

A TRULY GLOBAL HANDSET, BASED ON A SINGLE SKU, IS NOW FORESEEABLE IN THE FUTURE IF NOT ACHIEVABLE THIS YEAR. As we noted in our May 2012 report, the limiting factor that was precluding handsets from supporting more RF bands wasn't the baseband and to some extent it wasn't the transceiver, although no transceiver, including Qualcomm's latest offering comes close to *simultaneously* supporting the 34 frequency bands – 23 LTE FDD and 11 LTE TDD – that exist with Release 10. Future releases will include additional bands.

Instead, the problem was with the RF front-end, or the so-called RF plumbing that routes [and isolates] transmit and receive signals between the radio (transceiver) and the appropriate antenna – multiple antennas if you include MIMO/receive diversity. Each new band can require additional switches and filters/duplexers. Additionally, impedance mismatch can occur when the signals hit the antenna which can't be optimized for all frequency bands that span from below 700 MHz to 2600 MHz or even higher once operators make use of the 3 GHz band. Each new component has an incremental cost, it increases the RF front-end footprint, and it degrades the overall performance of the system due to insertion loss and other compromises that must be introduced.

To some extent, Qualcomm has single-handily addressed nearly all of the seven steps that we identified in our first report. For those of you keeping score at home, we do not believe that Qualcomm uses a standards-based interface (Step 5 – Open Interface Standards), such as MIPI or OpenET, with its home-grown solution but it is our understanding from talking with other companies in the industry that it supports them when working with third parties. Qualcomm also didn't announce tunable duplexers (Step 7 – Tunable Duplexers and the "Holy Grail" of a true SDR) – but one could argue that RF POP™ achieves somewhat similar benefits. The aforementioned transceiver was Step 6 (Advanced Transceiver Architectures). Worth noting, we're not convinced that its first generation transceiver with LTE support was the technology leader with respect to the number of bands it supported. However, unless someone else announces a new transceiver at MWC they can now claim to have the advantage.

With RF POP™ the duplexers can't be dynamically tuned, but supposedly they can be easily swapped without otherwise impacting the handset design and the layout of the RF footprint. The diagram from Qualcomm that we saw has the third-party duplexers and switches resting on top of the PA/switch module, meaning that changes to the band configuration occur in the vertical plane instead of the horizontal plane. This approach could make it easier for a handset manufacturer to ship quasi-customized products based on the same basic SKU. The customization would involve, for example, the addition of a unique frequency band that wasn't required or desired in other regions or markets. Alternatively, if a new band was required across all markets, it could be added without impacting the overall design of the handset. Isolation between bands is a critical challenge with traditional approaches, especially between certain band combinations, so it will be interesting to see how well this solution tackles the challenge. We also know that

RF POP could make it easier for a handset manufacturer to ship quasi-customized products based on the same basic SKU.

adding a new band can introduce insertion losses with the additional switches that are required, but if done correctly and with a finely-tuned system the losses can be minimized.

Qualcomm checked the box on Step 1 (Envelope Tracking - ET) and Step 2 (CMOS PA), and the two really go hand-in-hand since without ET, the CMOS power amplifier wouldn't be practical for multiband LTE applications. In summary, ET provides nearly instantaneous adjustments to the supply voltage with these adjustments corresponding with the waveform of the transmitted data. This feature allows the PA to run in saturation mode where the efficiency is the highest. Indirectly, higher efficiency means that a multiband power amplifier can be used since a multiband PA is always more inefficient than a single band power amplifier. ET also enables the potential use of an all CMOS power amplifier since one of the drawbacks of CMOS is its low linearity. We also note that LTE has a very high peak to average power ratio (PAPR) relative to legacy technologies so ET is far more important with LTE. Put another way, a CMOS PA for LTE that doesn't support ET isn't worth its weight in sand. A CMOS PA with ET that supports LTE is worth its weight in gold.

A CMOS PA with ET that supports LTE is worth its weight in gold.

Of all the product announcements that Qualcomm made, we are most cautious about the timing of ET *and* a CMOS PA [with an integrated switch] when it comes to supporting LTE later this year. Based on our research from last year, most experts in the industry felt that a CMOS PA that supported ET for LTE was still a few years away – although basically ready for HSPA+. If the planned schedule is met, it would accelerate the commercial timing by up to a couple of years relative to what we first thought.

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Finally, the antenna matching tuner (Step 3 – Switches/Tunable Antenna Switches) provides optimized support to allow a single antenna to span a much wider range of frequencies. LTE can be deployed in frequencies from 698 MHz to 3800 MHz, while there are movements to span the range in both directions. The antenna matching tuner can also adjust to changes in the impedance or other factors that impact RF performance due to various usage models – think sweaty palms, Apple's "Antenna-gate" and placing a handset next to a thick and nearly impenetrable object, better known as a cranium. Again, Qualcomm wasn't the first to offer this type of solution and it probably won't be the last. However, we believe that it is the first baseband supplier to do so, and there are implications.

Readers should also recognize that just because an LTE smartphone can support more bands that it will support more bands. In particular, a handset manufacturer still needs financial motivation to ship a smartphone with an additional frequency band enabled. Case in point, this announcement isn't necessarily going to result in a smartphone simultaneously supporting Band 13 (VZW) and Band 17 (AT&T) since neither operator would want to sell a subsidized handset that could be activated on a competitor's network. This scenario doesn't negate the benefits of a single SKU from the perspective of the handset manufacturer or the mobile operator, but it also doesn't mean that consumers will be able to purchase the mother-of-all smartphones that works on any operator's LTE network.

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The supplier landscape will need to respond to maintain their competitiveness.

When it comes to the wireless IC market, there are numerous examples of Roadkill due to the immaturity of a product (e.g., some of the first CMOS PA ventures), insufficient market share (e.g., the large number of 3G and WiMAX chipset suppliers that once existed) and the land grab mentality of the major suppliers. Most baseband suppliers, for example, now have their own RF transceiver so the merchant market opportunity for transceivers isn't what it used to be. We can

think of more than a few companies that have exited this particular market segment even though they still exist today.

By expanding beyond its traditional market, Qualcomm is taking more control of its destiny while also taking on more responsibility to address the needs of all market opportunities. It is no longer someone else's fault if a particular market opportunity isn't being addressed – think the Band 12 versus Band 17 issue that existed in the United States. Conversely, it is now potentially easier for handset manufacturers to target niche opportunities without introducing an entirely new SKU. Instead, it is now possible to introduce a new band and/or swap in a new band without having a material impact on the handset. In theory, this could make it less likely that the handset manufacturers use a completely different chipset manufacturer to address different market opportunities. Then again, handset manufacturers will always want a "Plan B" and even a "Plan C," much like mobile operators do not want Google or Apple to dominate their markets.

Looking at the scenario from this perspective, Qualcomm wins on two accounts – it captures at least some share of an entirely new market that is arguably very meaningful and it makes it more difficult for its baseband peers to compete. A rationale person can't disagree with this scenario although there will be a lot of debate about how much incremental success Qualcomm will actually achieve.

Qualcomm wins on two accounts.

On the flip side, Qualcomm's new foray could be the wakeup call that motivates the industry to respond in kind. Qualcomm still wins, but it benefits other companies as well. The degree to which Qualcomm wins versus others really depends on whether or not Qualcomm's system-based approach is fundamentally much better than what can be assembled via piece parts from multiple suppliers. If it merely mirrors solutions that are already on the market, either now or in the not-too-distant future, then the impact will not be as meaningful.

Qualcomm's new foray could be the wakeup call that motivates the industry to respond in kind.

For example, Qualcomm isn't the first company to announce a CMOS PA that supports envelope tracking. Nujira and Quantance support ET and several companies, including Amalfi Semiconductor, Black Sand Technologies, and Javelin Semiconductor, are working specifically on CMOS PAs. Some of these companies have even provided results from internal testing that they have done; Qualcomm has not. Most recently, Nujira indicated that its ET solution can achieve "57% final stage efficiency" with a CMOS PA supporting LTE, or comparable if not better than what is possible with a GaAs PA running in ET mode. Obviously in the absence of ET the GaAs efficiency would be much lower. Nujira also announced its own RFFE reference design that incorporates a multiband PA with its own ET technology, as well as the requisite duplexers and antenna switches.

The challenge for all of these companies is that they must work with each other to achieve their goals which may not coincide with each other. Envelope tracking requires reporting and feedback mechanisms between the baseband, the power amplifier, and the ET module. The aforementioned companies have gotten to this stage and we believe that virtually all baseband suppliers have partnered with one or more of the ET suppliers but it took some doing. Does Qualcomm or another baseband company really benefit if a third-party's power amplifier is more efficient? To some extent the answer is yes, but to a large extent the answer is no, at least not directly unless others are doing it as well. That being said, we believe that all of the baseband chipset suppliers, including Qualcomm, support the MIPI and/or the OpenET interfaces that make envelope tracking a reality. Further, many of the emerging and traditional PA suppliers have ET initiatives that involve working with other companies.

Qualcomm notes that by taking a systems-based approach that it can achieve better performance than what can be achieved by working with partners. This argument applies to its ET + CMOS PA solution as well as with its antenna tuner. Conceptually, we understand the argument since there could be an additional layer of optimization that is possible when everything is done in-house. Conversely, we don't have any proof points to support the claim.

Now that Qualcomm directly benefits from a better RF front-end solution, other baseband chipset suppliers could be more motivated to respond in kind. We wouldn't rule out the possibility for some of the larger players making acquisitions or everyone doing more to work closely with each other. There may be additional pain points associated with these collaborative efforts, and Qualcomm would still have a significant time-to-market advantage, but there may not be any other alternative. To borrow from the ancient Chinese proverb, "The enemy of my enemy is my friend."

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NVIDIA, for example, is getting attention in the press for its software defined radio (SDR) that reportedly allows seamless switching between LTE and 3G frequencies as well as support for new RF configurations after the handset is in the customers' hands. Although we're familiar with NVIDIA's (formally Icera's) software-based approach for the modem, we don't know the details about this newly-claimed capability. However, we do know that this feature will only be meaningful with an RF front-end that is also easily adaptable and configurable. Recall that the bottleneck isn't the baseband + transceiver, but the RF front-end. NVIDIA doesn't currently have an RF front-end solution but it does work with third parties. To the extent its partners can't deliver the goods, the company might have to bring the capability in-house.

It is also worth noting that some market opportunities may still be best served by a laser-focused effort and commitment versus a shotgun approach. The beauty of an all-in-one solution is that it can be used, reused and morphed to support the common and widely diverse needs of a large handset manufacturer. It can be cheaper, easier and faster to work with a single solution than to use an entirely new solution or to reconfigure the RF plumbing. For this reason, we see why a handset manufacturer might want to remain with a single multipurpose platform that is easily configurable, if it is also affordably priced.

Some market opportunities may still be best served by a laser-focused effort and commitment versus a shotgun approach.

There are, however, certain market opportunities that might be best served with fewer bells and whistles. For example, M2M modules generally don't roam and they may not even need to support more than a single band and a single technology. The same could be said for handsets/handset manufacturers that are serving a particular market niche or who don't want to be entirely dependent on a single supplier for the majority of the guts that comprise a commercial smartphone. Apple is the poster child for this strategy so it will be interesting to see what, if any, new actions they take. They use Qualcomm for their cellular radios, but for now they seem more interested in controlling their own destiny and handpicking the remaining internal components from individual suppliers. Whether or not they do one-stop shopping at Costco in the future is anybody's guess.

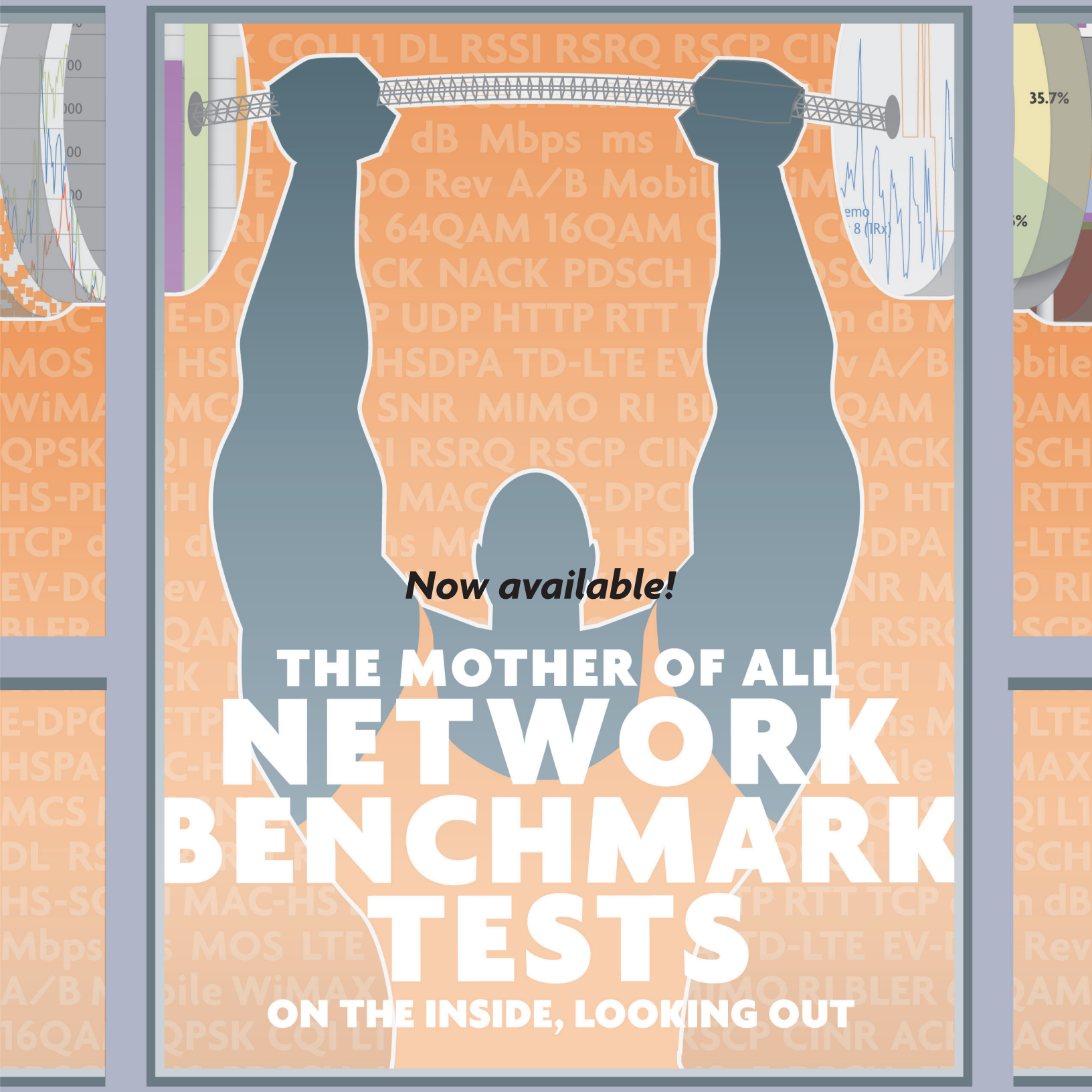
FINAL THOUGHTS

We will be out shortly with our long awaited "Chips and Salsa" LTE chipset benchmark study that provides the results from benchmarking eight different commercial and pre-commercial LTE chipsets. If all goes according to plan we'll be on an evening flight on Friday to Barcelona where we hope to touch down in time to see a national football game – that's soccer for our US readers. Until next time, be on the lookout for our next *Signals Ahead....*

Pending Topics

We have identified a list of pending research topics that we are currently considering or presently working on completing. The topics at the top of the list are definitive with many of them already in the works. The topics toward the bottom of the page are a bit more speculative. Obviously, this list is subject to change based on various factors and market trends. As always, we welcome suggestions from our readers.

- RCS and its impact on networks
- LTE chipset performance benchmark test results
- TD-LTE network and chipset performance benchmark results
- Multi-vendor LTE network benchmark study
- Self-Optimizing Networks (SON)
- Smartphone signaling implications across operating systems
- How network performance (throughput and latency) impacts the user experience
- Transmission Mode 3 versus Transmission Mode 4 in a Live Network and Test Lab
- The impact of Type 3i receivers on UE performance (includes chipset benchmark tests of leading solutions)
- Smartphone signaling implications and LTE
- HSPA+ (MIMO) network performance benchmark results
- The challenges of delivering video in a mobile network
- Cloud RAN and the use of a Distributed Network Architecture
- Public Safety Options with 700MHz
- LTE chipset landscape



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