Network Optimization for 5G

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MOBILE EXPERTS

Top mobile operators worldwide are gearing up for 5G, and along with a new air interface there are several new architectural changes that will be introduced soon:

- Massive MIMO will dramatically increase the spectral efficiency of macro base stations;
- Open RAN networks will dramatically reduce the cost of basic mobile networks;
- Core networks and Baseband processing will be virtualized;
- Edge Computing will be deployed to improve service to customers

Each of these basic changes in the network serve a purpose and mobile operators are currently engaged in a broad variety of trials to evaluate combinations of these various technologies.

This white paper examines Virtualization and Open RAN architectures, to illustrate the level of performance we can expect. More importantly, this white paper will suggest a change to the business model to enable optimization of Open RAN networks.

Open RAN and Virtualization

The broad Internet market has enjoyed massive success over the past twenty years, by following the 'open' model for Ethernet and other wired networks. This means that industry players follow standards that allow for interchangeable hardware. Mobile networks have been slow to adopt this philosophy, because the real-time nature of mobile signals requires very fast hardware/software coordination.

Recently, mobile operators have initiated a major push worldwide to adopt Open RAN standards between the Radio Unit (RU) and the Distributed Unit (DU, also known as a Baseband Unit). The idea is that, if an industry-wide interface can be adopted, then the RU and DU hardware cost can be dramatically reduced.
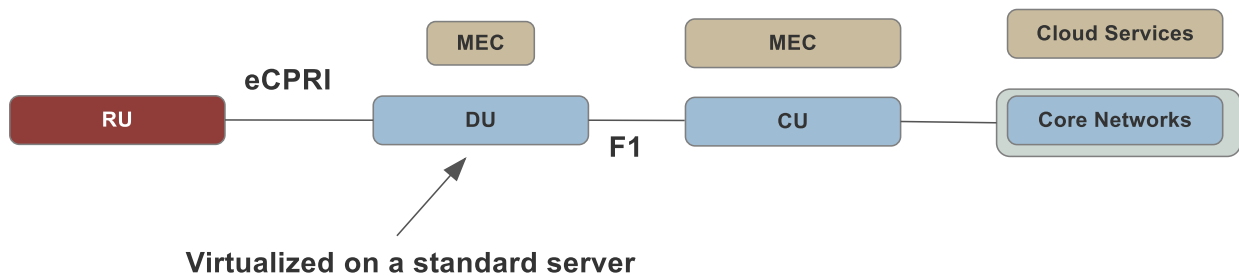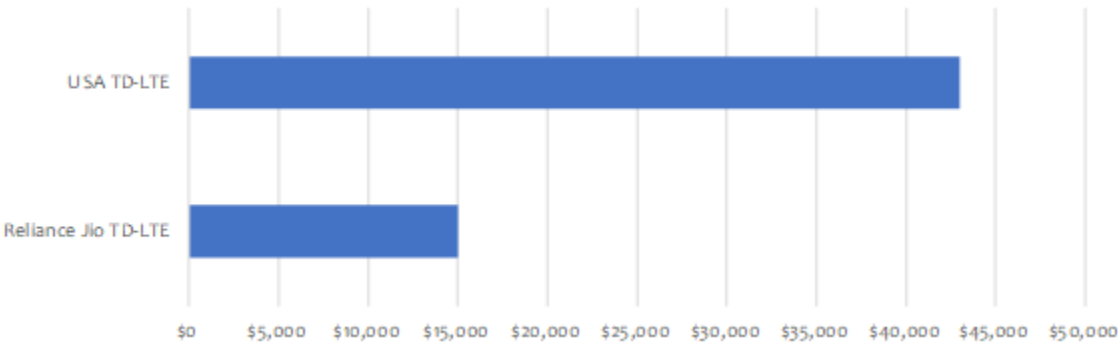

Source: Mobile Experts

Figure 1. Modern mobile network and Edge Computing architecture

The effort to define the RU-DU interface is well underway, with eCPRI (CPRI Alliance) and xRAN (Open RAN Alliance), as well as IEEE defining the various key specifications. Unlike the original CPRI development in 2003, the current process for developing eCPRI and Open RAN includes the key features that will be required for interoperability: standardized headers, O&M management info, as well as standard signaling and data flows.

At the same time, mobile operators expect to deploy Mobile Edge Computing, and we are likely to see Edge Computing resources in multiple locations throughout the network. Today, most mobile cloud services are centralized, either near a core network location or in a national-level data center. Over time, we expect Edge Computing servers to be co-located with Centralized Unit (CU), DU, and even RU hardware. The primary benefits of Edge Computing deployment will be to reduce latency for customers, and to reduce long-haul transport costs.

Open RAN will drive cost down

The new architecture holds promise for cost reduction, because hungry radio vendors or software companies can step in to replace elements of the network at a fraction of the major OEM's cost. The amount of cost savings is a subject of debate, but we have some examples from recent deployments that illustrate the idea.

Source: Mobile Experts

Figure 2.   Anecdotal Price Comparison for 20 MHz TD-LTE Base Stations in 2017

In India, companies such as Airspan and Samsung have taken the lead role in deployment of LTE networks, simply because they are offering much lower cost.   In the United States, a TD-LTE base station (a set of 3 radio units along with supporting baseband processing) costs more than $40,000. However, the hungry smaller competitors are selling the same product for $15,000 in India.

Companies such as Mavenir, Altiostar, and others have developed the software solutions and have surrounded themselves with hardware vendors to create a new ecosystem. It's a new business model with lower overall cost, and support from the operators is feeding serious investment in this direction.

Problems will arise

The cost reduction of Open RAN is very compelling, but technical issues are certain to arise. Interoperability testing is never perfect, and some radio performance issues are not covered in 3GPP standards.   The end-to-end RAN vendors include 30 years of wisdom in their proprietary RF

algorithms, so that the RU and the DU work together for best performance on non-3GPP challenges such as rogue interferors. ORAN products will lose that advantage.

For example, Passive Intermodulation (PIM) is a commonly known problem in the industry, but 3GPP has never addressed PIM in their specifications because the industry has addressed the problem through a combination of improved antenna quality, RAN vendor algorithms, and third-party PIM cancellation products.

Similarly, many people expect problems to arise in the new art of beamforming, as coordinating beams between multiple base stations has not been fully standardized by 3GPP.   These issues are fairly unknown today, but are expected to be solved by proprietary algorithms developed by each major RAN vendor.

This issue is nothing new… major RAN vendors have always used proprietary in-house techniques to solve system-level problems in 2G, 3G, and LTE. As the beamsteering, EVM sensitivity, bandwidth, and number of bands increase, proprietary optimization becomes increasingly important to the performance of the network.   For 5G massive MIMO, we estimate that buying an RU and DU from two different vendors will have 50% lower capacity than an optimized single-vendor bundle.
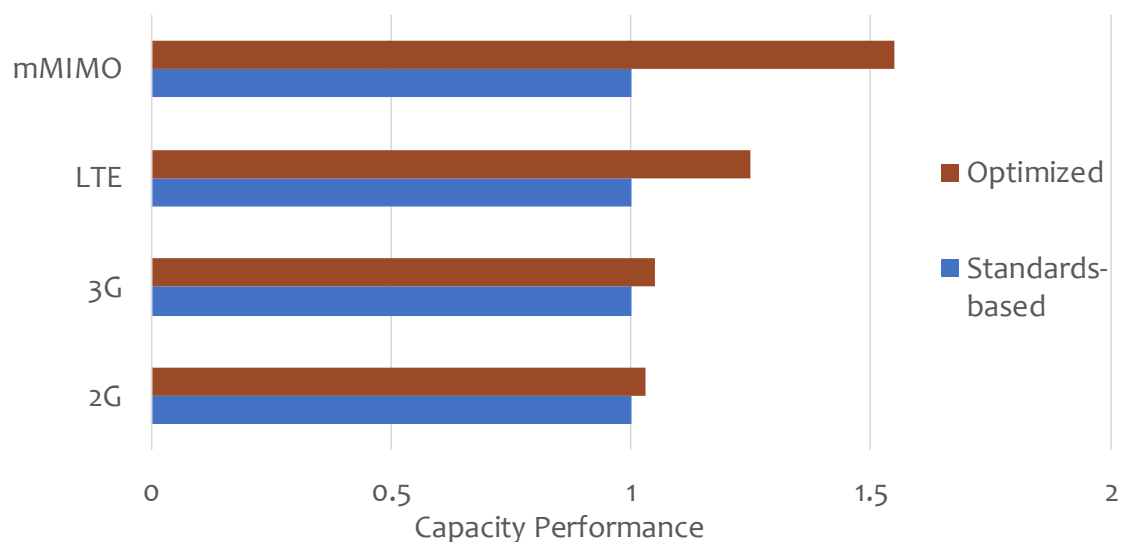
Source: Mobile Experts, based on survey of 24 operators and OEMs

Figure 3. Measured Benefit of Coordination between Radios

RF Link Budget Optimization

Even in networks that are seemingly "optimal" due to the use of a major RAN vendor's products and some sophisticated engineering, independent optimization by third-party companies can have a significant impact.   There are probably hundreds of different ways that the RF environment can be cluttered or degraded, but some optimization solutions focus on the top three issues:

1. Passive Intermodulation (PIM): In networks that are focused on high quality, PIM still arises due to multiple factors. Some factors can be anticipated by the RAN vendor, but others

cannot. For example, the transmitter power from multiple operators can mix together on a shared tower, causing intermodulation products that land within the receiver band.   This kind of unpredictable interference has become more commonplace, now that LTE is used in more than 3-4 frequency bands.   Data taken during 2018 indicate that between 8% and 20% of sites can suffer degradation in the range of 6 dB in the uplink.

2. Interference from nearby broadcast transmitters or other non-cellular sources can desensitize the receivers. This effect can also be unpredictable, affecting a large number of sites in some cases.

3. Inter-cell interference can be an issue, as antenna tilting and other ways of defining the cell edges are not perfect in the real world. This is likely to become a much bigger issue as beamforming and higher antenna gain comes into the market.

Over the past few years, some aftermarket products have emerged that improve the link budget through clever DSP processing to adjust the link conditions and filter/cancel out unwanted transmissions or PIM.   Field deployment of thousands of units has resulted in a 1-2 dB improvement on almost every site, and a roughly 6-8 dB improvement on 8-10% of sites.   The impact on both coverage and capacity can be significant, more than doubling the radius of a cell in many sites.

It's important to note that these concerns are already prevalent in proprietary, "optimized" networks from the top tier RAN vendors.   As the market moves to Open RAN networks, the existing "optimization" of the major RAN vendors will not be available, so the 1 dB to 6 dB impact of RF issues should be expected to become a major concern.

A Case Study

To determine how an operator should best address PIM and RF interference issues, it can be useful to construct a case study scenario.   Consider the case of a rural LTE network:

- Nominal expectation of 10,000 sites
- It's a rural network, where coverage is more important than capacity
- PIM impacts 8% of sites with a 6 dB reduction of SINR
- Other link interference impacts 100% of sites with 1 dB reduction of SINR
- Proprietary base stations can be used at a cost of $30,000 each
- ORAN base station options can be used at a cost of $15,000 each

The Value of RF Optimization

Third-party RF optimization solutions can be expensive in the existing LTE architecture, because they generally involve a stand-alone server with customized hardware. However, in a virtualized RAN environment the RF optimization can become a network function that operates on the existing baseband server, making the implementation much simpler and lower cost.   For the purposes of this case study, we assume that the link conditioning performed on 100% of sites can be achieved as a virtualized network function on the VRAN server.   More computation-intensive PIM cancellation could require the addition of a server, depending on the compute power available. In our case study,

we assume that the cost of 'Link Conditioning' is spread over several sites, and the cost of PIM solutions is only applied for the 8% of sites that have PIM issues.
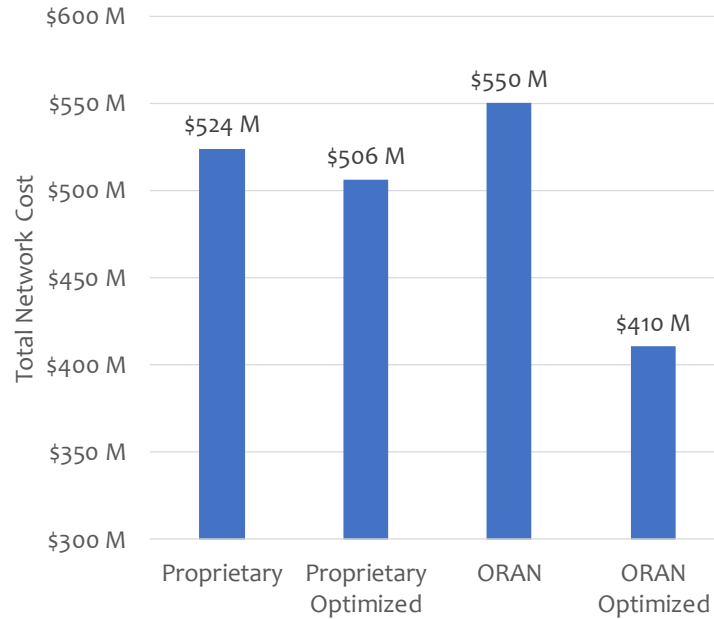
	Number of sites	Base Station cost per site	Link Conditioning Cost per Site	Optimization Cost (PIM Sites only)	Site Acq + Backhaul Cost per site	Trouble-shooting Cost	8 year OPEX	Total cost	Comments
Proprietary	10,800	$ 30,000		$ -	$ 7,500	$26 M	$93 M	$524 M	Need to add one site for every PIM-impacted site
Proprietary Optimized	10,000	$ 30,000	$ 1,500	$ 25,000	$ 7,500	$10 M	$86 M	$506 M	Reduced troubleshooting costs
ORAN	12,100	$ 15,000		$ -	$ 7,500	$53 M	$225 M	$550 M	High OPEX costs due to lack of support tools
ORAN Optimized	10,000	$ 15,000	$ 1,500	$ 25,000	$ 7,500	$24 M	$126 M	$410 M	Lowest cost with product to optimize the top 3 RF issues

Source: Mobile Experts

Figure 4. Total Cost impact of RAN Optimization

In our case study, we find that the RF planning would call for 10,000 sites.   But PIM issues on 8% of the sites would dramatically degrade 800 sites, requiring roughly 800 additional sites to be added to fill in the coverage holes.   Also, if the operator chooses to use an ORAN network without sophisticated interference mitigation, an additional 2,100 sites would be required due to at least 1 dB degradation of SINR in every site.   Optimization can be applied to either proprietary or ORAN networks to ensure that the actual network conforms to the plan: The RF planning called for 10,000 sites, and optimization prevents a scramble to deploy additional sites.

This saves millions of dollars in both CAPEX and OPEX, as fewer sites need hardware, site acquisition, backhaul, troubleshooting, and ongoing maintenance.   In addition, the ongoing OPEX cost can be much lower for networks that address the 1-6 dB RF issues, because smaller radio issues can be handled as routine items, not rushed projects.

Figure 5 bar chart:
- Proprietary: $524 M
- Proprietary Optimized: $506 M
- ORAN: $550 M
- ORAN Optimized: $410 M

Y-axis: Total Network Cost ($300 M to $600 M)

Figure 5.   Paying for optimization improves Total Cost of Ownership

Conclusion

This case study illustrates the third-party optimization tools can be useful in existing networks, mainly due to PIM cancellation to prevent cell shrinkage and huge troubleshooting costs.   More importantly, the case study shows that RF optimization will be absolutely critical for ORAN networks, because every site is likely to have a significant impact from RF issues that are simply not addressed in 3GPP standards.

The bottom line: ORAN networks are an opportunity to cut base station CAPEX in half, but the virtualized baseband processor solution must be open to third-party optimization solutions. Emerging software-based RAN vendors can save the industry a lot of money, but the low-cost RAN software must be paired with RF optimization that adapts gracefully to real-world surprises.