THE X FACTOR

A THIRD-PARTY BENCHMARK STUDY OF THE XCOM-LABS' XCOMP SOLUTION

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Prepared by
Signals Research Group

SIGNALS Research Group
www.signalsresearch.com

Study Conducted for XCOM-Labs

As the sole authors of this study, we stand fully behind the results and analysis that we provide in this paper, which leverage a methodology consistent with our benchmark studies that we have conducted for nearly two decades.

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)

Key Highlights

Signals Research Group (SRG) conducted a performance benchmark study of the XCOM-Labs' XCOMP solution, which is a coordinated multipoint radio system targeting dense deployments of 5G infrastructure to deliver significant capacity gains over traditional inbuilding solutions. This paper provides the results from our third-party study which looked at the performance of an XCOMP capable network designed to support various use cases the company is targeting with its solution.

XCOMP differs from traditional inbuilding solutions, such as small cells and DAS (Distributed Antenna Systems), in that it provides extremely high downlink and uplink capacity that can be both ubiquitous and highly concentrated in nature. Further, it achieves these performance gains within a single logical cell comprised of multiple RRU (Remote Radio Units), meaning that inter-cell interference is nonexistent and brief interruptions due to cell handovers are a thing of the past. Most impressive, the bidirectional capacity gains we documented were largely immune to the location and concentration of the devices in the network. We leveraged up to 204 devices in a single test, including a mix of smartphones and modules, as part of this benchmark study.

XCOMP provides extremely high downlink and uplink capacity that can be both ubiquitous and highly concentrated in nature.

Key highlights from our benchmark testing include the following:

XCOMP delivered very high downlink and uplink capacity due to high reuse of nearly all resource blocks on each MIMO layer. Average downlink capacity reached over 4.5 Gbps in 100 MHz of TDD spectrum (64.6 bps/Hz) while in the uplink we documented an average throughput of nearly 770 Mbps (38.3 bps/Hz) with a spectrum allocation that was biased toward the downlink direction. High reuse of network resources – up to 16 downlink MIMO layers and up to 12 uplink MIMO layers with nearly full reuse of all resource blocks (RBs) on each layer – largely explains the observed gains. Even more MIMO layers are possible in one or both directions depending on the network configuration and device capabilities.

Results were largely impervious to the location and concentration of the devices. In many of our tests we incorporated 1 to 96 devices located adjacent to each other on up to 12 carts distributed across the 8 RRU network – up to 204 devices at a time. In one test we pushed all 12 carts together so there were 204 devices located directly under a single RRU. There were only modest differences in the total network capacity between these configurations. It is one thing to obtain high bidirectional spectral efficiency with distributed devices. Achieving this performance with devices literally on top of each other is another thing altogether.

As an example, in one challenging test with 48 devices grouped together on 6 adjacent carts, the spectral efficiency during a bidirectional test was an impressive 38.1 bps/Hz (downlink) and 34.5 bps/Hz (uplink). This high performance was achieved by a near-perfect reuse of all possible RBs in the downlink and uplink directions along with the complete use of all MIMO layers. In the subsequent sections, we identify other pertinent information for these tests, such as the channel bandwidth, downlink/uplink slot allocations, etc. Even with 204 UEs placed under a single RRU, the uplink spectral efficiency during a test involving uplink performance was an impressive 23.7 bps/Hz with near-perfect reuse of RBs.

XCOMP is ideal for public venues and private networks that have challenging RF environments. Stadiums, arenas, and similar venues are ideal for XCOMP since there are high concentrations of smartphones generating significant data traffic in both directions – fans watching another sporting event on their phones or concert goers streaming the live concert to all their friends who couldn't get a ticket to the show. However, the merits of XCOMP are even more important for private inbuilding networks targeting factories, warehouses, and other large building structures where there could be a limited amount of spectrum available and where there is a need for a robust network that provides highly-reliable ubiquitous coverage while satisfying the demands for concentrated capacity that can vary over time and location.

Modern warehouses and micro fulfillment centers frequently leverage automation and bots to move boxes and other containers throughout the inbuilding structure. These buildings can have aisles separated by tall shelves which reach the ceiling, and intermixed with small self-contained rooms, such as refrigeration units, which make it difficult, if not impossible, to deploy seamless connectivity with the high reliability KPIs which are necessary to keep the automated functions up and running. Further, with autonomous bots roaming the floors the demands on the uplink performance can take precedence over the downlink requirements. The downlink/uplink capacity requirements of the network can vary in both time and space, meaning that evenly distributed capacity won't support high concentrations of automated bots while it would be cost prohibitive to deploy sufficient capacity via small cells, even if the inherent issues due to inter-cell interference could be solved.

Extended Reality (XR) is another use case that places high demands on data capacity. Ideally, this capacity is not restricted to a single location (e.g., a sofa) since this limitation would prevent more compelling use cases involving mobility and larger geographic areas. Examples that come to mind include military and public safety training, not to mention highly realistic gaming and related entertainment activities, such as next-generation laser tag or XR-based haunted houses.

The following sections of this paper provide the results from our benchmark study which we conducted at the XCOM-Labs' facility in California. We start off with a short technical description of XCOMP and how it compares and contrasts with DAS and small cells. The bulk of this paper follows in the next section which provides the results and analysis of the tests that we conducted as part of this study. We then include some background information about Signals Research Group.

Table of Contents

Index of Figures

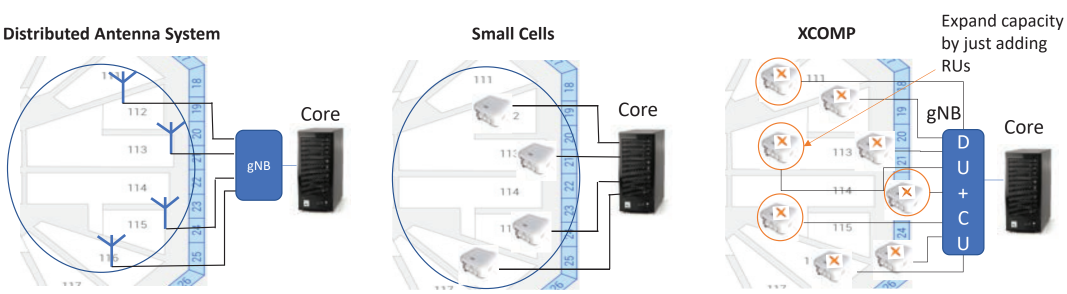
XCOMP Technology Primer

SU-MIMO (Single-User MIMO) and MU-MIMO (Multi-User MIMO) are similar in that with certain radio conditions they can reuse the same resource in the time and frequency domain, resulting in higher data speeds and sector throughput. With SU-MIMO, the network scheduler can simultaneously assign the same network resource, or Resource Block (RB), to serve a single mobile device. For example, 2x2 SU-MIMO can reuse the same RB twice to nearly double the data speed and 4x4 SU-MIMO can reuse the same RB four times to theoretically quadruple the data speed.

MU-MIMO is conceptually like SU-MIMO in that it can reuse network resources when certain channel conditions are satisfied. It differs in that the total number of layers is higher than what is possible with SU-MIMO and the layers can be shared between multiple mobile devices, assuming they meet certain algorithmic parameters.

XCOMP is neither DAS nor a small cell architecture, but it leverages some attributes from both solutions, while forgoing their limitations. In fact, it takes the strengths of both solutions and magnifies their potential in ways that are not possible without the system-level approach that XCOMP invokes. Figure 1 shows the XCOMP architecture along with DAS and small cells. DAS uses a single source of network capacity that is then evenly shared across a number of antennas. The coverage is as good as the layout of the antennas but since the capacity is equally shared across all antennas, it can't adjust its capacity to support network traffic that is concentrated in one part of the network. DAS works great at an airport gate until there is a plane getting ready to board. DAS also doesn't support capacity enhancement features, such as MU-MIMO, so it can't support large amounts of data traffic unless there is an ample amount of spectrum available.

Figure 1. DAS, Small Cells and XCOMP



Source: XCOM-Labs

Each small cell comes with its own source of additional bandwidth, but the bandwidth doesn't scale with the increase in the number of small cells. In other words, a 2x increase in the number of small cells does not double the network capacity since adjacent small cells generate interference with each other, thus reducing the inherent amount of available capacity. Additionally, cell handovers occur whenever moving between small cells and these handovers can degrade overall performance and reliability – especially with a dense concentration of small cells. Isolating the small cells can minimize inter-cell interference but it comes at the expense of ubiquitous coverage.

XCOMP has a single source of capacity – a distributed unit or DU that is based on the Open RAN architecture – which combined with a centralized unit (CU) and remote radio units (RRUs) provides a complete radio access network. The intelligence resides in the DU, meaning that third-party RRUs can be used in the network if they support certain functionality. XCOMP is really a commercial implementation of CoMP (Coordinated Multipoint), which is an advanced flavor of MIMO that has been discussed since the days of LTE. CoMP is also one of the key technology enablers for 5G as it can extend the capabilities of MU-MIMO, but it also requires a high level of coordination and the availability of channel state information, not to mention the ability to act on that information.

With XCOMP, all network resources, or resource blocks (RBs), targeting the UEs in the network, are transmitted/received through all RRUs in the network. However, since the RRUs are spatially separated and interspersed throughout the network along with the UEs, it is possible to intelligently reuse the RBs and their corresponding MIMO layers multiple times. This capability places a very high demand on network synchronization and transmit power levels to ensure RBs transmitted from each RRU arrive at their respective UEs at the same time and with appropriate power levels so that they can be decoded by the UE. Much of the secret sauce behind XCOMP lies in these capabilities and the necessary messaging between the DU and RRUs that is required to make it all work seamlessly. Any commercial UE works in an XCOMP network since the UE is unaware of what is occurring within the network.

With XCOMP, all resource blocks (RBs) targeting a particular UE are transmitted/received through all RRUs in the network.

Since UEs are being served from multiple surrounding RRUs, it is "much easier" to reuse RBs and increase the number of MIMO layers while maintaining the orthogonality or uniqueness of each transmitted RB. Traditional massive MIMO is similar to XCOMP/CoMP with the biggest difference being that with massive MIMO there is only a single RRU (cell site) involved in the transmissions. This limitation makes it far more difficult to have good MU-MIMO performance when UEs are located close to each other. A traditional massive MIMO system that is not based on XCOMP is most appropriate for outdoor deployments where it becomes more challenging to deploy an XCOMP solution.

One last critical distinction for XCOMP is that it is a single cell network. For example, the 8 RRU network that we tested as part of this study was comprised of a single PCI (Physical Cell ID). This feature meant that we never encountered any cell handovers when moving UEs around the network. Cell handover boundaries are prone to interference from adjacent cells while moving between different cells generates handovers and their corresponding signaling requirements. In a dense small cell network, the combination of frequent handovers and large handover zones relative to the coverage area of each small cell results in degraded performance.

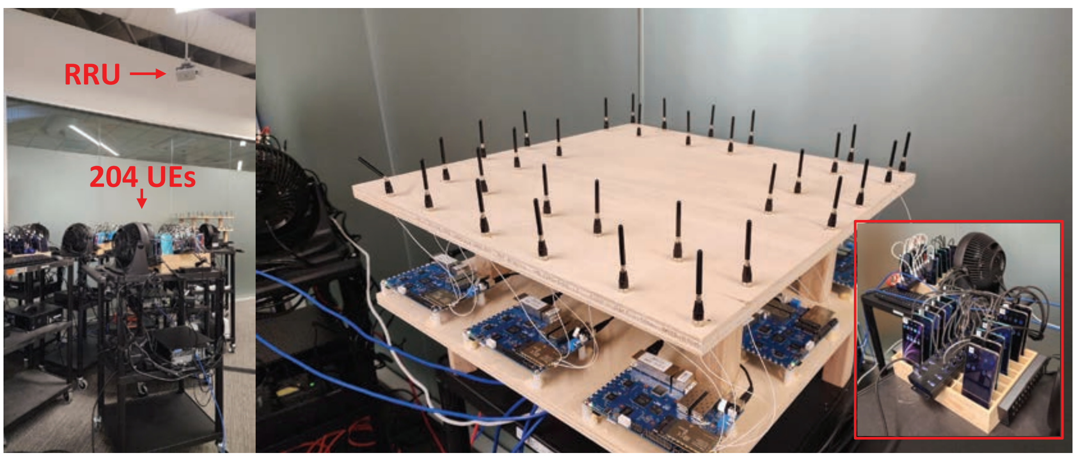
XCOMP is a single cell network.

XCOMP delivers superior downlink and uplink capacity with bidirectional data traffic

In most of our tests, we leveraged RRUs deployed as part of the XCOMP-enabled network to test the network's performance with XCOMP functionality disabled as well as enabled. We then compared the results between the two configurations to demonstrate the performance gains due to XCOMP. With XCOMP functionality disabled, the network architecture was comparable to traditional DAS (Distributed Antenna System). It wasn't logistically feasible to test directly against a small cell architecture, but we do offer good reasoning for why the XCOMP-enabled network's performance will be much better than a small cell architecture in the use cases we tested.

Figure 2 shows the positioning of carts during one of the tests we conducted as well as the very dense clustering of UEs (modules and smartphones) on the carts. Depending on the test, we used anywhere from 1 to 12 carts that were also repositioned for various tests as described later in this paper.

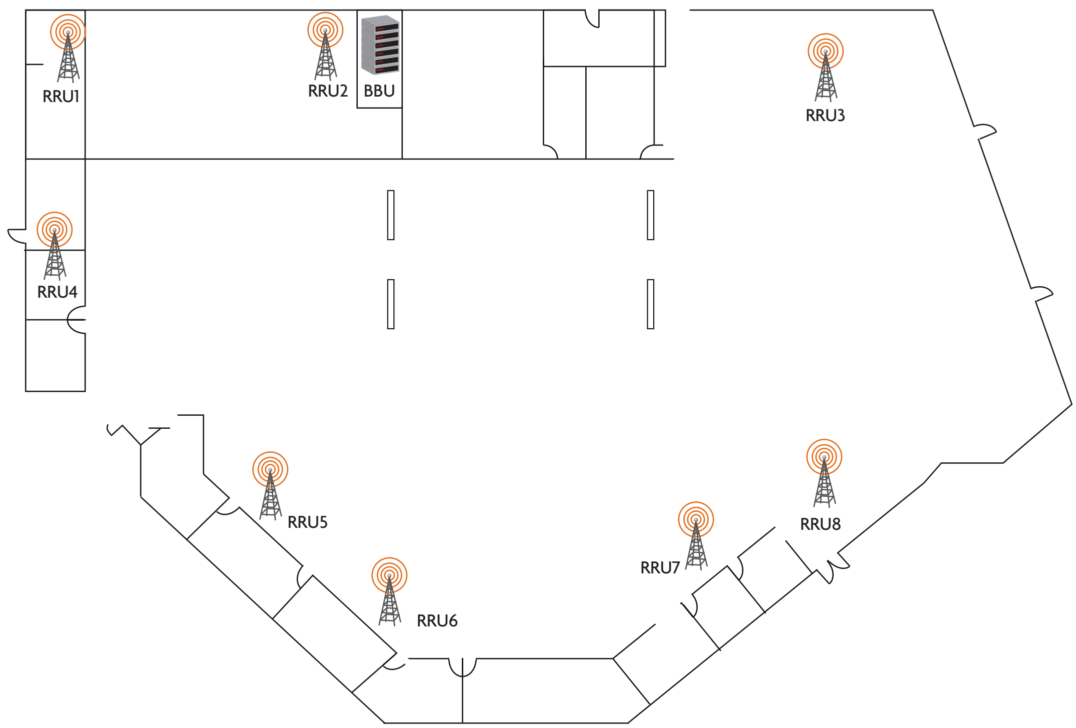
Figure 2. UE Placement



Source: Signals Research Group

Each cart held 12 Android smartphones or 8 modules. Depending on the test, we used anywhere from 1 UE per cart (module or phone) to all 204 UEs on all 12 carts. We also repositioned the carts throughout the lab facilities for some of our tests. Figure 3 shows the placement of the RRUs. The location of the carts with the UEs varied, based upon the test scenario.

Figure 3. Network Diagram

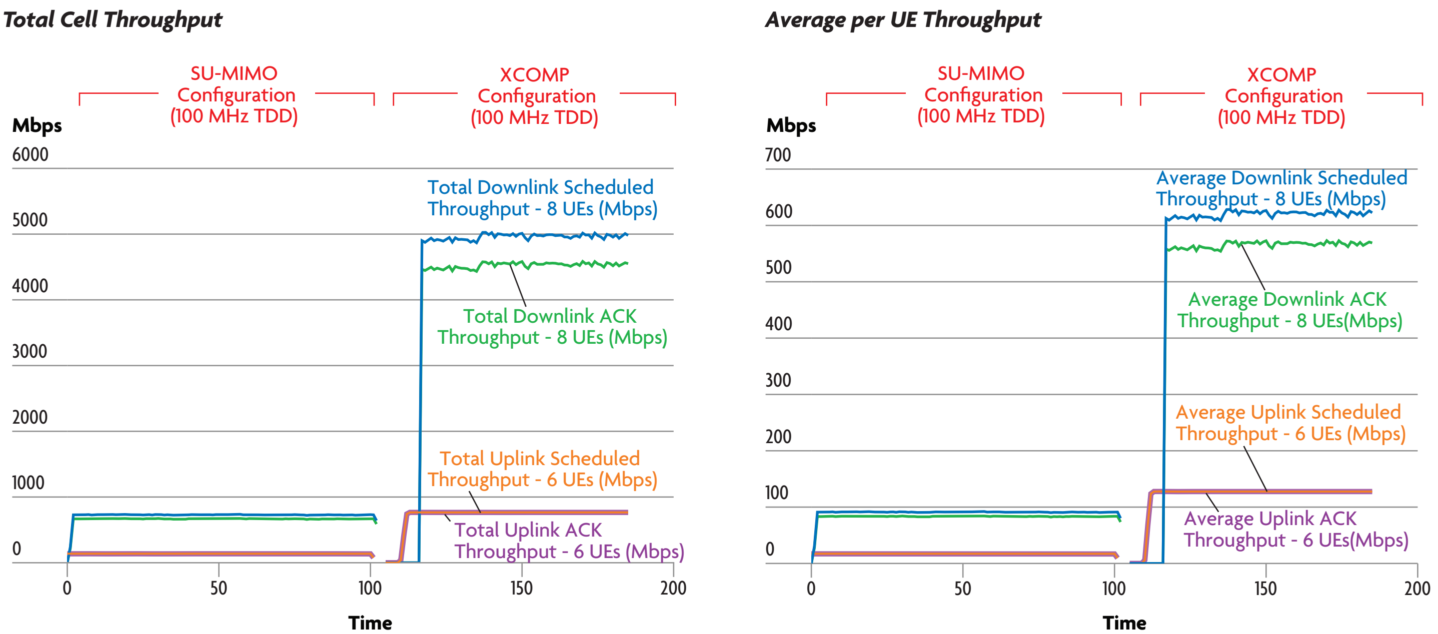


Source: XCOM - Labs (recreated by SRG)

As an initial test, we had a high bit rate bidirectional data stream transferring data to and from one UE on each cart – eight UEs in total. We conducted the test with XCOMP disabled (SU-MIMO) and with XCOMP enabled. For this test the Band n78 channel bandwidth was 100 MHz with a 7/2/1 slot allocation, meaning 70% of the bandwidth was allocated to the downlink direction, 20% to the uplink direction, and 10% for the special slot/guard band.

Figure 4 shows the downlink and uplink throughput during the tests with the two network configurations. The left figure shows the total throughput, and the right figure shows the average throughput for each UE in the network. The figure includes acknowledged (ACK) throughput, or the confirmed throughput at the receive end of the transmission, as well as scheduled throughput, or the origination throughput at either the UE (uplink) or cell site (downlink).

Figure 4. Bidirectional Throughput with 8 Distributed UEs – SU-MIMO and XCOMP Configurations

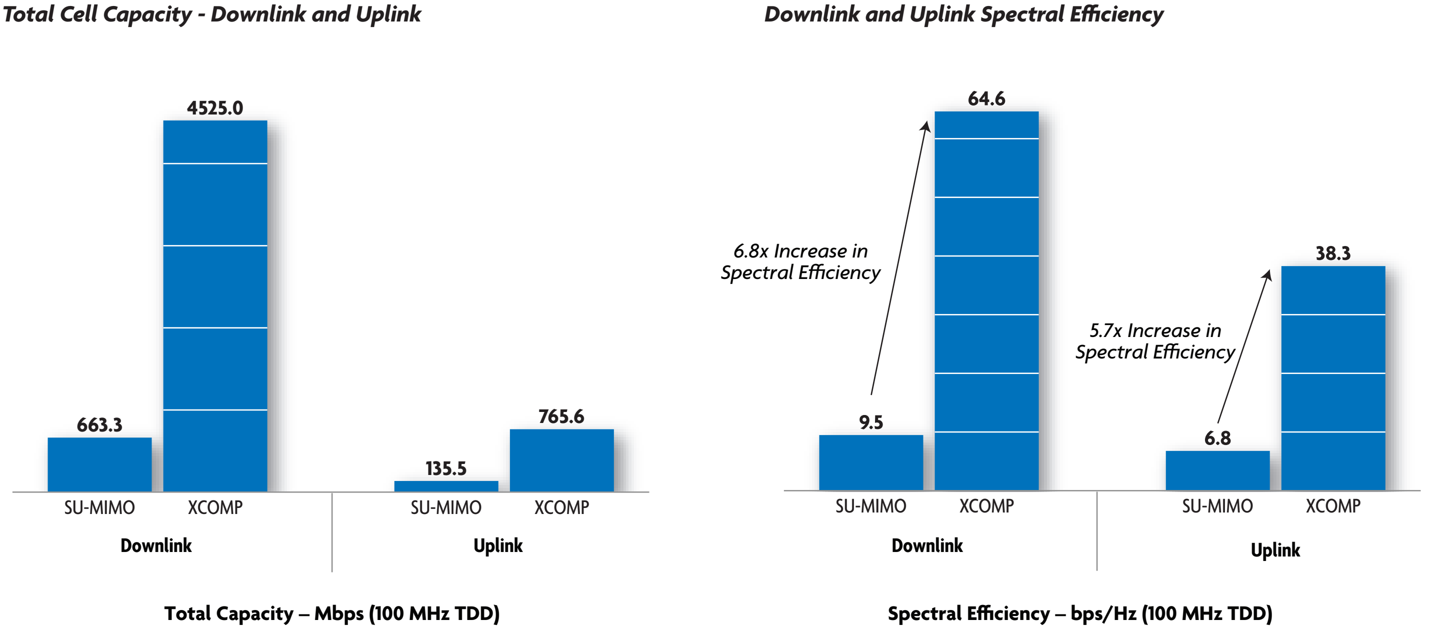


Source: Signals Research Group

As shown in Figure 5, the downlink capacity with XCOMP enabled was over 4.5 Gbps and the uplink capacity was 765.6 Mbps. For the 100 MHz channel, this capacity equated to a downlink spectral efficiency of 64.6 bps/Hz (6.8x increase over SU-MIMO) and an uplink spectral efficiency of 38.3 bps/Hz (5.7x increase over SU-MIMO). As shown in a subsequent figure, the devices were limited to MIMO Rank 2 in the downlink. With MIMO Rank 4 enabled on the devices, the downlink capacity with SU-MIMO could have been up to twice as high as shown in the figure. However, with many of the more demanding tests that we conducted it isn't clear if increasing the total number of possible MIMO layers would have benefited overall performance.

The downlink capacity with XCOMP enabled was over 4.5 Gbps (64.6 bps/Hz) and the uplink capacity was 765.6 Mbps (38.3 bps/Hz).

Figure 5. Bidirectional Capacity and Spectral Efficiency with 8 Distributed UEs – SU-MIMO and XCOMP Configurations

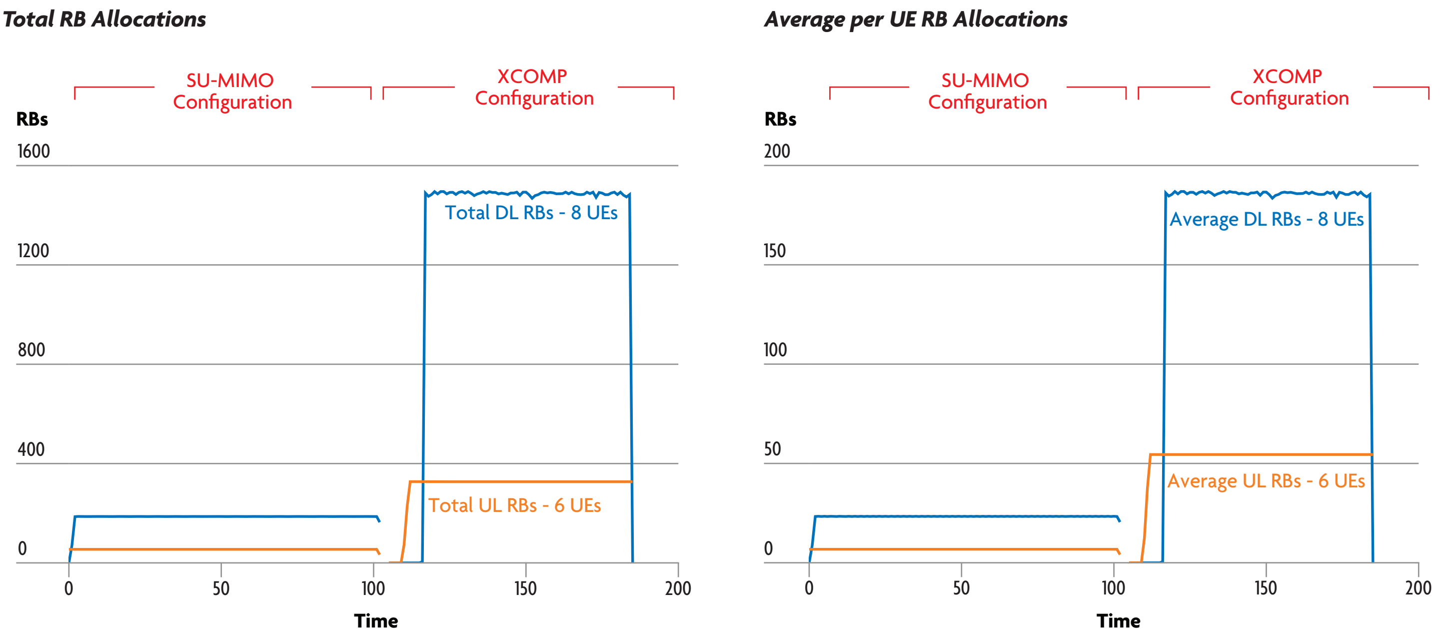


Source: Signals Research Group

The next group of figures explains the significant gains in bidirectional throughput due to XCOMP. First, XCOMP allowed the network to reuse network resources (Resource Blocks) in both directions. Since each RB carries a data payload, reusing an RB to simultaneously schedule other UEs inherently increases the total throughput of the network without consuming any additional network resources. Figure 6 shows the downlink and uplink RB allocations during the test with the two network configurations and Figure 7 provides the average values for the two tests.

When calculating the RBs shown in these figures and in subsequent figures throughout this paper, we took into consideration the total number of RBs, as well as the number of slots reserved for downlink and uplink data traffic. In effect, if the network allocated all possible RBs then with a 7/2/1 slot ratio, 70% of the total RBs are PDSCH RBs and 20% of the total RBs are PUSCH RBs.

Figure 6. Downlink and Uplink Resource Block Allocations with 8 Distributed UEs – SU-MIMO and XCOMP Configurations

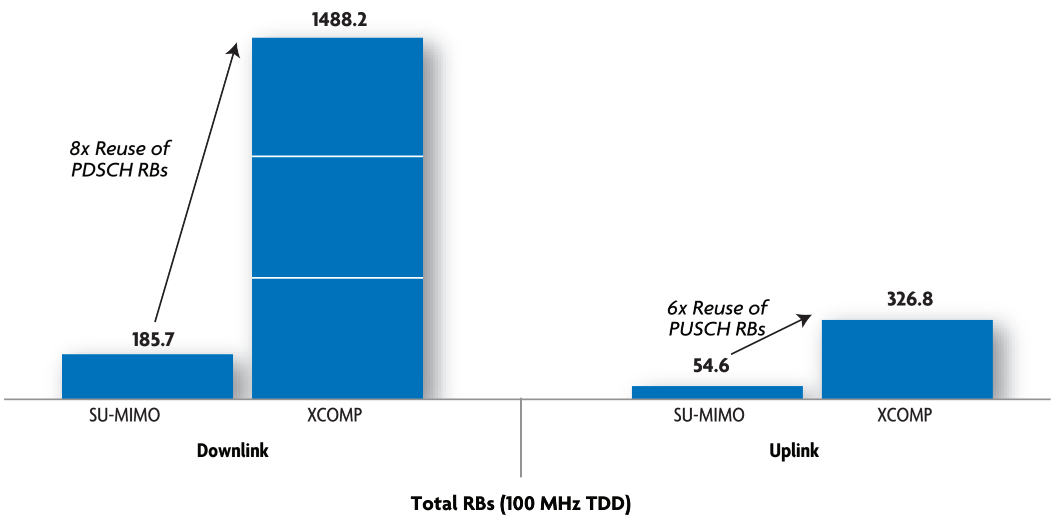


Source: Signals Research Group

XCOMP increased the RB reuse by 8x in the downlink direction and by 6x in the uplink. The XCOMP-enabled DU schedules up to 8 UEs in a single slot, hence the 8x increase in PDSCH RBs suggests a perfect reuse of the downlink RBs. As configured, XCOMP supported up to 12 uplink MIMO layers, and since the UEs were configured to support MIMO Rank 2, the reuse of PUSCH RBs was limited by the number of concurrent MIMO layers, hence the uplink reuse of RBs was "only" 6x.

XCOMP increased the RB reuse by 8x in the downlink direction and by 6x in the uplink direction.

Figure 7. Average Downlink and Uplink Resource Block Allocations with Distributed UEs – SU-MIMO and XCOMP Configurations

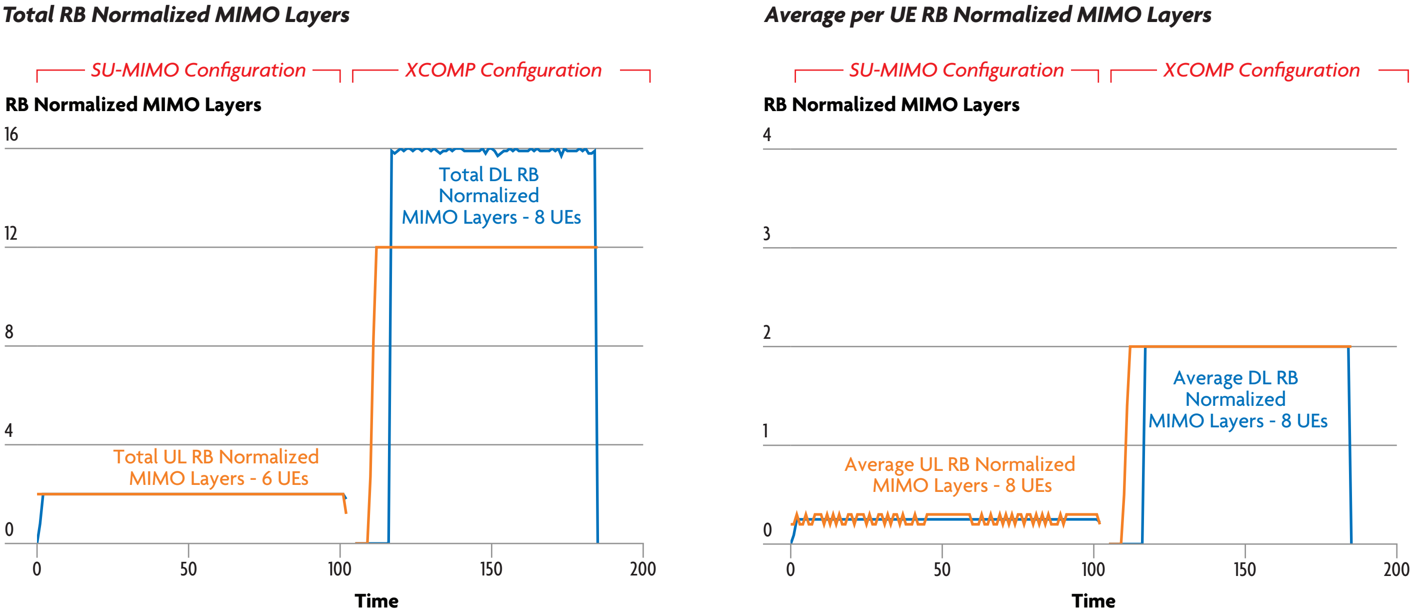


Source: Signals Research Group

Another factor that impacts capacity is the number of MIMO layers. With this test configuration and 8 devices, XCOMP was capable of delivering up to 16 MIMO layers in the downlink and up to 12 MIMO layers in the uplink direction. As shown in Figure 8 and Figure 9, the results were close to perfect, with an average of 15.7 RB normalized MIMO layers in the downlink direction and an average of 12 RB normalized MIMO layers in the uplink direction.

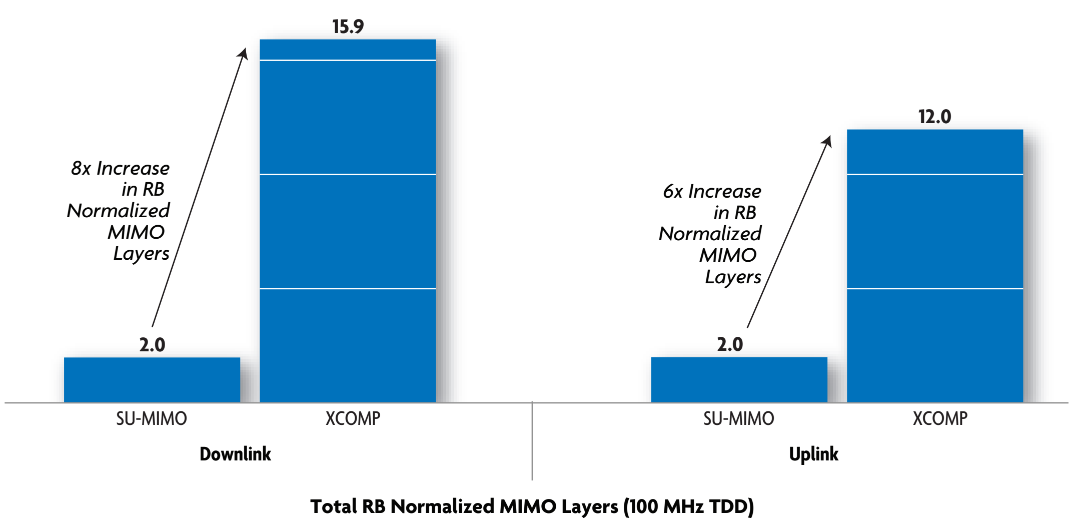
We use the term "RB Normalized MIMO Layers" throughout this paper as it is a term that we always use in our benchmark studies. When calculating the total number of MIMO layers for each device, we adjusted its reported number of MIMO layers by the total number of possible RBs. For example, if a device reported 2 MIMO layers but it only used 50% of the possible MIMO layers then its RB Normalized MIMO layer count would be 1 layer (2 layers x 0.5 = 1 layer). Put another way, achieving 16 MIMO layers means all possible RBs were being scheduled all the time with each RB using 2 MIMO layers.

Figure 8. Downlink and Uplink RB Normalized MIMO Layers with 8 Distributed UEs – SU-MIMO and XCOMP Configurations



Source: Signals Research Group

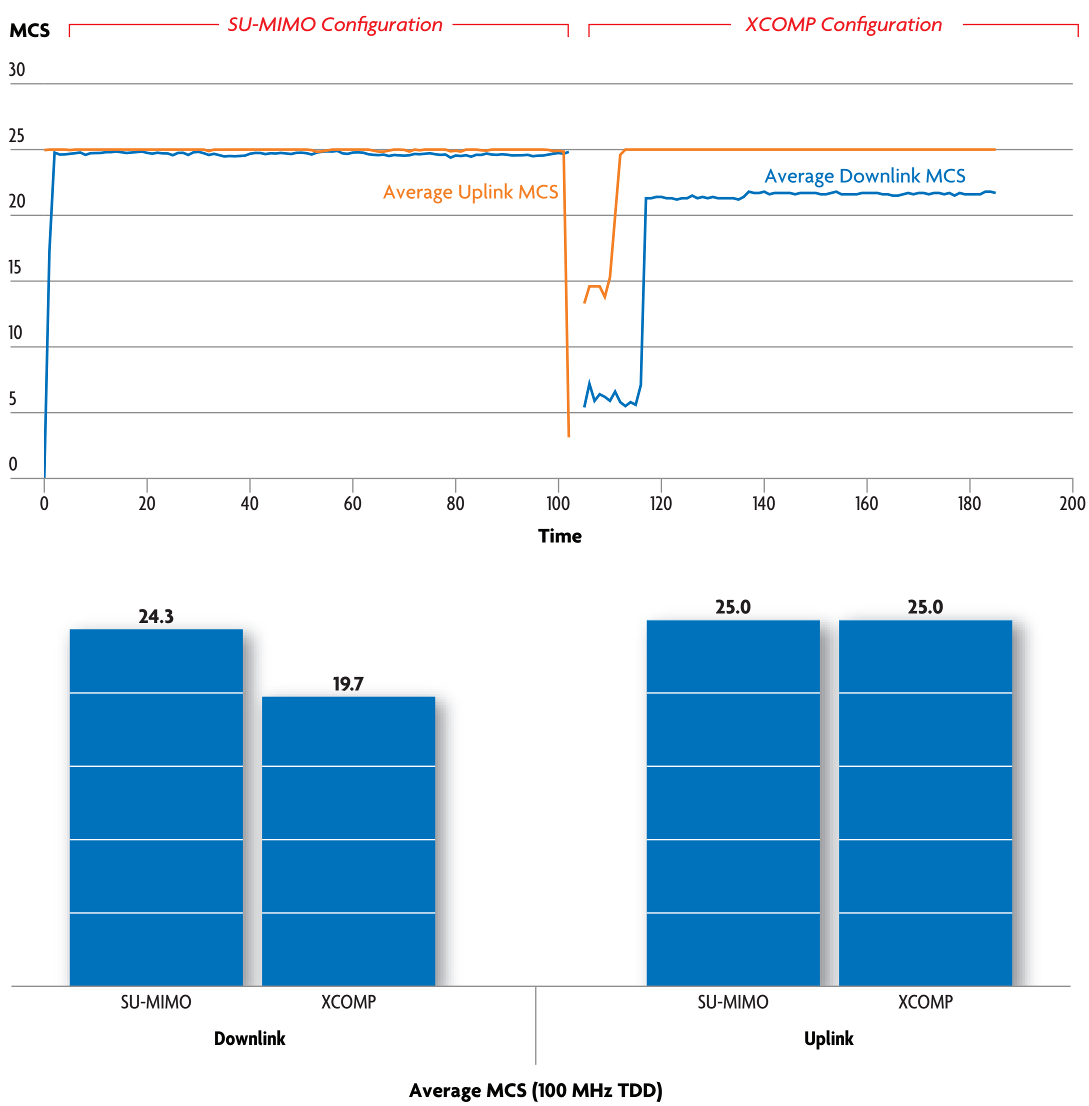
Figure 9. Average Downlink and Uplink RB Normalized MIMO Layers with Distributed UEs – SU-MIMO and XCOMP Configurations



Source: Signals Research Group

The last variable which influences throughput and spectral efficiency is the MCS, or Modulation and Coding Scheme. Readers that are familiar with MCS know that an MCS value equates to a certain data payload that can be determined from tables published in 3GPP 5G specifications, with higher MCS values equating to higher payloads. Figure 10 shows the average downlink and uplink MCS values with the two network configurations. With XCOMP enabled, the MCS was lower in the downlink while it was only modestly lower in uplink. Limiting the MIMO layers could have resulted in higher MCS values, but it could have also come at the expense of overall lower throughput.

Figure 10. Average MCS Values with 8 Distributed UEs – SU-MIMO and XCOMP Configurations



Source: Signals Research Group

XCOMP performance is robust and able to support large numbers of devices clustered together

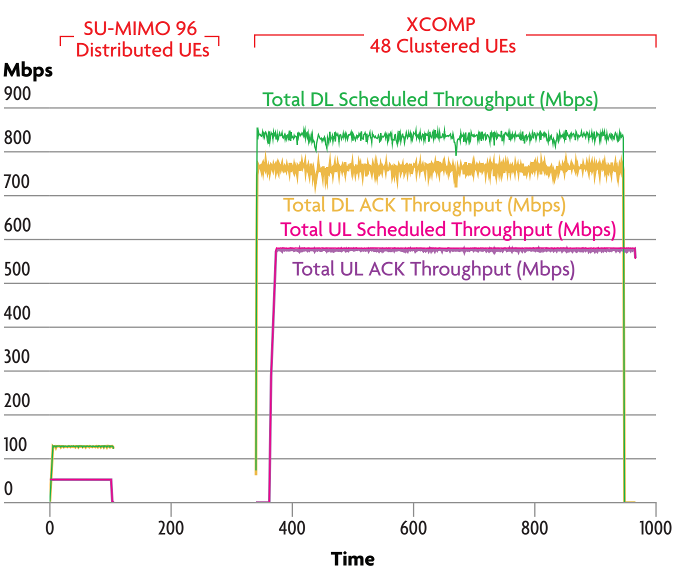
The features of XCOMP are best applicable for addressing the capacity needs of large numbers of UEs, especially UEs that are clustered next to each other. The results in this section demonstrate the benefits of XCOMP for this use case.

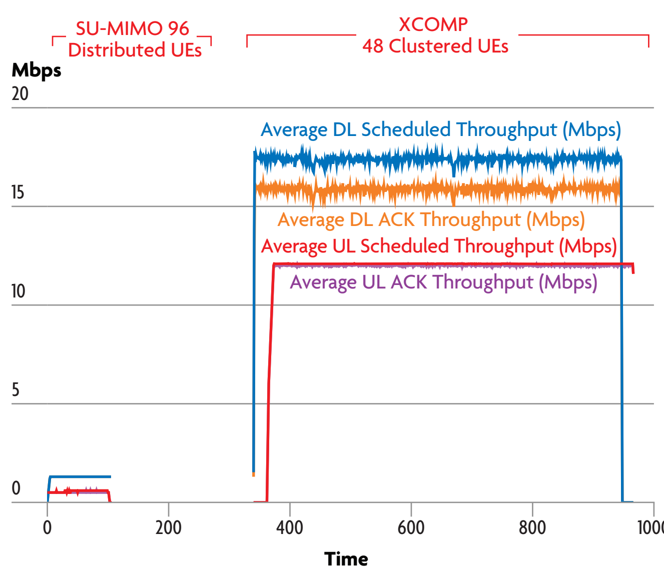
For this first comparative test, we analyzed how XCOMP performed with 48 clustered devices. To achieve this scenario, we pushed 8 carts next to each other, resulting in a total of 48 devices located next to each other. The location of the 8 collocated carts was somewhat random, but the carts were spaced between several nearby RRUs. We used a separate SU-MIMO test involving 96 UEs spread across the network on 8 carts for comparison purposes, although we note higher throughput might have been possible with SU-MIMO if the network had been configured to support 4 MIMO layers in the downlink and 2 MIMO layers in the uplink.

Figure 11 provides a time series plot of the bidirectional throughput with the two network configurations and device placements. Figure 12 shows the average throughput and spectral efficiency. For this test, and all subsequent tests in this paper, we used a 40 MHz TDD channel in Band n78 with a 5/4/1 slot allocation. Although the slot allocation still favored the downlink direction, it was more biased to the uplink direction than commercial 5G networks. However, this slot allocation can be more practical for industrial applications where there is a greater demand placed on the uplink capacity than the downlink capacity.

These results are based on using a 40 MHz TDD channel with a 5/4/1 slot allocation.

Figure 11. Throughput with Distributed and Clustered UEs – SU-MIMO and XCOMP Configurations





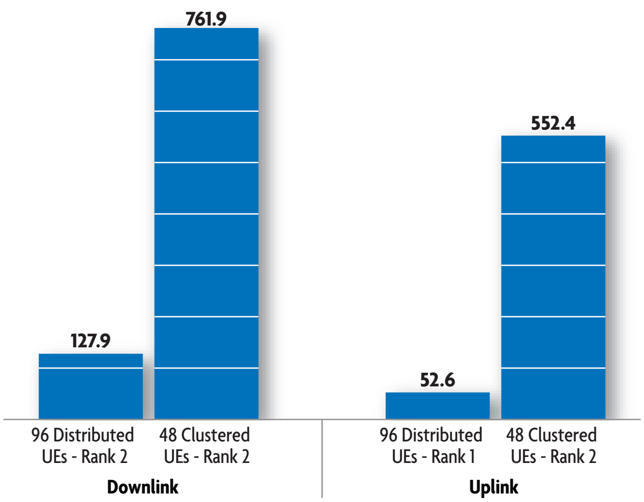
Source: Signals Research Group

As shown in Figure 12, the downlink capacity increased by 6.0x and the uplink capacity increased by 10.5x with XCOMP. It is also important to remind readers that the XCOMP test results also involved 48 UEs that were placed adjacent to each other, presumably making it more difficult to achieve high RB reuse with more MIMO layers. The SU-MIMO results stem from devices that were distributed throughout the network. The results, however, suggest that concentrating the devices in a single area still resulted in very high performance.

With 48 UEs clustered together, XCOMP delivered downlink spectral efficiency of 38.1 bps/Hz and uplink spectral efficiency of 34.5 bps/Hz.

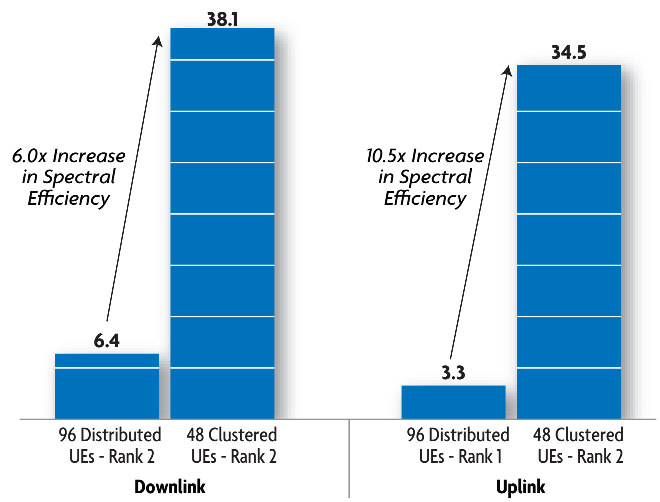
Figure 12. Capacity and Spectral Efficiency with Distributed and Clustered UEs – SU-MIMO and XCOMP Configurations

Total Capacity



Total Capacity – Mbps (40 MHz TDD 5/4/1/ Slot Allocation)

Spectral Efficiency

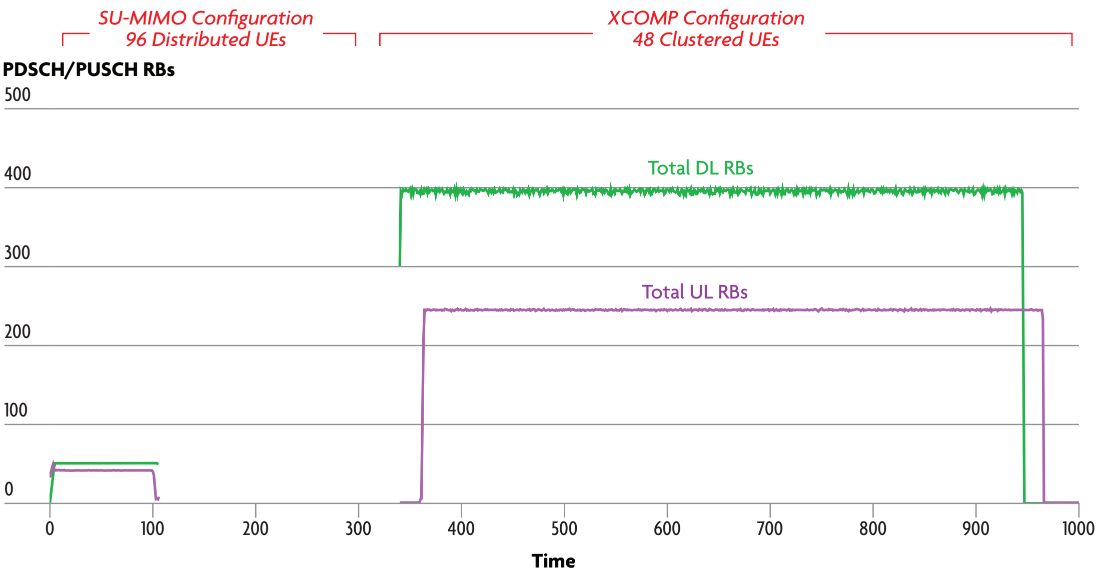


Spectral Efficiency – bps/Hz (40 MHz TDD 5/4/1/ Slot Allocation)

Source: Signals Research Group

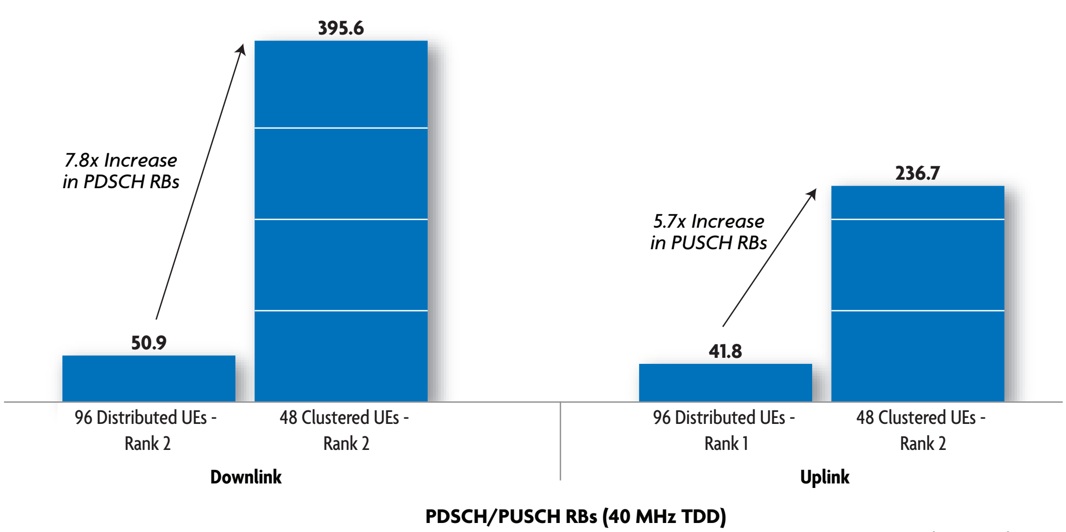
Consistent with the earlier test results, the increase in throughput was due to a combination of high reuse of network resources (RBs) and an increase in the number of RB normalized MIMO layers. Figure 13 (time series) and Figure 14 (averages) show the downlink and uplink RB allocations for the two test scenarios. With XCOMP, the PDSCH RBs were reused 7.8x times and the total uplink PUSCH RBs were reused 5.7x times, compared with SU-MIMO.

Figure 13. Resource Block Allocations with Distributed and Clustered UEs – SU-MIMO and XCOMP Configurations



Source: Signals Research Group

Figure 14. Average Resource Block Allocations with 8 Distributed UEs – SU-MIMO and XCOMP Configurations

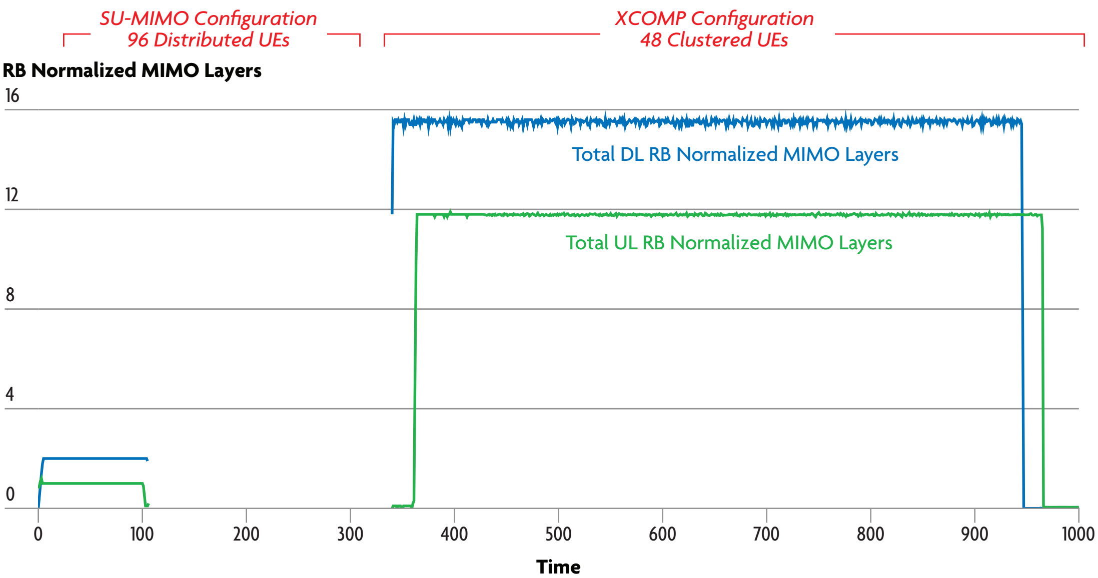


Source: Signals Research Group

In addition to high reuse of network resource blocks, the RB normalized MIMO layers increased, as shown in Figure 15 and Figure 16. Of note, despite 48 UEs located next to each other on 8 adjacent carts, XCOMP delivered close to the theoretical maximum number of RB normalized MIMO layers, or 15.5 layers in the downlink direction and 11.4 layers in the uplink direction.

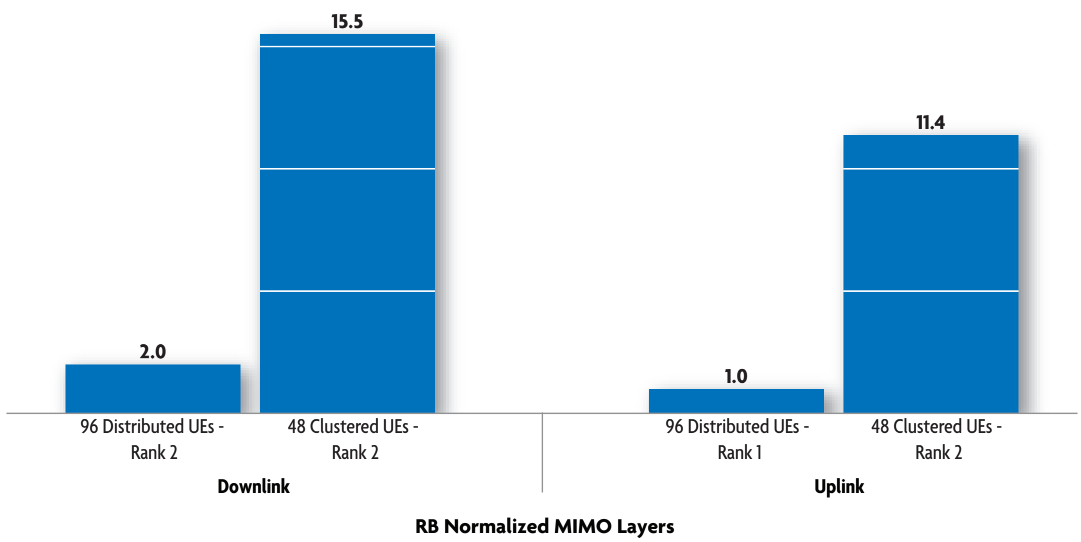
With 48 devices adjacent to each other, XCOMP still delivered close to the theoretical maximum number of RB normalized MIMO layers in both directions.

Figure 15. RB Normalized MIMO Layers with Distributed and Clustered UEs – SU-MIMO and XCOMP Configurations



Source: Signals Research Group

Figure 16. Average RB Normalized MIMO Layers with Distributed and Clustered UEs – SU-MIMO and XCOMP Configurations



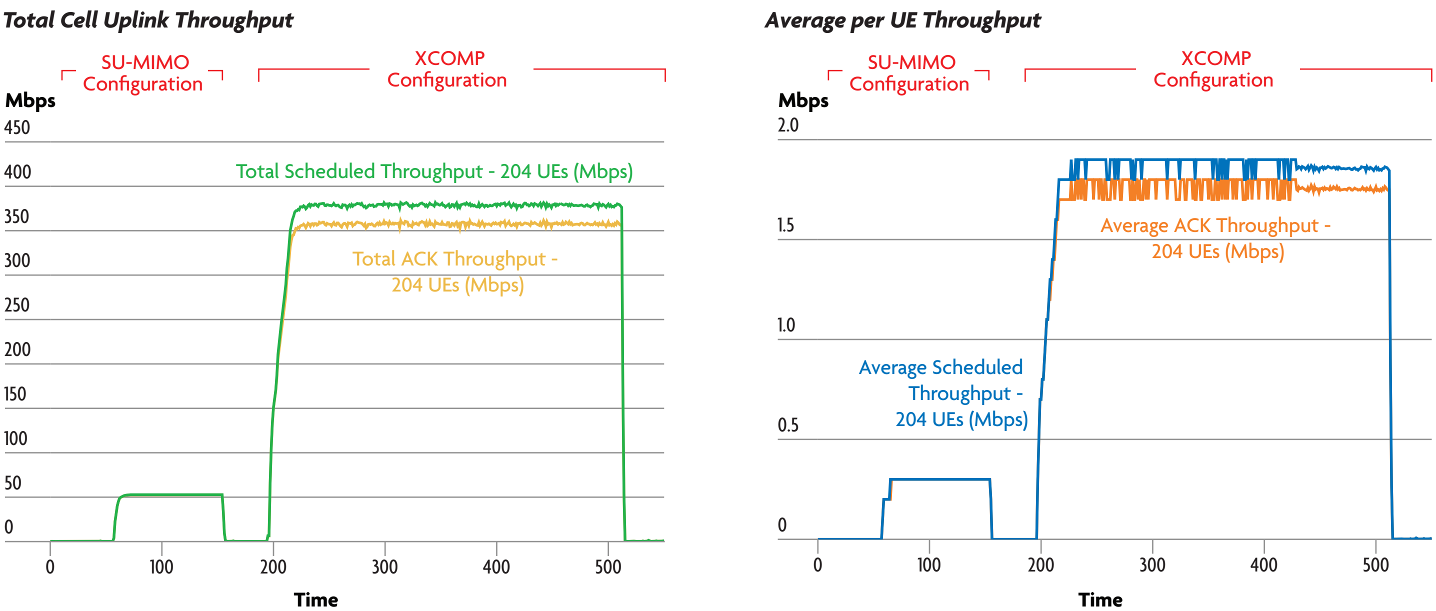
Source: Signals Research Group

Uplink Test with 204 UEs

We next placed 204 devices, including a mix of modules and smartphones, directly under a single RRU to evaluate how XCOMP performed under an extreme use case. We did an uplink test with this configuration since the uplink direction is frequently more important in networks supporting factories and warehouses.

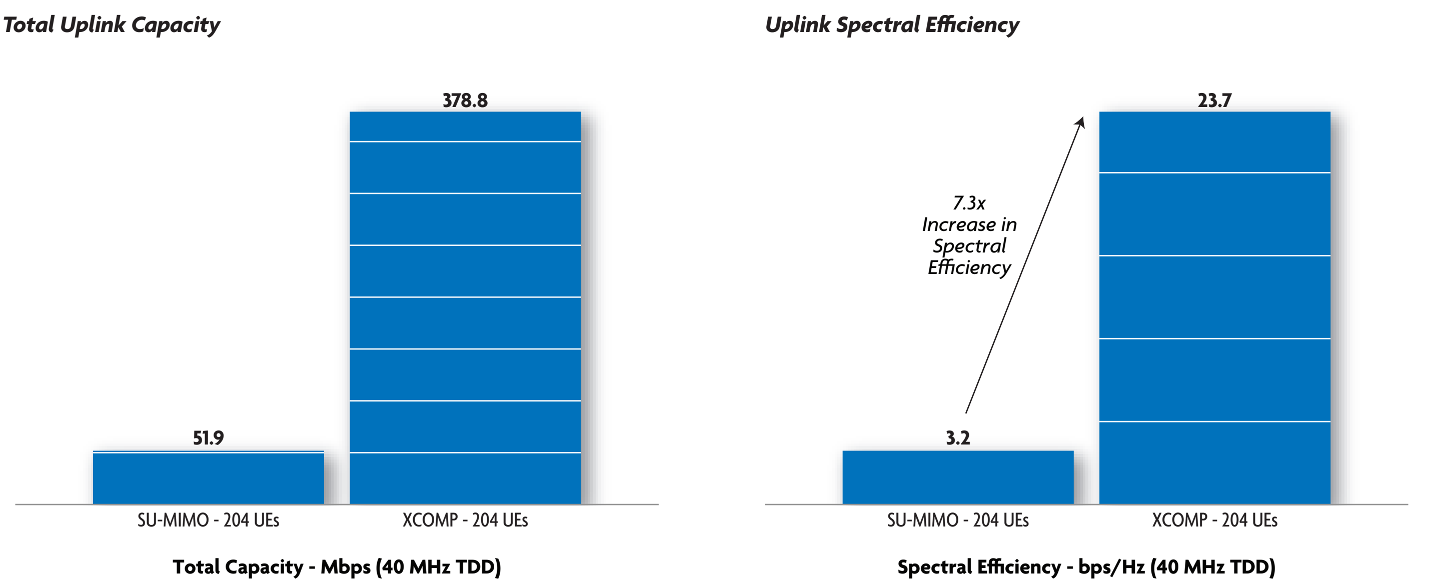
Compared with SU-MIMO, the uplink throughput increased by 7.3x with XCOMP to deliver an uplink spectral efficiency of 23.7 bps/Hz, even more impressive considering the 204 devices were confined to 12 adjacent carts. Figure 17 and Figure 18 show the uplink throughput from this series of tests.

Figure 17. Uplink Throughput with 204 Collocated UEs – SU-MIMO and XCOMP Configurations



Source: Signals Research Group

Figure 18. Uplink Capacity and Spectral Efficiency with 204 Collocated UEs – SU-MIMO and XCOMP Configurations

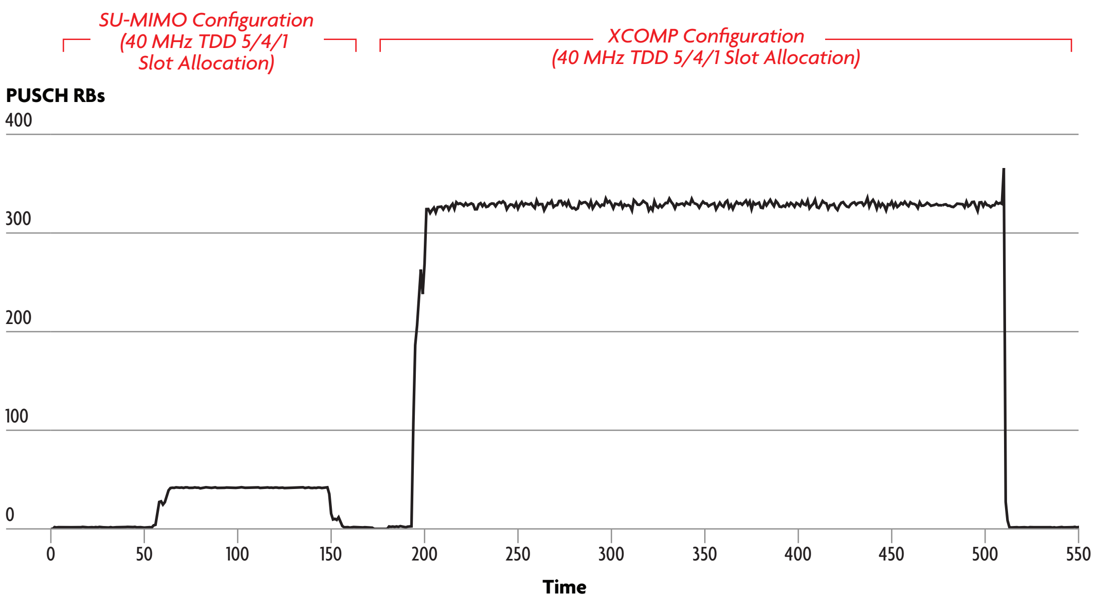


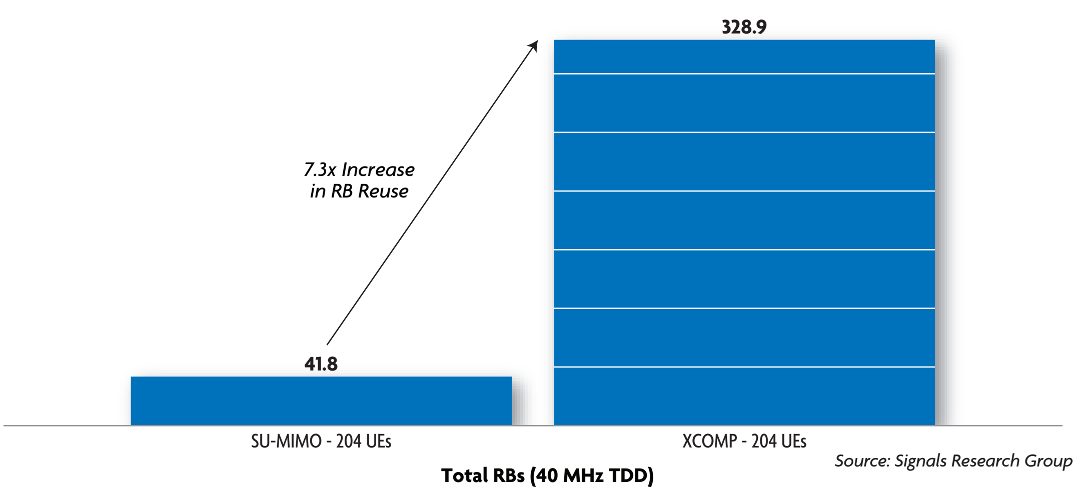
Source: Signals Research Group

Uplink Test with 204 UEs

As one might expect, the higher uplink throughput was due to a combination of high RB reuse and more uplink MIMO layers. In this test, the RB reuse was 7.9x higher than possible with SU-MIMO and the RB normalized MIMO layer count was 7.9 MIMO layers. In this test the devices were limited to a single MIMO layer in the uplink direction since the smartphones could only support a single uplink layer. Since the XCOMP DU schedules 8 UEs in a single slot and each UE was only supporting a single uplink MIMO layer, the total uplink MIMO layer count was configured for 8 layers. Figure 19 shows the uplink RB allocations for the two network configurations and Figure 20 provides the total number of uplink MIMO layers.

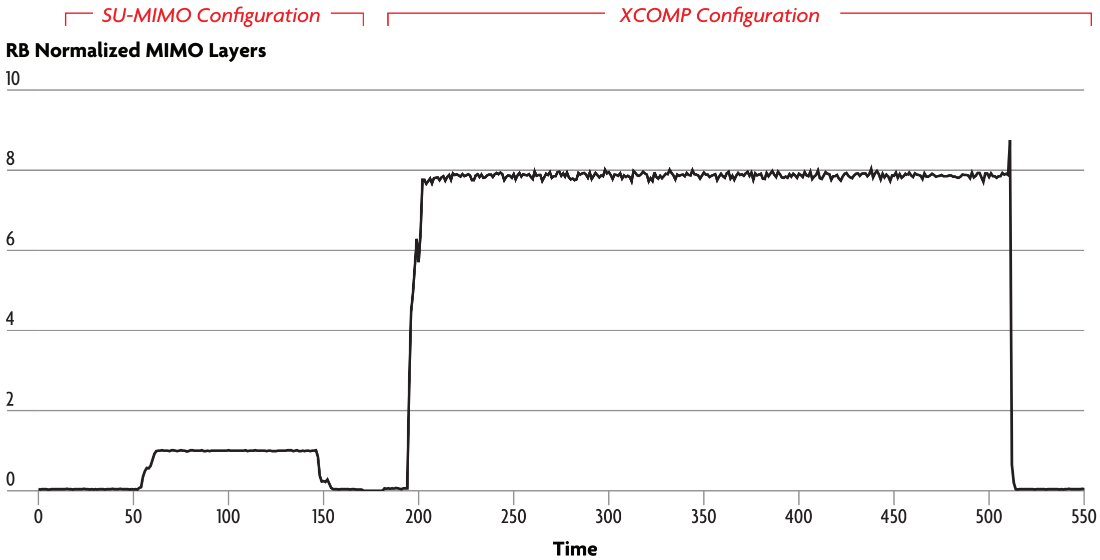
Figure 19. Uplink Resource Block Allocations with 204 Collocated UEs – SU-MIMO and XCOMP Configurations

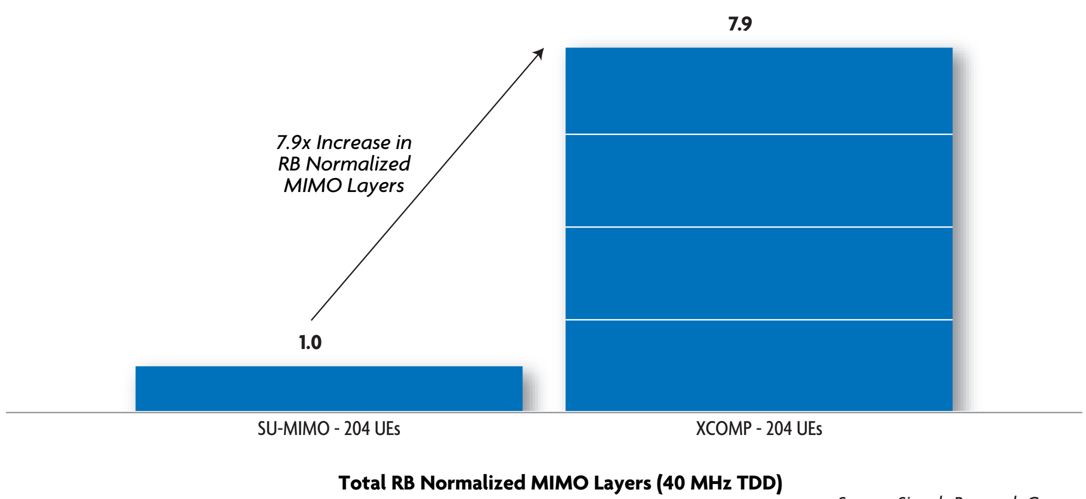




Source: Signals Research Group

Figure 20. RB Normalized MIMO Layers with 204 Collocated UEs – SU-MIMO and XCOMP Configurations

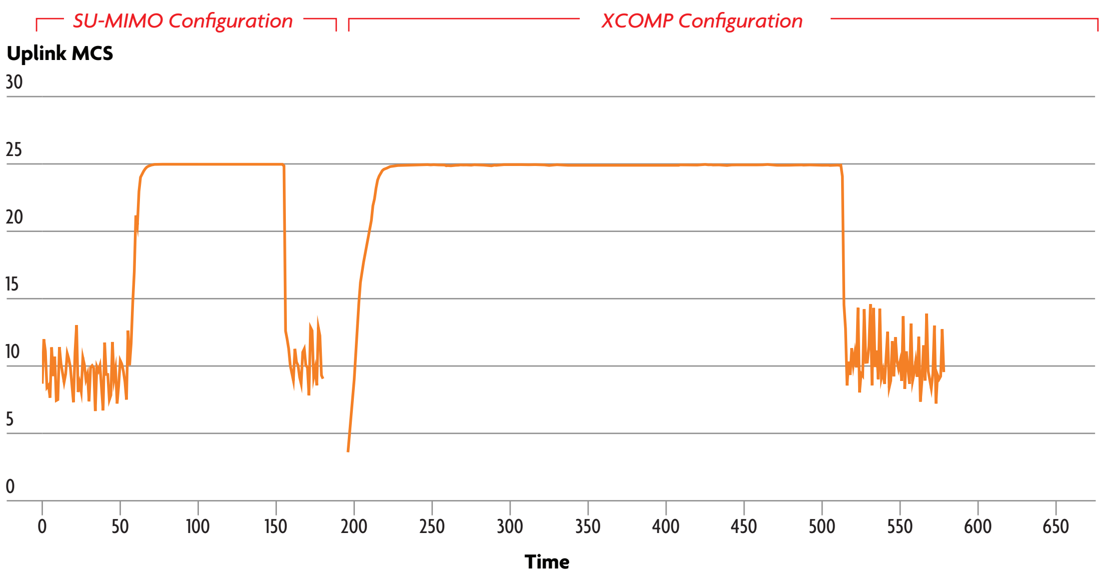


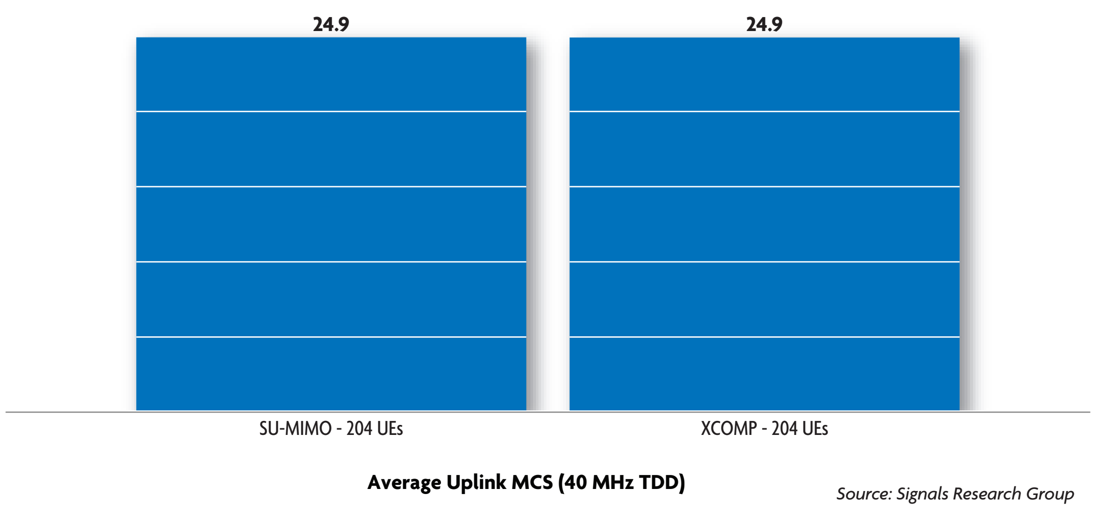


Source: Signals Research Group

With both network configurations the uplink MCS values remained unchanged, despite the nearly perfect reuse of uplink RBs and available MIMO layers. The average MCS with SU-MIMO and XCOMP was 24.9, as shown in Figure 21.

Figure 21. Average MCS Values with 204 Collocated UEs – SU-MIMO and XCOMP Configurations





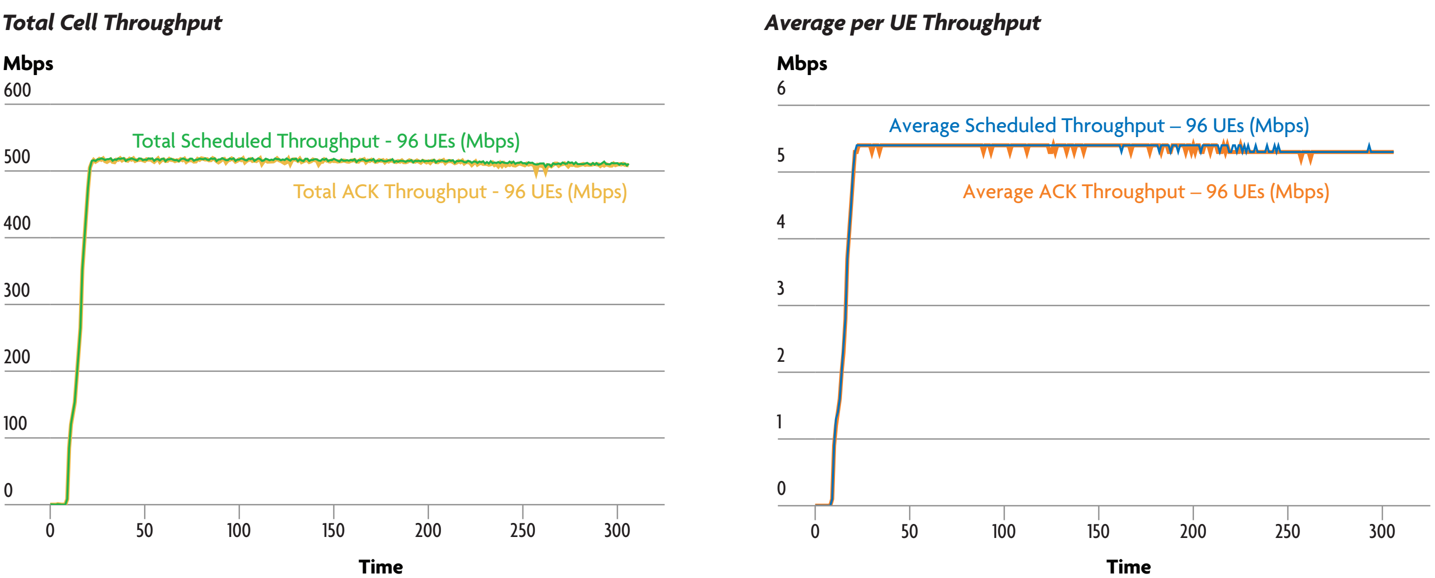
Source: Signals Research Group

Downlink Test with 96 UEs

Although perhaps less interesting given the earlier results, we are including one more set of results in this section from another test that we conducted as part of this study. In this test, we used 8 modules on each of the 12 carts, or 96 total UEs. The 12 carts were distributed throughout the network as shown in Figure 2. The modules were also restricted to a single downlink MIMO layer, which helps improve overall performance when there is a large number of devices. We once again used a 40 MHz TDD channel with a 5/4/1/ slot allocation. Readers can also compare these XCOMP results with the results shown SU-MIMO results provided in Figures 11 through 16.

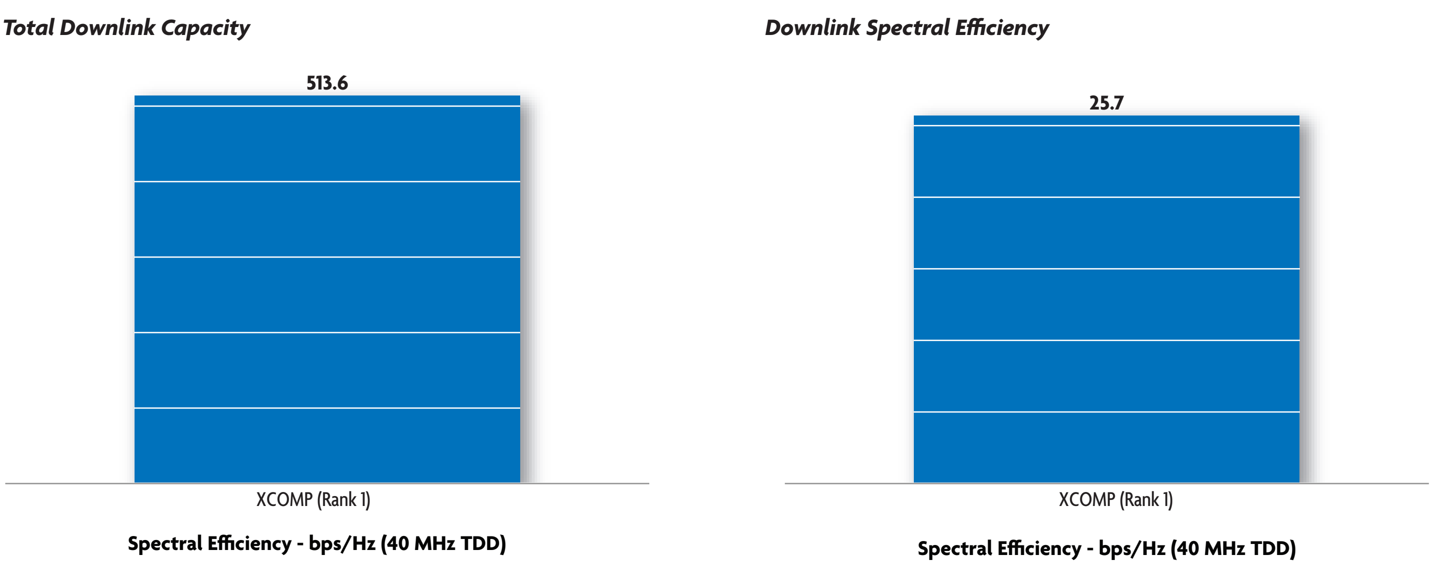
In this test, the total downlink throughput was 513.6 Mbps, resulting in a spectral efficiency of 25.7 bps/Hz. Figure 22 and Figure 23 support this statement.

Figure 22. Downlink Throughput with 96 Distributed UEs – XCOMP



Source: Signals Research Group

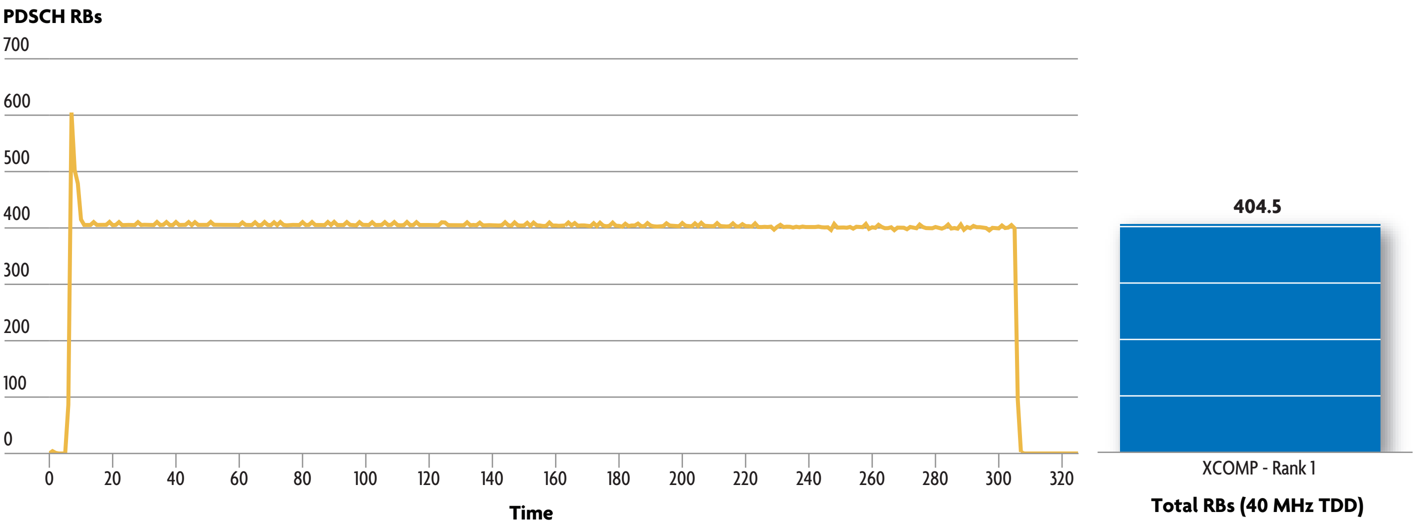
Figure 23. Downlink Capacity and Spectral Efficiency with 96 Distributed UEs – XCOMP



Source: Signals Research Group

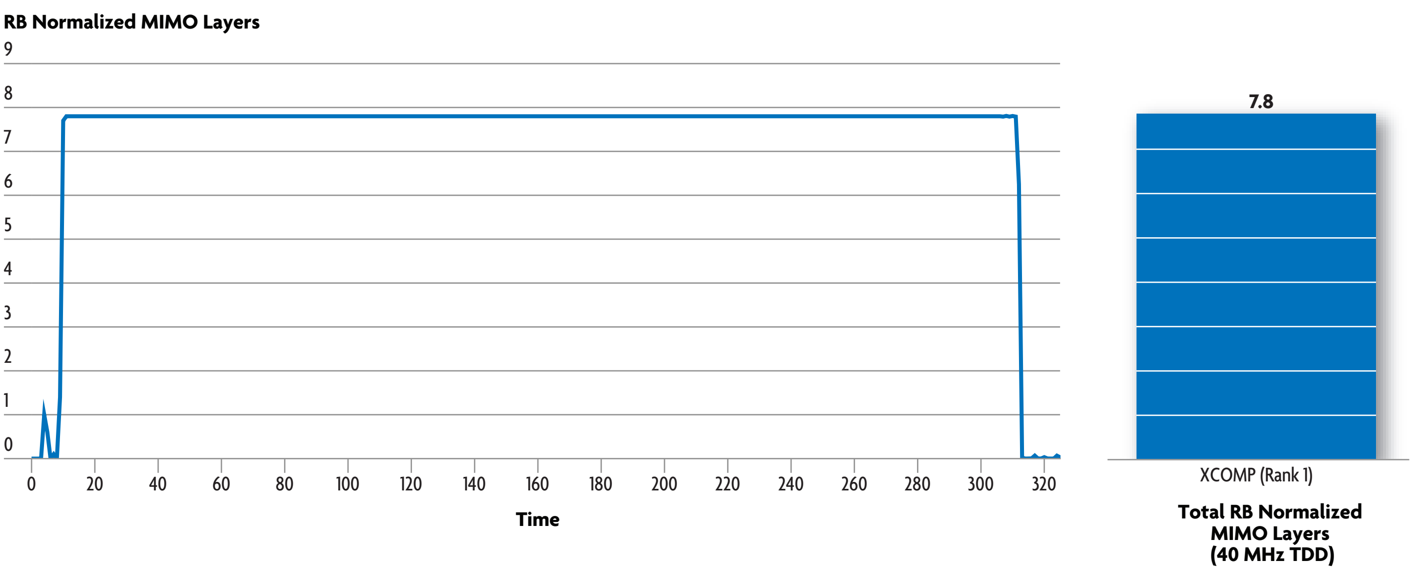
During this test, the RB reuse was near perfect, as was the total number of MIMO layers. With the modules restricted to a single downlink MIMO layer, the best possible outcome was 8 layers. Although not shown in this paper, the average MCS was 25. Figure 24 provides the information regarding the PDSCH RBs and Figure 25 shows the MIMO layers during this test.

Figure 24. Downlink Resource Block Allocations with 96 Distributed UEs –XCOMP



Source: Signals Research Group

Figure 25. RB Normalized MIMO Layers with 96 Distributed UEs – XCOMP



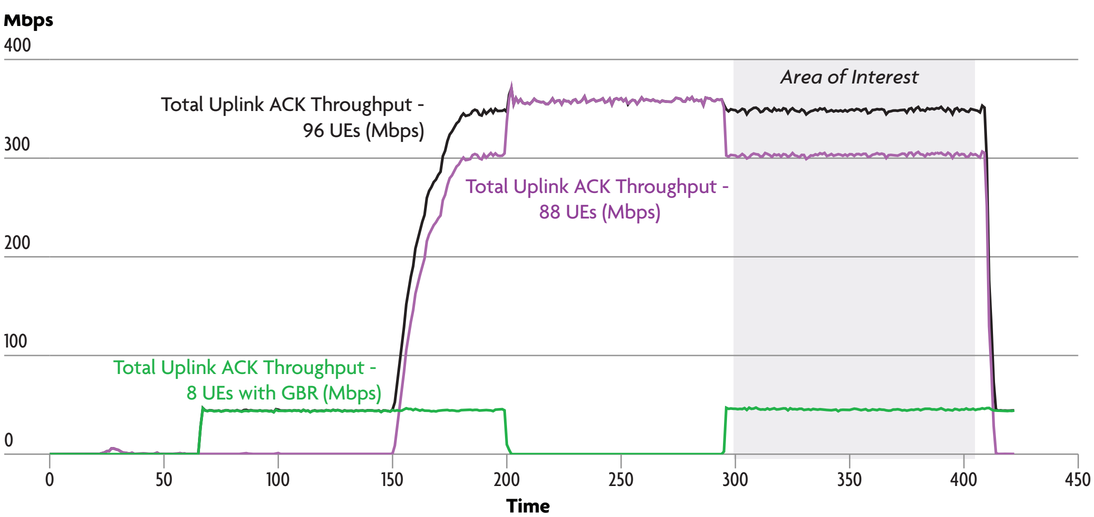
Source: Signals Research Group

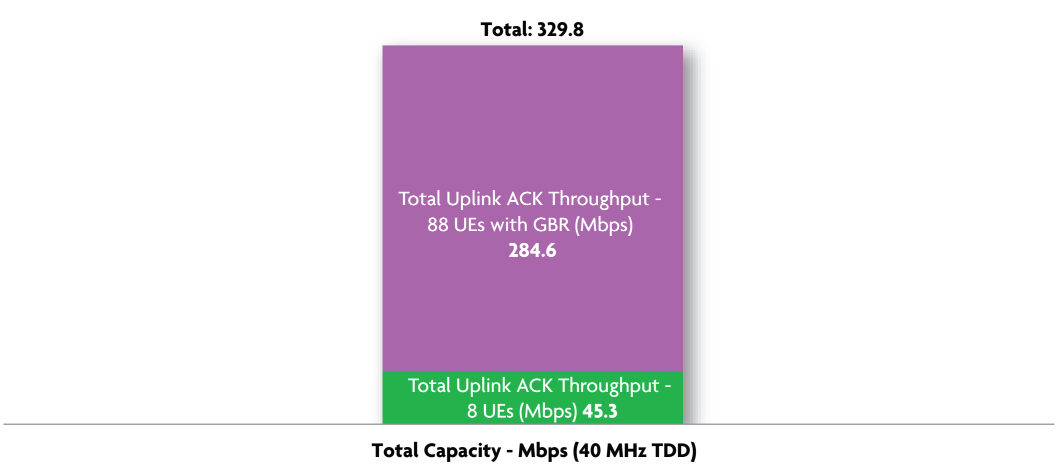
XCOMP achieved these results while also supporting prioritized traffic flows involving GBR

We also did an exploratory test involving 96 devices, of which 8 devices were assigned a guaranteed bi-directional bit rate (GBR) of 5 Mbps at the application layer while the remaining 88 devices used best effort. For this test, we used 8 devices on each cart with the distribution of carts documented in Figure 2. The network (40 MHz TDD, 5/4/1 slot allocation) was configured to support SU-MIMO in the downlink and XCOMP in the uplink. In order to avoid any confusion and since this benchmark study was focused on the performance of XCOMP, we are only showing the results for the uplink direction. We point out the GBR was also maintained in the downlink direction, although given the limitations of SU-MIMO, the total throughput was relatively low compared to what it would have been with XCOMP.

In this test, we first started the data transfer sessions to the 8 devices with the 5 Mbps GBR (~60 to ~75 seconds) and then switched the data transfer sessions to the other 88 devices. Finally, we had data transfers occurring with all 96 devices – labeled "Area of Interest" in the following figures. Figure 26 shows the total uplink throughput as well as the combined throughput for both sets of devices. The figures show that the network successfully provided 5 Mbps in the uplink direction to the 8 phones with the GBR, while allocating the remaining bandwidth to the 88 other phones on a best effort basis.

Figure 26. Total Uplink Throughput with 96 UEs – 8 UEs with GBR and 88 UEs with Best Effort

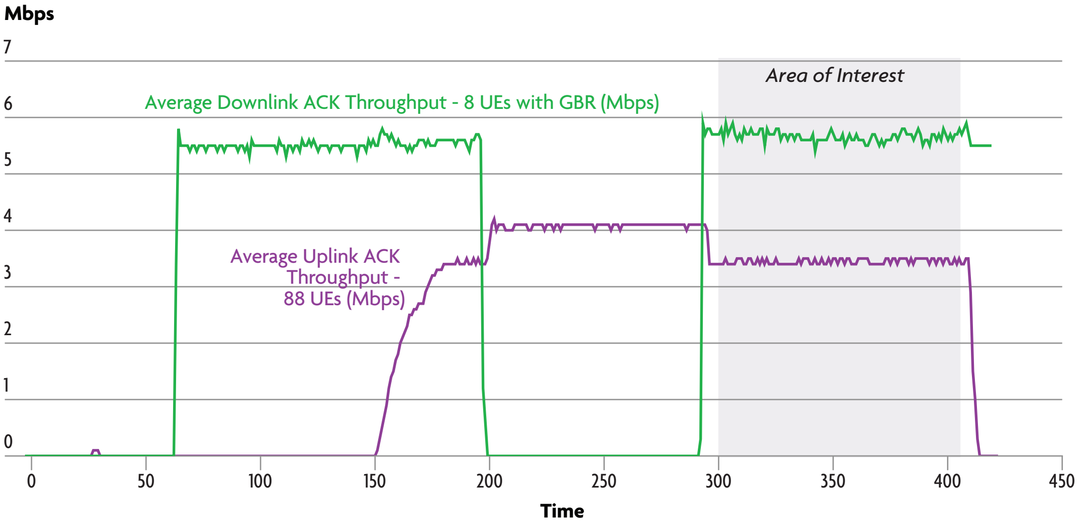


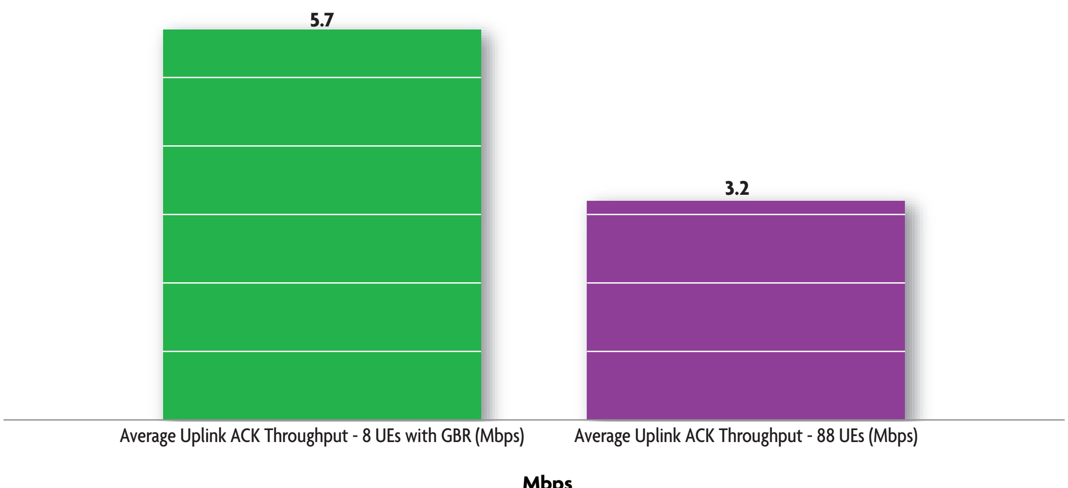


Source: Signals Research Group

Figure 27 shows the same basic information, albeit based for the average uplink throughput for each device in the two groups.

Figure 27. Average Uplink Throughput with 96 UEs – 8 UEs with GBR and 88 UEs with Best Effort

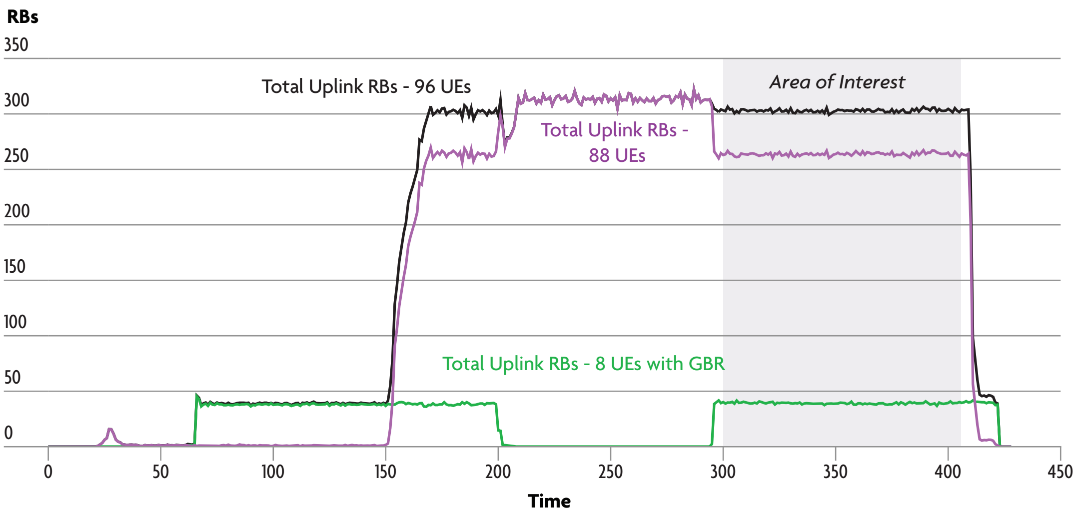


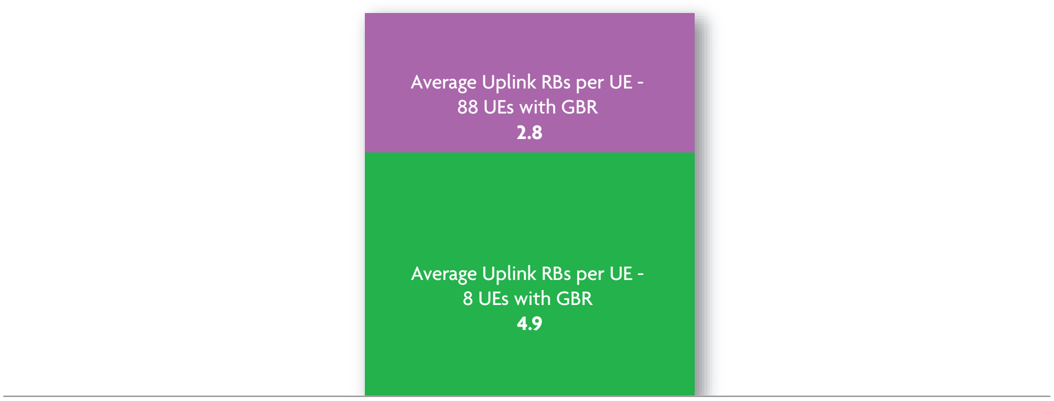


Source: Signals Research Group

The network sustained the GBR to the eight devices by allocating those devices more network resources (RBs), which subsequently increased their RB normalized MIMO layers. Figure 28 shows the average number of RB allocations on a per UE basis for both sets of phones and Figure 29 provides the information for the RB normalized MIMO layers. With both parameters, the network biased the allocation of resources to ensure the GBR was maintained, despite the concurrent data traffic associated with the additional 88 UEs.

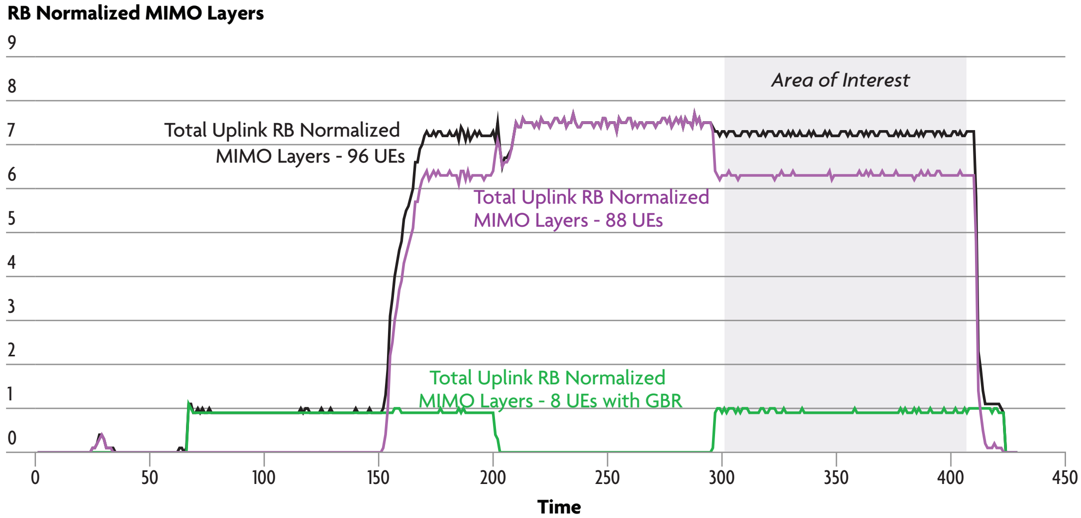
Figure 28. Total Downlink and Uplink RBs with 96 UEs – 8 UEs with GBR and 88 UEs with Best Effort

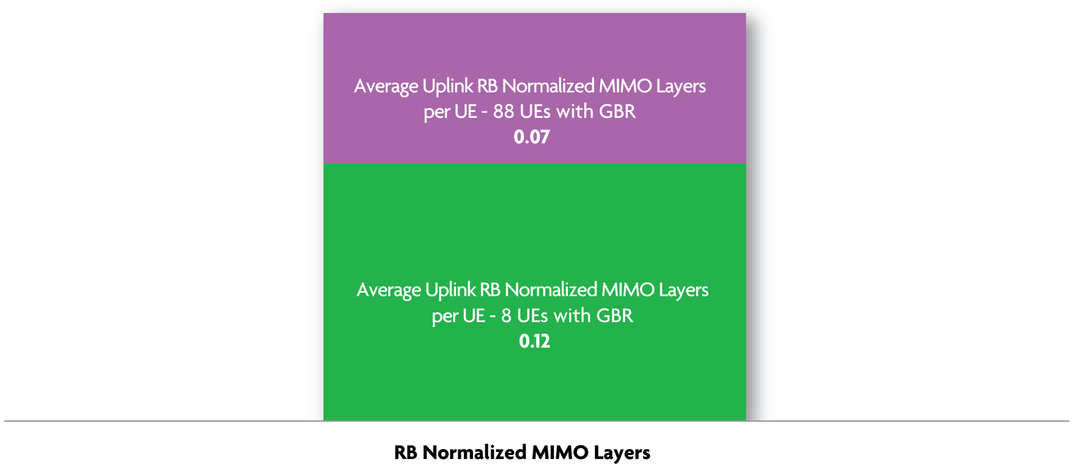




Source: Signals Research Group

Figure 29. Total Downlink and Uplink RB Normalized MIMO Layers with 96 UEs – 8 UEs with GBR and 88 UEs with Best Effort





Source: Signals Research Group

Background

SRG is a US-based research consultancy that has been in existence since 2004. We publish a subscription-based research product called Signals Ahead, which has corporate subscribers that span the globe and involve all facets of the wireless ecosystem. Our corporate readership includes many of the largest mobile operators in the world, the leading infrastructure suppliers, subsystem suppliers, handset manufacturers, content providers, component suppliers, and financial institutions.

One key focus area of our research where we are widely recognized is benchmark studies. These studies have taken us all over the world to test emerging cellular technologies and features immediately after they reach commercial status. As an example, since the launch of the world's first 5G network in 2018, we've published 38 benchmark studies in Signals Ahead pertaining to the next generation technology through the end of January 2024. These studies have included a wide range of frequencies, device, and chipset performance, not to mention new features within 5G and how 5G impacts the user experience with frequently used mobile applications.

Our philosophy in doing benchmark studies is that we are even keeled, data-driven, and as objective as possible. We present the study's findings with as much performance data and analysis as possible and then let the results speak for themselves.