Samsung 16-Layer Massive MIMO Increases Cell Capacity in Commercial Network

Today, 4G LTE technology continues to evolve and deliver cutting edge features and techniques that were originally conceived for highly specialized and complex use cases. With these features now being developed on a commercial scale, they will benefit mobile network operators for years to come. Massive MIMO with beamforming is one of these crucial new advancements that operators have as part of their arsenals to increase cell throughput and maximize the usage of their spectrum. This technology will serve as an essential foundation for both 4G and 5G networks of the future.

Massive MIMO solutions provide more efficient use of spectrum by forming multiple transmission beams towards the target areas of coverage. By using different transmission modes, a cell site can simultaneously transmit 2, 4, 8 or 16 unique data streams that can be dynamically assigned across multiple users. While there is some overhead required to assign each flow to a particular user, the overall benefit is the significant increase in aggregate cell throughput. With 16-layer massive MIMO, the cell sector can serve up to 16 users simultaneously per Transmit Time Interval (TTI), (where TTI represents the shortest time duration for broadcasting data over the radio interface.) As a frame of reference, legacy 2x2 MIMO only serves a single user per TTI.

Recently, Samsung used a live network cell site in Illinois carrying commercial traffic to demonstrate the viability and effectiveness of 16-layer massive MIMO. In Samsung's implementation of massive MIMO, the radio sends up to sixteen different streams of data to different user devices. The Samsung 64T64R Massive MIMO Unit (MMU) incorporates zero-forcing beamforming (ZFBF) to minimize interference that would otherwise be caused by overlapping of signals of adjacent beams. Without ZFBF, this interference would disrupt the successful reception of the desired data stream. In effect, ZFBF narrows the transmitted beams, providing a cleaner, higher quality signal to the end user's device or smartphone. In more technical terms, ZFBF creates more favorable radio conditions to improve the probability of orthogonality and a higher signal-to-noise ratio (SINR) to each desired user signal stream.

In addition to ZFBF, Samsung's 64T64R MMU utilizes 128 antenna elements in a sixteen (horizontal) by four (vertical) array configuration. This layout provides much more granular horizontal beams, maximizing both signal orthogonality and ZFBF resolution for users that are spatially separated in the horizontal plane. In the case of overlapping users, ZFBF can still leverage the specific fading environment of the user to deliver clear signals, as surrounding clutter can reflect and refract each user's beam.

16-layer massive MIMO delivers significant gains in cell throughput, resulting in higher system-level spectral efficiency for the network operator.

The Samsung Massive MIMO demonstration outlined in this paper used a simple activation of 16-layer massive MIMO in a live network. The existing commercial site did not require any additional optimization, network engineering, or specialized equipment to realize the performance benefits observed and reported here. While others may indicate that 8-layer massive MIMO is sufficient, this demonstration proves that 16-layer M-MIMO provides significant gains in overall cell throughput and per-user throughput, resulting in better user experiences and system-level spectral efficiency.

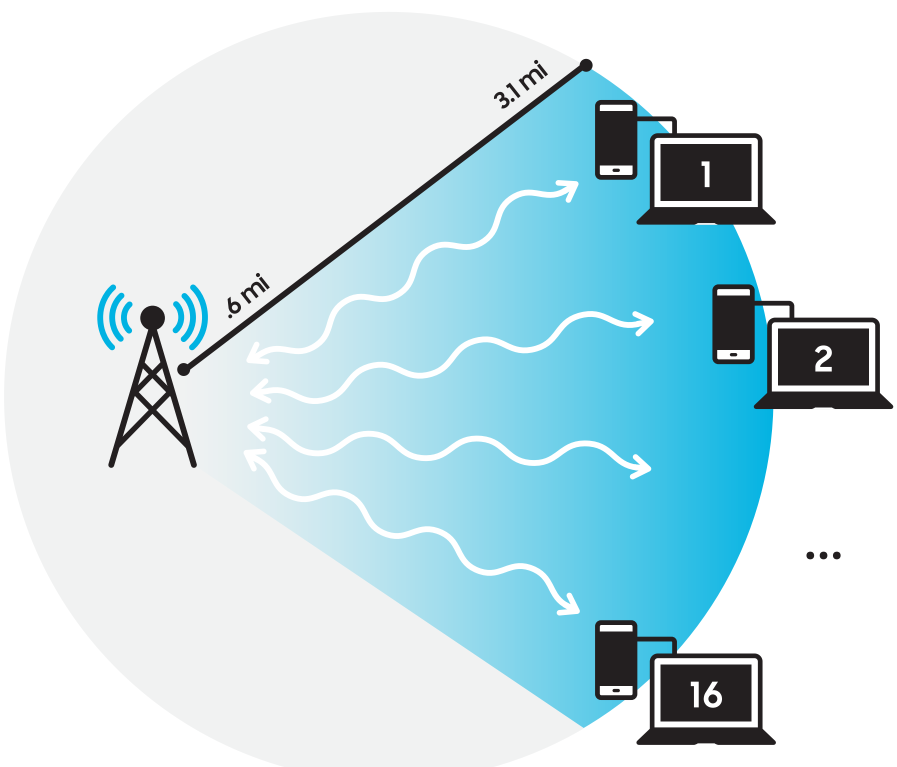
Demonstration Overview

This particular Samsung Massive MIMO demonstration occurred on April 4, 2019 and utilized Samsung's existing 64T64R MMU equipment in commercial operation. At the cell tower, Samsung 64T64R MMUs were already carrying live 4G LTE traffic on a single 20 MHz TDD carrier in the 2.5 GHz band.

The setup for each user consisted of a laptop tethered by a USB cable to a commercially available Samsung Galaxy S9 that served as a modem for the computer. The team set up two user deployment scenarios to provide the opportunity to capture throughput metrics for near-field and far-field cases. The intention was to understand the impacts on throughput from massive MIMO systems when users are in different locations. The demonstration examined results from clusters of devices located within 1 km (or 0.6 miles) of the cell tower and from 1 km to 5 km (0.6 miles to 3.1 miles) away from the cell tower.

Initially, the team established a baseline throughput of 50 Mbps using 2x2 MIMO covering the demonstration area. The demonstration created the requisite traffic levels using a standard iPerf client/server setup. iPerf is a network performance tool installed both on a laptop as a client and on a remote server, and in this demonstration, the pairing produced standardized performance measurements using UDP sessions.

No specialized engineering of the cell sector (including antenna tilting or network optimization) occurred before, during, or after the demonstration.

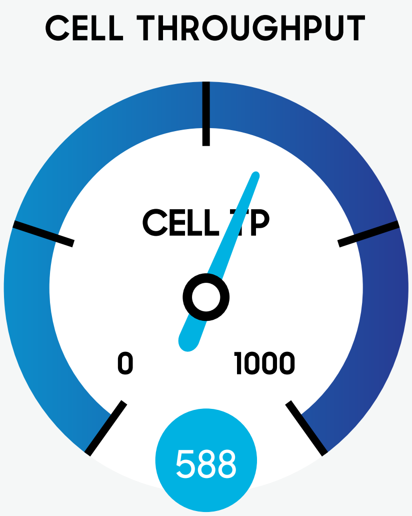


16-Layer Massive MIMO
Simultaneously transmitting to 16 different users.

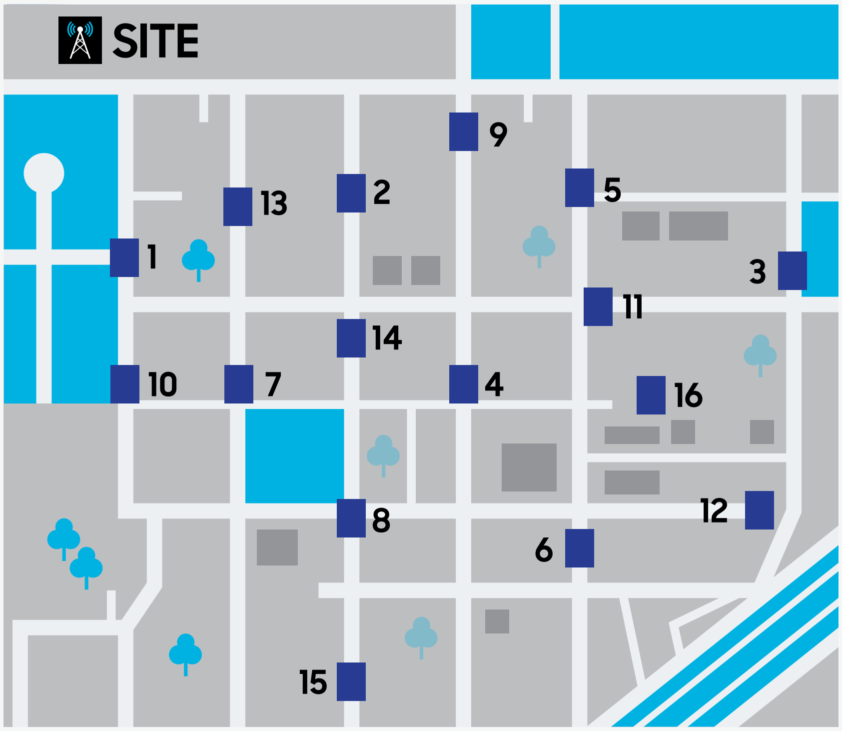
Near-Field Case

For the near-field case, the sixteen users spread themselves randomly to fixed locations within 1 km (or 0.6 miles) from the tower as indicated in the diagram. The demonstration team activated 16-layer massive MIMO by enabling Transmission Mode 7 (TM7) on the cell for all users, and all users began simultaneously downloading data using iPerf.

Measurements indicated that cell exceeded an aggregate throughput of 580 Mbps. Over the course of the three rounds of testing, the sixteen users averaged a simultaneous throughput of 36.75 Mbps, with one user experiencing the highest average throughput of 51 Mbps and another user experiencing the lowest average throughput of 25 Mbps.



In this scenario, the cell site exceeded 580 Mbps, and the 16 users averaged in excess of 36.75 Mbps across the three data sessions.

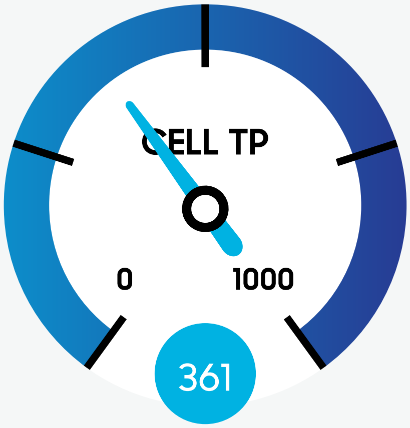


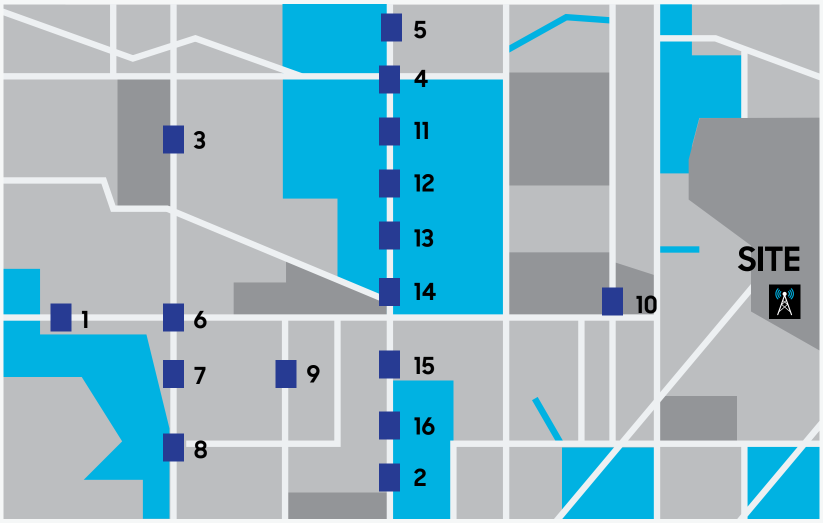
Far-Field Case

For the far-field scenario, the sixteen users moved to a different location of the same site and deployed between 1 and 5 km (0.6 to 3.6 miles) from the cell tower. The demo team configured the sector to operate in 16-layer massive MIMO mode, and again the users began simultaneously downloading data using iPerf.

In this case, the cell site exceeded an aggregate throughput of 360 Mbps. Over the course of the testing in this scenario, the sixteen users averaged more than 23 Mbps across the three data sessions.

CELL THROUGHPUT





In this scenario, the cell site exceeded 360 Mbps, and the 16 users averaged more than 23 Mbps across the three data sessions.

Key Considerations

Note that all field testing in this demonstration focused on stationary user performance (considering an FWA or nomadic mobility use case), and this event did not include any mobility testing. It is essential to point out that the commercially available Samsung Galaxy S9 devices used for this massive MIMO testing do not have the high-gain directional antenna typically used by Customer Premise Equipment (CPE) devices deployed to support FWA services. The higher gain antennas of a CPE will provide improved link budget plus better interference rejection due to the directionality of the CPE antenna compared to the omni smartphone form-factor used for this field test.

Since this demonstration occurred in a commercial network carrying live user traffic on the site's other carriers, the team monitored the shared 1 Gbps backhaul link to ensure the aggregate traffic did not introduce any congestion. The team confirmed that the backhaul link did not experience any congestion throughout the entire duration of the demonstration interval.

Summary

Samsung continues to demonstrate leadership in implementing commercially viable massive MIMO technology. This demonstration proved that, without any additional engineering or site optimization, zero-forcing beamforming with TM7 effectively increases aggregate cell throughput by at least seven times (from 50 Mbps to 360 Mbps for the far-field scenario) for the sixteen users. Samsung would like to highlight that the actual performance gains for FWA deployments are expected to be considerably higher than reported here since FWA solutions will deploy CPEs with high-gain directional antennas that further boost receive signal levels and increase SINR (interference rejection) that maximize the benefits of Samsung's ZFBF functionality. The same beamforming capabilities in the Samsung B41 (2.5 GHz) 64T64R MMU tested in this trial are also available in Samsung's CBRS (3.5 GHz) 64T64R MMU.

While others may say 8-layer massive MIMO is sufficient, Samsung is delivering 16-layer massive MIMO and proving its effectiveness in providing superior user experiences with maximum network performance.

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