

# Massive MIMO Comes of Age

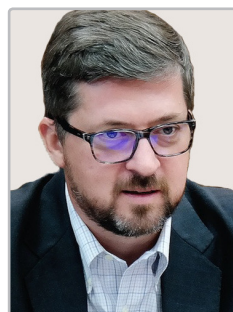
New active antenna technologies play a major role in the evolution of mobile broadband networks



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Daryl covers the wireless infrastructure space at Ovum, with a primary focus on market activities as they apply to the radio access network (RAN). RAN coverage includes macro-, micro-, and picocell solutions for CDMA EVDO, HSPA/HSPA+, LTE (TDD and FDD), and LTE-Advanced. Daryl's research includes not only what infrastructure vendors are developing, but how mobile operators are deploying and using these wireless networking solutions. Daryl also leads Ovum's Next-Generation Infrastructure team. That team covers all access technologies, fixed and mobile, along with operator trends with network transformation around NFV and SDN.

As an industry analyst, Daryl has been involved in such projects as helping technology vendors develop use cases for new products and services, identifying new technology trends, and providing market sizing and market share support. He regularly speaks at industry and vendor events on trends impacting the wireless infrastructure market. He is also sought out by trade publications to comment on mergers and acquisitions, new product announcements, and market developments as they relate to his coverage area.

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## Summary

### In brief

Mobile operators, especially in mature LTE markets where data usage is high, need more network capacity. Massive MIMO provides an effective way to inject new capacity into those networks. Massive MIMO increases network capacity without the high costs of buying more spectrum or adding new base station sites. Also, massive MIMO has a long lifespan because it can be used with 5G.

### Ovum view

- Massive MIMO is one of the quickest and most efficient ways mobile operators can increase network capacity.
- While TDD is generally associated with massive MIMO, massive MIMO can be applied to FDD bands. This will be especially important for when operators start to use their FDD spectrum for 5G.
- The joint Samsung–Sprint massive MIMO trial shows the performance capabilities of massive MIMO in a real-world situation.

### Recommendations

Mobile operators should look at massive MIMO as one of a series of enabling technologies that will help them achieve gigabit LTE along with eventually deploying 5G. Furthermore, mobile operators should not view massive MIMO as just a solution for TDD spectrum; it can be used in FDD bands as well. Given the never-ending growth of data traffic, massive MIMO provides a very efficient way for operators to increase network capacity to meet that data traffic growth.

## Massive MIMO overview

### What is massive MIMO?

MIMO stands for multiple-input, multiple-output antenna. MIMO increases the number of antennas on a radio. For example, a radio using 2T2R MIMO would have two antennas that are used for both transmit and receive. The same would go for 4T4R and 8T8R MIMO. MIMO improves spectral efficiency by creating multiple receive and transmit paths between the base station and the end device.

MIMO itself is nothing new. Both Wi-Fi and LTE networks use MIMO antennas. Most deployments of LTE are either of the 2T2R or 4T4R variety. Sprint has taken it a step further by deploying 8T8R MIMO in its 2.5GHz TDD band.

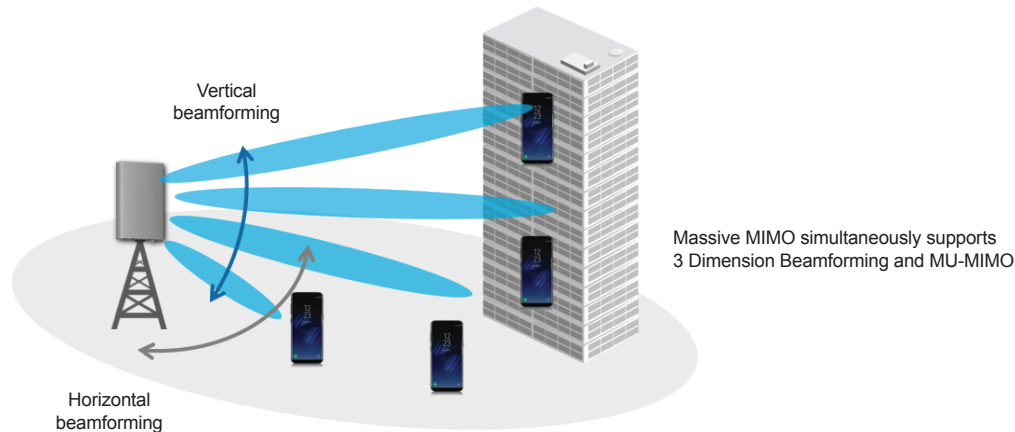
Massive MIMO does not have a specific meaning other than having more antennas than what is currently used in mobile networks. With massive MIMO comes beamforming, which allows for the focusing of the radio signal on areas of demand on specific user devices. It improves spectral efficiency mainly because the advanced beamforming helps to generate greater signal accuracy, including better call quality at the cell edge. Another technology trend emerging with massive MIMO is multiuser MIMO (MU-MIMO). MU-MIMO allows for the transceiver to talk to more than one receiver at a time.

TDD has been the first mover when it comes to massive MIMO, but FDD, despite having some challenges not found with TDD, will use massive MIMO as well. Beamforming requires a channel quality report. Because TDD uses the same frequency for both downlink and uplink (channel reciprocity), the uplink channel quality information can be used for the downlink as well. This makes beamforming easier to do with TDD than FDD. In the case of FDD, it is possible to use alternative techniques to obtain the feedback information necessary to implement beamforming but in a less efficient and accurate manner.



Figure 1 below illustrates a massive MIMO antenna deployment.

Figure 1: Massive MIMO illustration – advanced 3D beamforming



Source: Samsung

### The benefits of massive MIMO

Essentially, the benefit of massive MIMO comes from increasing network capacity without using additional spectrum or base stations. For mmWave bands used in 5G, massive MIMO is a critical component to enabling broader signal coverage.

The following provides more details on the benefits of massive MIMO:

- **Improved spectral efficiency and network capacity for higher throughput.** The system sends and receives multiple data signals over the same radio channel, which increases the spectral efficiency per cell and the number of users who can be served simultaneously. This raises the peak and average cell throughput more cost-effectively than other techniques, such as new spectrum or additional sites.
- **Stronger signal and reduction of interference for better coverage.** Beamforming provides accurate and narrow beams through aiming of the signal, which reduces interference and improves signal quality, especially at the cell edge. Beamforming allows for expanded reach of the cell compared to traditional antennas. This is particularly true for higher frequencies where beamforming compensates for the higher path loss.

### Why is massive MIMO becoming more important?

LTE Advanced Pro and 5G are the two big drivers for increased interest in the use of massive MIMO antennas.

In more advanced LTE markets with heavy data usage, operators need to add capacity and, as outlined in the benefits section, massive MIMO is one of the most efficient ways to accomplish this. Key areas for deployments are dense urban traffic hotspots and high-rise buildings where beamforming can better reach indoor users. Plus, starting the network evolution toward massive MIMO will help mobile operators get their networks ready for 5G.

Massive MIMO is one of the major underpinnings to 5G, along with greater channel bandwidth, access to new spectrum bands, and network slicing. Massive MIMO will help improve both coverage and capacity of the 5G network. 5G will be fully standardized by 2020, with initial deployments using an initial standard going commercial in 2018. The nearness of the 5G timeline has accelerated massive MIMO interest.

## Sprint and its quest for massive MIMO

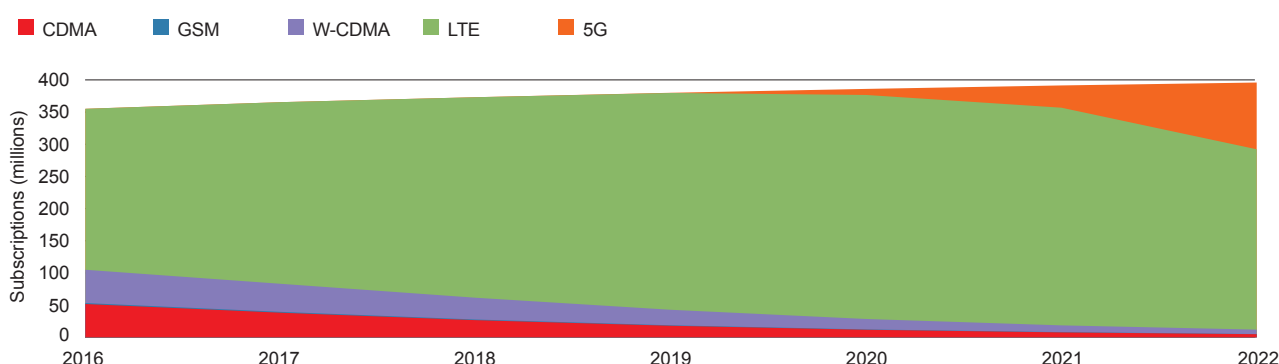
### The US mobile market

The US is one of the most developed and competitive markets when it comes to mobile broadband services. Ovum estimates the total number of mobile subscribers in this market to be around 356 million (excluding IOT, as of the end of 2016), and expects this to grow by another 40 million through 2022. During that period, LTE will account for no less than 70% of all subscribers for any given year.

In terms of services, the US has historically offered large monthly data packages with unlimited data service becoming more common. For post-paid subscribers, voice and texting are almost always unlimited. Handset incentives are often a way of enticing new subscribers.

Figure 2 shows Ovum's forecast for mobile subscribers for 2016 through 2022 by air interface.

Figure 2: US mobile subscribers in millions, 2016–22



Source: Ovum

### Sprint's competitive position and spectrum holdings

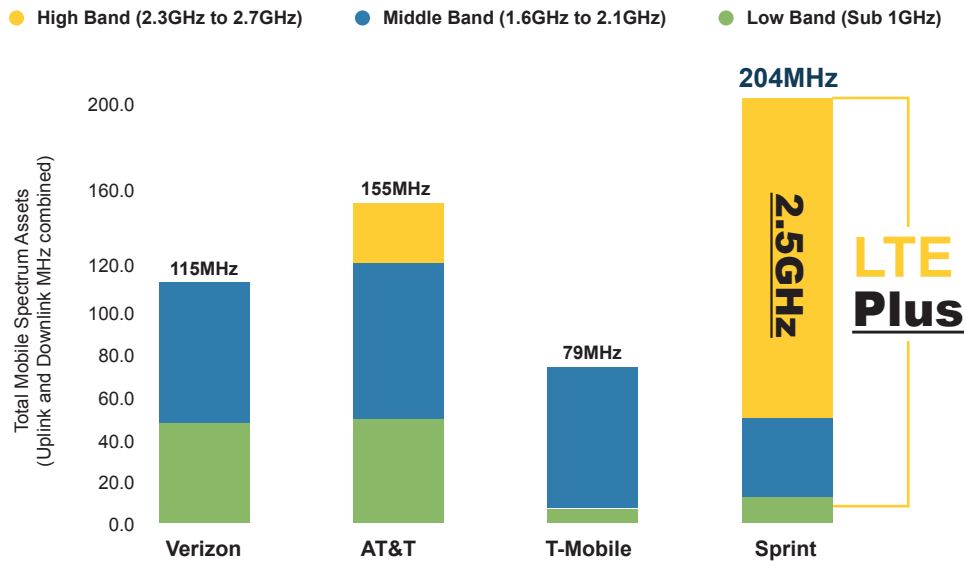
Four mobile operators account for nearly 95% of all subscriptions in the US. Of those four operators, Sprint has the smallest share with 13.7% at the end of 2016.

Sprint's US operations are based in Overland Park, Kansas. When it comes to consumer services, Sprint is a mobile-only provider. It does not have a fixed broadband service. With LTE, Sprint is notable for using both FDD and TDD spectrum. Sprint is the only mobile operator in the US currently using both spectrum types for LTE.

As for spectrum holdings, Sprint leads its competitors in total MHz owned. The company has 204MHz consisting of a mix of low, mid, and high bands. The company's high band, 2.5GHz, is its crown jewel. The vendor has 160MHz of spectrum in that band. Sprint operates its LTE TDD network at 2.5GHz. The company already uses 8T8R MIMO in that band and plans to eventually have massive 64T64R MIMO there when it switches on 5G in that spectrum.

Figure 3 below compares Sprint's sub-3.5GHz spectrum holdings versus its major competitors. This figure is from February 2017. Since then, T-Mobile has acquired on average 35MHz of 600MHz across the US. While this does increase T-Mobile's spectrum position, it does not change Sprint's overall spectrum position versus its competitors.

Figure 3: Sprint's sub-3.5GHz spectrum holdings versus its major competitors



Nationwide, population-weighted average spectrum assets as of 2/7/17. These numbers are national averages and do not represent the spectrum assets in any specific market.  
Source: Sprint

### Sprint and Samsung test massive MIMO

Sprint has partnered with Samsung as it takes steps to achieve what it claims will be the first massive MIMO LTE deployment in the US. During the second quarter of 2017, Sprint went to South Korea to test massive MIMO performance with the Networks R&D team at Samsung. The test was designed by Sprint, conducted outdoors in the city of Suwon, and used radios, antennas, and devices supplied by Samsung.

The test involved the use of two base stations supporting four base station sectors and 32T32R MIMO. Eight Samsung Galaxy phones were used as well. Sprint reported peak speeds of over 320Mbps in a 20MHz spectrum carrier.

The trial was not just about how well 32T32R MIMO worked. It was also to compare 32T32R MIMO performance versus 8T8R MIMO that Sprint currently has in commercial use with the operator. Both types of antennas were used and co-located for performance measurement. Figure 4 shows one of those co-located sites.

Figure 4: Co-located 32T32R and 8T8R MIMO antennas



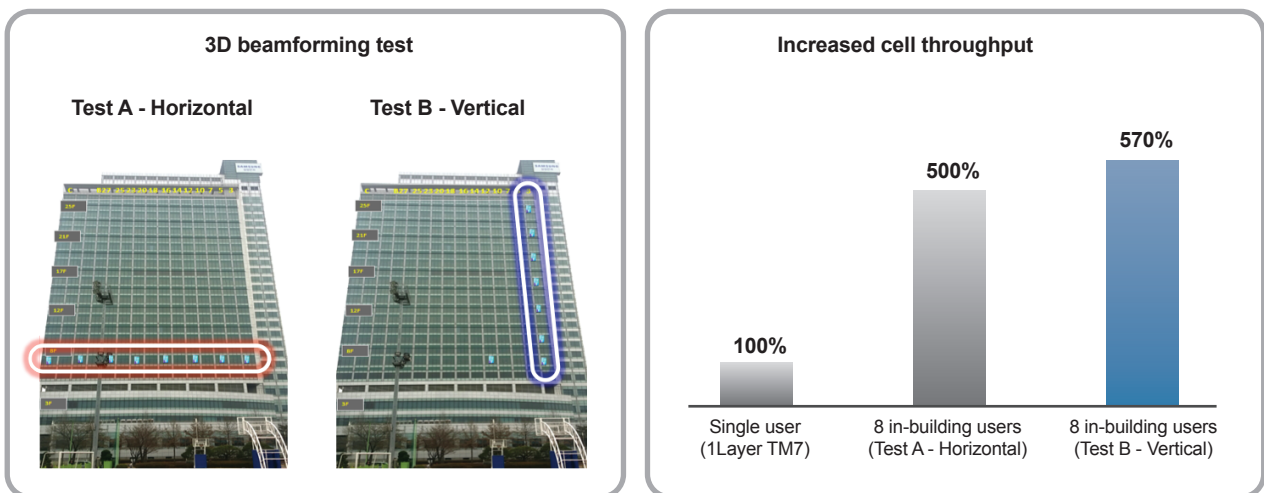
Source: Samsung

Sprint said 32T32R MIMO brought a fourfold increase in peak per-carrier capacity, a threefold increase in cell-edge capacity, and an extension in overall coverage. The trial also included network handovers and latency measures. The massive MIMO implementation did well with both of those performance tests. The system was tested for both indoor and outdoor performance.

Sprint and Samsung also tested elevation beamforming, evaluating cell throughput using eight phones placed at the same floor first, then placing another eight phones in different floors of Samsung Networks' R&D Center.

As shown in the graph below right, total downlink cell throughput for eight phones on multiple floors of a high-rise building outperformed total downlink cell throughput for eight phones on the same floor of the building. This shows that 3D beamforming (elevation) achieves similar performance at the device in elevation scenarios as is achieved in horizontal-plan-only beamforming.

Figure 5: 3D beamforming test (elevation beamforming for high-rise building) at Samsung



Source: Samsung



John Saw, CTO of Sprint

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## Interview with Sprint

Sprint CTO John Saw talks about massive MIMO and Samsung

To gain a mobile operator's insights into massive MIMO and Samsung Networks, Ovum interviewed John Saw of Sprint. The interview was conducted by way of email during the month of August.

### **Ovum: Why did Sprint choose Samsung for this massive MIMO project?**

John Saw: Sprint and Samsung have been collaborating on the advancement and successful deployment of LTE technology, and Samsung continues to be a key partner in Sprint's journey from 4G to 5G. The introduction of massive MIMO technology in Sprint's 4G network is a major step in this direction. The early availability of Samsung's pre-commercial massive MIMO radio in Band 41 (2.5GHz) led to Sprint and Samsung conducting a joint trial in Suwon, South Korea, earlier this year.

### **Ovum: Why does Sprint want to deploy massive MIMO? What has changed over the last few years to make massive MIMO more attractive?**

John Saw: Sprint's Band 41 network already offers exceptional performance due to three-carrier aggregation and beamforming capabilities. With growing end-user traffic demands, as well as the use of significant numbers of outdoor small cells and Sprint Magic Boxes utilizing Band 41 for backhaul, there is a clear need for greater spectrum efficiency on our 4G network. Massive MIMO provides a solution to do exactly that, with capacity boosts expected in the 4x-8x range.

Massive MIMO extrapolates beamforming technology by improving performance through scaled-up transmitter capabilities, which allows the realization of multiuser MIMO beyond the orders of 2 or 4, and up to 8 or 16. In the last few years, we have seen the promise of these massive MIMO systems validated in lab and field trials. The achievable spectral efficiency has also been increasing over the years through support of a greater number of layers or orders of multiuser MIMO. We are seeing support for multiple carriers with massive MIMO, as well as carrier aggregation.

### **Ovum: What are your deployment plans for the massive MIMO project? (commercialization schedule, regions, etc.)**

John Saw: Sprint plans to initially deploy massive MIMO technology in Band 41 sites beginning 1H18. Deployment will be scheduled in multiple markets to augment existing capacity and demonstrate the technology advantage of our Band 41 spectrum assets.

### **Ovum: What is Sprint's 5G network strategy beyond just deploying massive MIMO and does massive MIMO play a role in this?**

Sprint's strategy is to launch 5G using Band 41, leveraging the capability to upgrade the massive MIMO 4G infrastructure. Massive MIMO will be an integral part of 5G for Sprint and globally for other operators in sub-6GHz bands.



**Ovum: What are the end-user benefits of massive MIMO and do end users need devices with massive MIMO antenna arrays to benefit from the network having massive MIMO?**

With massive MIMO, end users will experience improved throughput rates, increased signal strengths, and lower interference levels. This will translate to an overall better end-user experience, even in congested sites or in poor RF conditions. A unique aspect of massive MIMO technology is that all legacy LTE devices will benefit from the performance gains, as massive MIMO antenna arrays are not required on devices to experience improved performance.

**Ovum: Do you see MIMO moving beyond 64x64?**

John Saw: Sprint continues to pursue innovative approaches with our technology partners to implement solutions that fully leverage the power of massive MIMO. The decision to utilize antennas beyond 64T64R depends on the incremental gains achievable, the antenna size increase, and the associated costs of deployment. Given the current state of this technology, 64T64R implementations provide a good compromise in cost, size, and performance trade-offs in Band 41.

## THE BENEFITS OFFERED BY SAMSUNG'S MASSIVE MIMO PORTFOLIO

*Note: The following section was written by Samsung.*

Samsung has devoted significant R&D and product development resources to focus on LTE enhancements, with the objective of driving end-user throughput and spectral efficiency. Samsung's massive MIMO solutions are a result of this focus and are designed to fine-tune current 4G LTE services and to prepare for the arrival of 5G.

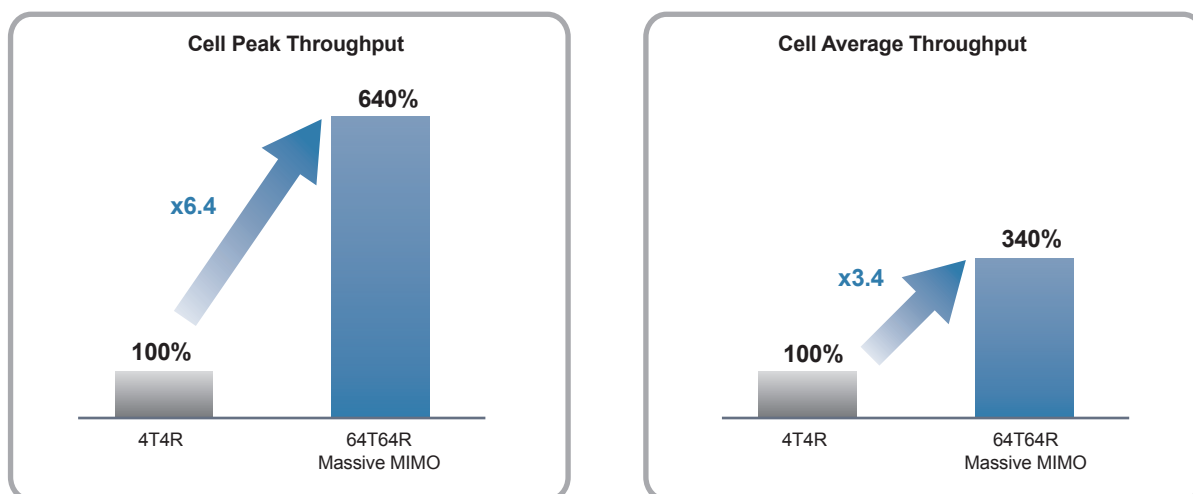
Samsung plans to launch commercial massive MIMO products in TDD spectrum bands in October 2017 and FDD bands in 2018. The performance of these solutions has been verified through field tests in LTE data-dense markets such as Korea and Japan. Samsung also plans on expanding into dense urban markets such as the US and India, where the appetite for data is big.

### Advanced 3D beamforming enhances end-user throughput

Samsung's massive MIMO solution enables a three-dimensional end-user-specific beamforming approach, by supporting both vertical and horizontal beamforming, to effectively increase the multiuser MIMO gain. In other words, with the Samsung solution, the number of subscribers that can be supported simultaneously increases by a factor of eight in the case of 32T32R MIMO, and by a factor of 16 with 64T64R.

Under the supposition that a TDD LTE operator switches from 4T4R MIMO to Samsung's 64T64R MIMO solution, the cell peak throughput can increase by more than 6.4 times, and average cell throughput by over 3 times.

Figure 6: Samsung massive MIMO improves cell throughput



Source: Samsung

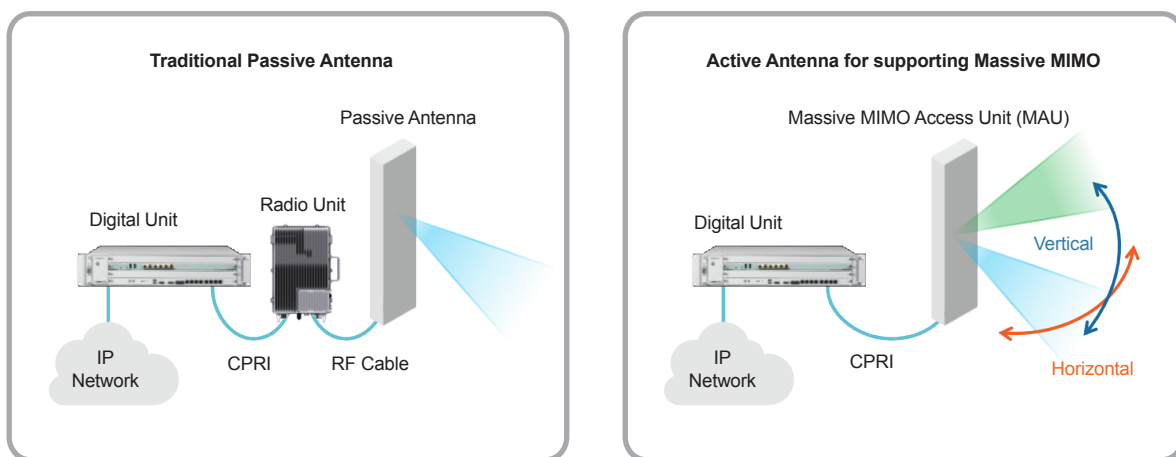
### Field-proven, commercially available, multicarrier aggregation

Samsung's massive MIMO solution supports aggregation of up to five LTE carriers. It is crucial that multicarrier aggregation is still supported with the commercial deployment of massive MIMO because most operators already have multicarrier aggregation (CA) service available.

### More compact, with easier and cost-effective installation

The Samsung massive MIMO Access Unit (MAU) is an integrated solution with a radio unit and the active antennas of an LTE base station in a compact and lightweight form factor. It is designed to be installed easily and cost-effectively. Further adding to the MAU's compact design and efficiency, Samsung adopted natural convection cooling without any fans. The reliability and convenience of this approach has already been proven through field trials in Japan in April 2017, as managing heat (heat generation) properly is essential for commercial use due to the multiple antenna elements and radio units that are squeezed into the small form factor.

Figure 7: Samsung massive MIMO Access Unit (MAU)e



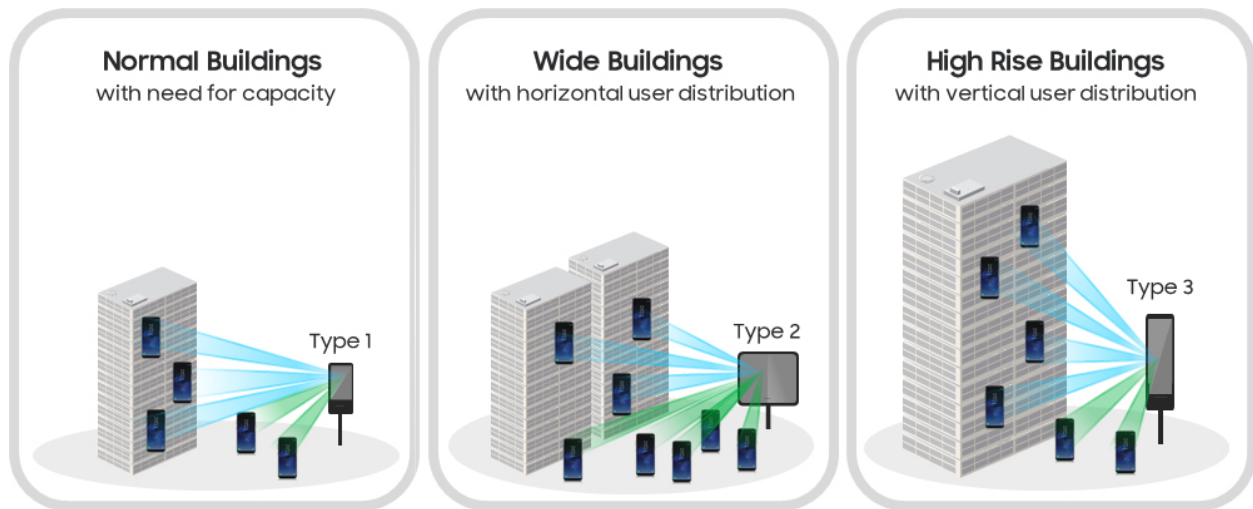
Source: Samsung

### Diverse portfolio: In-building solution for high-rise buildings

Samsung has expanded its portfolio for diverse deployment scenarios, suited to distinctive market needs. For urban areas with higher traffic demands, Samsung has introduced a new type of Samsung massive MIMO Access Unit to be used as an in-building solution for high-rise buildings through vertical beamforming.

In May 2017, Samsung successfully tested and verified the performance of this MAU in South Korea together with Sprint. To address the roughly 80% of current data traffic that occurs indoors and is expected to increase further, the solution can be used as an alternative, cost-effective in-building solution specialized for high-rise buildings.

Figure 8: Diverse deployments scenarios using Samsung's massive MIMO Access Unit



Source: Samsung

#### Support for LTE and 5G New Radio (5G readiness)

The smooth migration from 4G to 5G is pivotal. The Samsung massive MIMO Access Unit utilizes existing LTE resources to the highest possible degree, and is upgradable to 5G NR mainly through software. Thanks to a straightforward upgrade process, operators that plan to transition from 4G to 5G using sub-6GHz frequencies will be able to achieve fast time-to-market service launch in a cost-effective manner.

#### FDD massive MIMO supporting current commercial LTE devices

Samsung will introduce its FDD massive MIMO solution around the second half of 2018. In addition to supporting 5G, the FDD version will increase spectral efficiency and enhance cell throughput and cell-edge performance. Like the TDD version of the MAU, the FDD version will have a lightweight and compact form factor.



## ABOUT OVUM

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