

How 5G massive MIMO transforms your mobile experiences

Now in the age of 5G, we no longer think twice about downloading a file even when our cellular connection is at one or two bars or video chatting or streaming blockbuster movies. Often the case, performing such activities is as smooth as streaming music. 5G NR (New Radio) massive MIMO (Multiple Input Multiple Output) technology is one of the major keys to unlocking these 5G user experiences.

And as the capabilities of today's mobile networks dramatically increase with the global deployment of 5G, users' expectations also rise. In our ongoing series of blog posts aimed at explaining our breakthrough inventions that make 5G a reality, we covered the concepts of mm Wave for mobile, beamforming, and low latency. Now, we offer a view into 5G NR massive MIMO and how this technology delivers improvements for both mobile device users and networks.

MIMO gets massive

MIMO systems require a combination of antenna expansion and complex algorithms. It's multifaceted, but MIMO has been used in wireless communications for a long time now it's common for both mobile devices and networks to have multiple antennas to enhance connectivity and offer better speeds and user experiences. MIMO algorithms come into play to control how data maps into antennas and where to focus energy in space. Both network and mobile devices need to have tight coordination among each other to make MIMO work.

Now, with the design of new 5G NR networks, MIMO becomes "massive" and crucial for 5G NR deployments.

Massive MIMO which is an extension of MIMO expands beyond the legacy systems by adding a much higher number of antennas on the base station. The "massive" number of antennas helps focus energy, which brings drastic improvements in throughput and efficiency. Along with the increased number of antennas, both the network and mobile devices implement more complex designs to coordinate MIMO operations. That's all to say, these advancements are all aimed at achieving performance improvements needed to underpin the 5G experiences consumers expect in this new era.

Demystifying massive MIMO technology

Let's dive deeper into the building blocks of MIMO systems. They capitalize on three key concepts, which are spatial diversity, spatial multiplexing, and beamforming:

Spatial diversity and spatial multiplexing

Spatial diversity is one of the fundamental benefits of MIMO technology. In brief, diversity aims at improving the reliability of the system by sending the same data across different propagation, or spatial, paths.

Spatial diversity evolves into a more complex concept, which is “spatial multiplexing”. Now, not only are the diverse experiences of the over-air-channel utilized for performance improvements, but multiple messages can be transmitted simultaneously without interfering with one another since they are separated in space.

To better visualize the concept of spatial multiplexing, think of a pipeline through which data is flowing between the base station and the phone on a mobile network. Envision a situation with one antenna on the base station and one on the phone that allows for only so much data to flow. Now, by installing more antennas on either side with proper spatial separation (see illustration below), multiple virtual pipelines can be created in the space between phone and the base station. This creates multiple paths for more data to travel between the base station and mobile.

By nature, this solution is very dynamic. With the continuous movement of the mobile user and changes in the surrounding environment, the mobile phone and the network require more advanced capabilities to continuously coordinate the link and manage the data transmission.

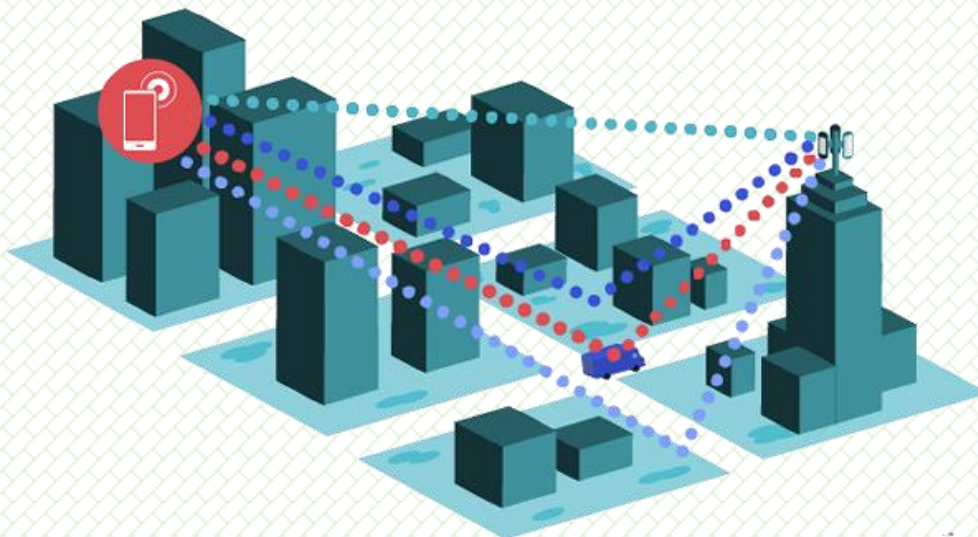


Figure 1 Spatial Multiplexing

Beamforming

Beamforming is another key wireless technique that utilizes advanced antenna technologies on both mobile devices and networks' base stations to focus a wireless signal in a specific direction, rather than broadcasting to a wide area. Think of the difference between using a flashlight which kind of floods everyone in the room versus a laser pointer, which can pinpoint and continuously track a given user.

With the massive number of antenna elements in a massive MIMO system, beamforming becomes “3D Beamforming”. 3D Beamforming creates horizontal *and* vertical beams toward users, increasing data rates (and capacity) for all users even those located in the top floors of high-rise buildings (see illustration below).

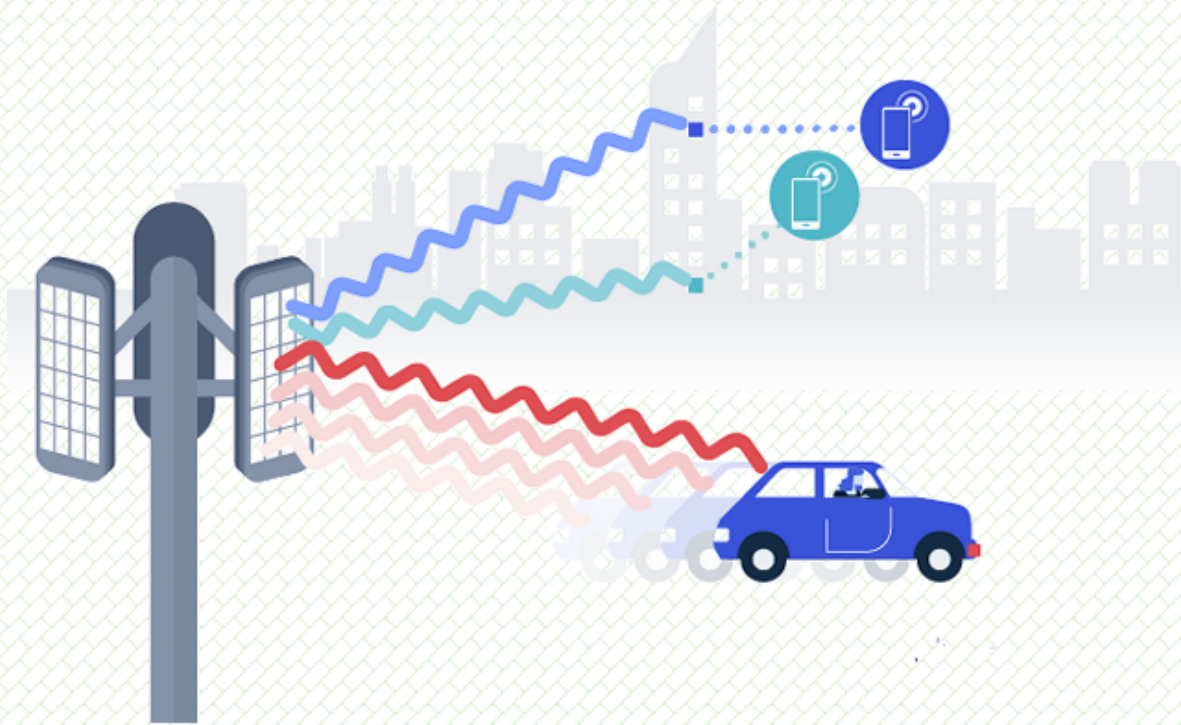


Figure 2 3D Beamforming

Mobile feedbacks to the network, allow the network's beam to find any point in space, so a mobile user can always be served by a focused beam to their devices, as they are moving on the street or between different floors in a building. Also having such narrow, direct beams reduces interference between beams directed in different directions.

Multi-User MIMO

But wait there's more: MIMO technology also allows multiple users to share the same network resources, simultaneously. Multi-User MIMO or "MU-MIMO" allows messages for different users to travel securely along the same data pipelines, then be sorted to individual users when the data arrives at their mobile devices. Think of it as similar to your online shopping order traveling in a delivery van along with other orders. Your order shares space in the van, yet only gets delivered to you the intended recipient. Serving multiple users with same transmission increases capacity and allows for better utilization of resources. That adds up to the ability to download or stream with an improved experience for the user even in crowded area.

This shared transportation of data means a faster and more efficient system for all users (see illustration below). That adds up to the ability to download or stream with an improved experience for the user, even in crowded areas.

Also, networks can dynamically switch between serving one or multiple users. When a single user is served, typically the beam is more direct and power is more focused. However, with multiple users, beams tend to be wider as users may scatter in various directions.

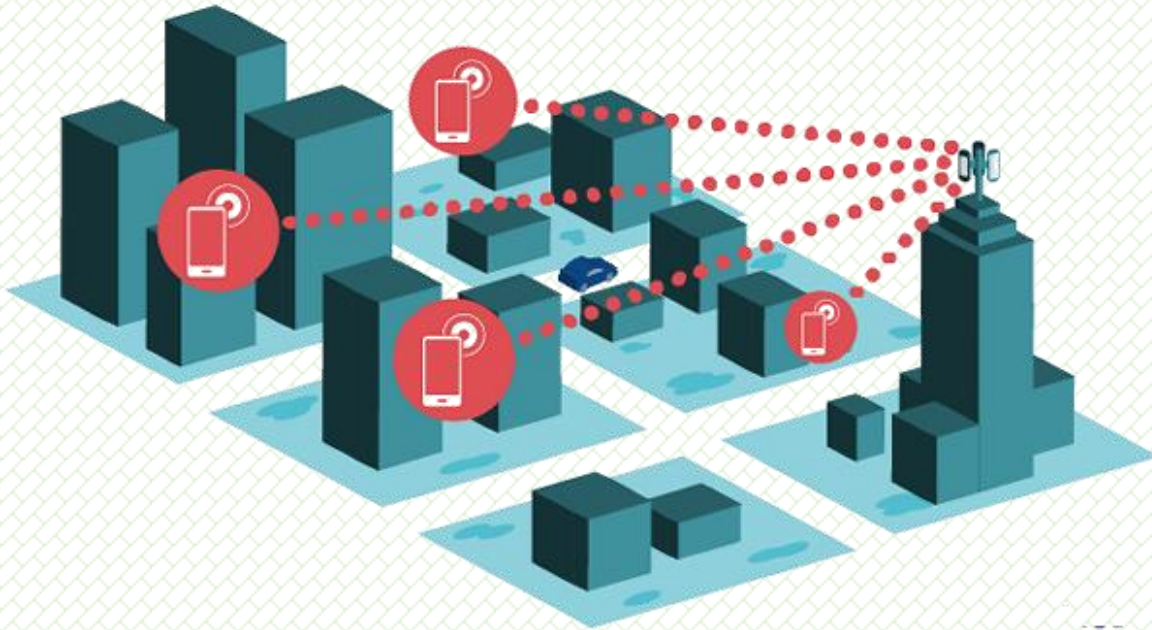


Figure 3 Multi-User MIMO

Benefits of massive MIMO

Massive MIMO is a key enabler of 5G's extremely fast data rates and promises to raise 5G's potential to a new level. The primary benefits of massive MIMO to the network and end users can be summed up as:

- **Increased Network Capacity** – Network Capacity is defined as the total data volume that can be served to a user and the maximum number of users that can be served with certain level of expected service. Massive MIMO contributes to increased capacity first by enabling 5G NR deployment in the higher frequency range in Sub-6 GHz (e.g., 3.5 GHz); and second by employing MU-MIMO where multiple users are served with the same time and frequency resources.
- **Improved Coverage** – With massive MIMO, users enjoy a more uniform experience across the network, even at the cell's edge – so users can expect high data rate service almost everywhere. Moreover, 3D beamforming enables dynamic coverage required for moving users (e.g., users traveling in cars or connected cars) and adjusts the coverage to suit user location, even in locations that have relatively weak network coverage.
- **User experience** – Ultimately, the above two benefits result in a better overall user experience users can transfer large data files or download movies, or use data-hungry apps on the go, wherever life takes them.

As mentioned earlier, MIMO has been used in wireless communications for many years. But now, in the context of 5G NR, massive MIMO is radically changing how and when we choose to use our mobile devices. We no longer have to second guess if we're in a good area to download or transfer large files. The user experience is about to take an immense leap forward.

Massive MIMO is just one example of the many breakthrough inventions we have brought forth from decades of research and development to unlock 5G for the mobile industry and beyond, and transform how the world computes, connects and communicates.

-Ashwini Haryan