5G Massive MIMO
Network Application

Table of contents

Figures

Tables

Executive summary

One of the greatest things in our era is that 5G is helping realize the Intelligent Internet of Everything (IIoE), bringing great changes to people's lives, many vertical industries and the entire society with making the world a better connected and digital one. Massive MIMO, as one of the core technologies of 5G, is key to meeting the high performance requirements and new service requirements of this amazing new era.

Though Massive MIMO does offer great promises for highly capable 5G with wider bandwidth, more connections, lower latency and better reliability, realizing its full potentials requires effective responses to the challenges of network coverage, user experience, and network capability, which is relevant to all the mobile network operators and system vendors.

After the Massive MIMO technology is introduced, the differentiation and flexibility of wireless network coverage in three-dimensional space have been greatly improved. The radio wave propagation model, user behavior and service distribution, beam management and beamforming are more complicated, flexible and difficult to measure. The location of problems in wireless networks, the effectiveness of response solutions, and the effectiveness and impacts of new functions become more complicated as the network scale increases. How to effectively predict, find, and evaluate the optimal solution in advance before the complicated real network encounters problems?
While Massive MIMO enables 5G with much higher diversity and flexibility of network accessibility and capability in a three-dimensional space, the complexity of the network raises the questions in identifying network issues, offering effective solutions, and maximizing the benefits of the new technologies without paying too high a price. How can we predict what network problems would happen under which circumstances, and come up with the optimal solutions and evaluate them, before the problems really happen?

This white paper will address all these challenges with some analyses and suggestions.

Massive MIMO is a core technology of the 5th generation mobile communication

Massive MIMO, a large-scale antenna technology, is a core 5G technology that can improve network coverage, user experience and network capability.

While the traditional radio devices often have just two, four, or maximum eight TRX channels, the radio devices powered by Massive MIMO technology can have 32 or 64 TRX channels, with up to 512 or even more antenna elements, which can lead to substantially higher capacity gain than traditional equipment. Furthermore, while the traditional devices focus more on coverage in horizontal dimension, Massive MIMO offers much better flexibility also in vertical dimension. Massive MIMO can exploit to a great extent the resources in space dimension and enable the users under the same base station to use the same time and frequency resources, which significantly enhances the network capacity without denser base stations and wider frequency bandwidth.

The Massive MIMO technology was first introduced into mobile networks in Pre5G era. With deployments of 5G around the world, it has now been widely adopted on a large scale.

Challenges of Massive MIMO in 5G network deployment

Massive MIMO technology can significantly improve the system capacity, but there are still many challenges to be overcome while deploying the actual networks. These challenges are coupled mainly to three key aspects of deploying 5G: network coverage, user experience and network capability.

The above three aspects will benefit greatly from the typical technical features and advantages of Massive MIMO, and the corresponding technical difficulties will be solved at the same time.

Taking synchronization signal and PBCH block (SSB) configuration as an example, SSB determines the basic coverage performance of the network. 4G broadcast channel is sent with a fixed wide beam, and its coverage does not change in most cases. However, 5G SSB can be configured with up to 7 (2.5 ms frame structure) or 8 (5 ms frame structure) beams according to frame structure. More SSB beams result in flexible configuration, i.e. multiple horizontal beams can be configured, or combination of horizontal and vertical beams can be configured. Different beams can be flexibly configured with different widths and heights, so that the 5G SSB beam configuration can support abundant scenarios and accurately meet differential coverage requirements. However, the increase in flexibility also brings a significant increases in configuration complexity. There are more than tens of thousands of combinations of antenna parameters configuration for 5G SSB beams. Here arises a huge technical problem on how to quickly and accurately find the configuration that is most suitable for the current scenario among tens of thousands of antenna parameters , and efficiently match the configuration with the change of scenarios and user behavior modes.

Based on the quasi-orthogonal characteristics among multi-user channels, Massive MIMO can greatly improve the network capacity through SDMA. Due to the complexity of wireless channel propagation, and the randomness of user distribution and services, the design of a base station requires a well-performed algorithm for downlink transmission and uplink receiving to obtain a stable multi-user SDMA gain and anti-interference performance. Under the condition of a given number of antennas, the complexity of the Massive MIMO algorithm increases rapidly with the increase of the number of users and the maximum number of MU-MIMO multiplexing layers, which becomes one of the key technical difficulties affecting system capacity.

Network coverage

This aspect focuses on network coverage in various scenarios.

Similar to the roll out of 4G, 5G also takes multiple steps and starts from dense urban areas where radio environment can be very diverse and complex, including business district with skyscrapers, a variety of shopping malls and office buildings, residential areas, business streets and plazas alike. The first challenge is to roll out 5G with decent coverage for all these different deployment scenarios, particularly when deploying macro base stations at the early stages of 5G roll out is a much higher priority than deploying dedicated indoor systems. Massive MIMO needs to be fully leveraged, along with the flexibility and precision of SSB, to set solid foundation for optimal user experiences and outstanding network capability.

Figure 1 5G typical network coverage scenario

User experience

User experience optimization needs to compensate for the weakness in weak-field environments, thereby providing a high-quality experience anytime and anywhere.

From a radio access network perspective, user experience is first strongly dependent on network coverage and mobility performance. Generally speaking, the farther the user is away from the base station, the weaker the signal they receive, and consequently the lower the data rate. Cell edge is often the weakest spot of the network in terms of both coverage and user experience. Massive MIMO, with its ability to form more precise and energy-concentrated beams, can greatly enhance the signals received at cell edge, reduce interference to neighboring cells and improve user experience.

Another typical case of poor user experience is when the users are moving really fast, which makes the basis of Massive MIMO's good performance – reliable channel state information and channel estimation – questionable. In medium- or high-speed mobility cases, the radio channels between the terminal and the base station are in constant and fast change, which leads to channel aging and therefore the deterioration of the reliability of channel information and channel estimation. The network needs to accurately detect the channel state information in a timely manner, and match the corresponding algorithm policies and parameter configurations. For example, shorten the transmission period of the reference signal, improve the feedback speed and accuracy of the channel state information, and make the service channel beamforming more accurate to ensure user experience.

Network capability

With the explosive growth of the number of users and service types, this will be the most commercially valuable aspect of 5G network applications and development.

5G network can further benefit from Massive MIMO on other fronts than just coverage and experience, so that 5G not only offers better coverage and faster speed, but also helps create more values. One thing is to further exploit the space dimension, when spectrum is limited, to meet the ever-increasing demands of data. At the same time, QoS-based service differentiation and smart resource allocation can be used to offer enhanced services with even more capabilities, and to materialize network potentials and improve the financial performance of network operation. In dense areas, for example, MU-MIMO space division multiplexing can be further optimized to increase the maximum number of concurrent users, improve transmission efficiency, and also reduce the time it takes to transmit data and therefore lower the power consumption and the network's carbon footprint. For those terminals that don't move much, optimal switch over path can be determined and then used for smoother user experience. As for the areas with tidal-traffic patterns, smart beam management can be used to ensure more precise beams targeting high-value areas and users.

Furthermore, some latency-sensitive services, such as large-scale interactive online gaming and industrial robots, also require network capabilities more tailored to their respective special needs. For example, SU-MIMO, rather than MU-MIMO, can be a better option for latency-sensitive services in order to reduce the likelihood of retransmission due to interference of MU-MIMO pairing.

The key technologies of Massive MIMO at the aspects of 5G network development and application are summarized in the following table.

Network development	Major challenges	Key technologies of Massive MIMO
Network coverage	• Coverage in various scenarios, such as high-rise buildings • Managing various types of interference	• Accurate and intelligent SSB configuration • Interference mitigation technologies
User experience	• User experience improvement in poor-performing scenarios such as cell edge and high mobility.	• Precise beamforming and intra-cell and inter-cell interference control • Configuration of reference signals and demodulation signals to make feedback information more timely and accurate.
Network capability	• Support accessing more users and more services. • Better user and service differentiation and value creation	• SDMA of control channels and service channels increases the capacity. • Differentiated QoS management and intelligent resource allocation, providing accurate user-level service capability

Table 1 Summary of features/challenges/key technical points at each aspect of 5G network development and application

Massive MIMO supports continuous development of 5G network application

Massive MIMO core technologies support the development requirements of each aspect of 5G network application:

Network coverage: Multi-beam management and beamforming lay a foundation for better coverage.
User experience: SU-MIMO and scenario-based enhanced algorithm provide the best user experience anytime and anywhere.
Network capability: MU-MIMO and multi-user/multi-layer pairing key algorithm maximize the full-dimension values such as system capacity, experience and energy consumption.

To address these challenges, Massive MIMO technologies can be leveraged with advanced beam management, enhanced algorithms and other innovative solutions.

Multi-beam management and beamforming lay a foundation for better coverage

5G SSB offers much better flexibility for broadcast channel coverage than 4G

The broadcast control channel transmission and coverage of 4G – as the case of 2G and 3G, is through a wide beam.
In 5G era, the large-scale antenna array technology is introduced. Like the PDSCH service channel, through the cooperation of all antenna elements and RF transmission channels in the antenna array, 5G system provides SSB narrow beamforming capability. Multiple SSB narrow beams can be scanned and transmitted in time domain and space domain. In this way, SSB can achieve not only the same coverage performance as service channel, but also three-dimensional flexible coverage mode in horizontal and vertical dimensions.

5G, on the other hand, uses beamforming technologies based on a massive array of antenna elements and RF transmission channels to transmit multiple narrow beams of SSB in both time domain and space domain, in the same way of PDSCH transmission. This helps achieve the same coverage of SSB and of service channels and very flexible coverage in a three-dimensional space.

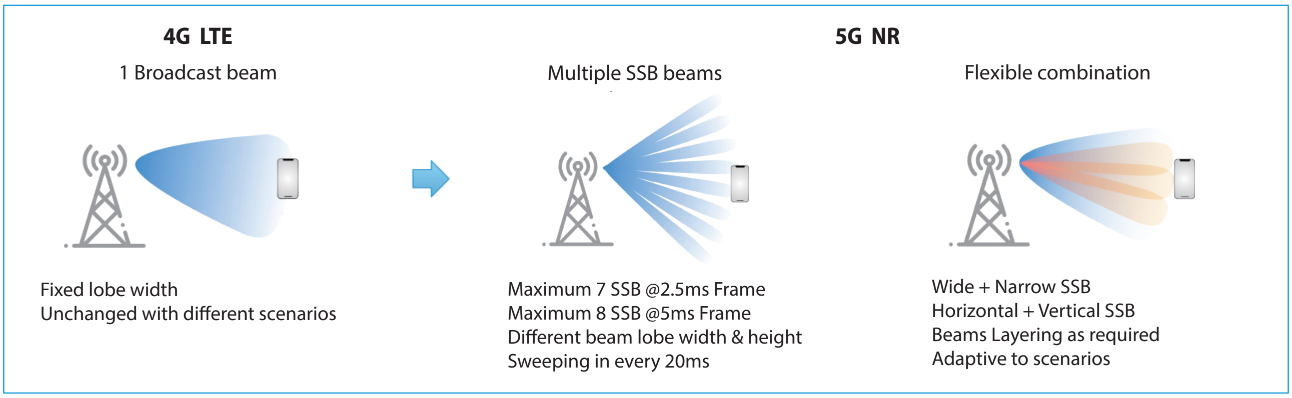


Figure 2 Comparison between 4G broadcast channel and 5G SSB

The five-dimensional antenna parameters of Massive MIMO technology include horizontal beam width, vertical beam width, horizontal azimuth, vertical downtilt, and number of SSB beams.

There are five key parameters determining Massive MIMO SSB configuration: horizontal beam width, vertical beam width, horizontal azimuth, vertical tilt, and number of SSB beams. This helps achieve great flexibility in meeting various coverage requirements.

While 4G uses a fixed wide beam for broadcast channel, 5G enjoys flexible options of SSB transmission:

- Each cell transmitting a single fixed wide beam with neighboring cells staggering their beams in time domain.
- Each cell transmitting a single fixed wide beam with no staggering of the beams by neighboring cells – better resource utilization but worse interference.
- Beam sweeping. This is a transmission method that multiple SSB beams are sent in different directions while being staggered in time domain, which not only ensures each SSB beam is targeting its own intended direction but also helps mitigate interference among neighboring cells. It is currently widely adopted in commercial networks.

Multi-beam SSB offers significantly better coverage than single-beam SSB. A drive test in a commercial network showed that horizontal 8-beam SSB had 7 to 8 dB gain of RSRP and another 7 to 8 dB gain of SINR over those with horizontal single wide beam SSB. In the 5% worst area in terms of coverage, RSRP was improved by 13 to 14 dB and SINR by 7 to 8 dB after single-beam SSB was changed to multi-beam SSB. In another place where another drive test was done, RSRP with horizontal 7-beam SSB was 6 dB better than that with horizontal single wide beam and SINR was 6 dB better.

Evolution from horizontal multi-beam basic coverage to full-scenario three-dimensional coverage

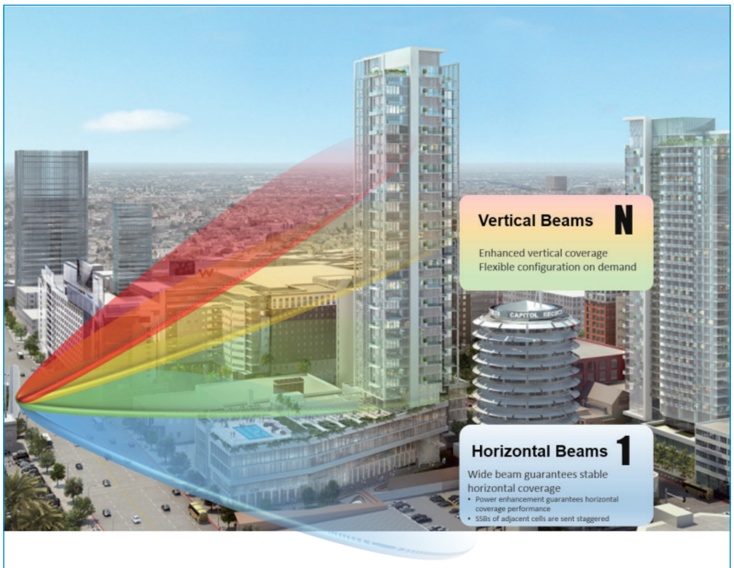


Figure 3 Full-scenario three-dimensional SSB coverage solution

In dense urban areas where there are many high-rise buildings, SSB coverage in vertical dimension needs more considerations besides horizontal dimension.

One innovative solution is to user one wide horizontal beam SSB, with enhanced transmission power, to provide a basic level of coverage, and also to use a flexible number of vertical beams, narrow or wide, depending on the ever-changing of user distribution and coverage requirements. While the horizontal coverage of this solution can be about the same level as that of multi-beam SSB, the vertical coverage can be substantially improved, benefiting network performance in the high-rise buildings.

This solution has the following three advantages:

❶ The vertical coverage can be enhanced without costing the horizontal coverage

As mentioned before, the wide beam can provide horizontal coverage and the flexible number of vertical beams can provide on-demand vertical coverage, altogether realizing enhanced three-dimensional coverage.

❷ Simpler SSB beam configuration scheme saves resources and also reduces power consumption

The number of SSB beams required can be much fewer than the case of horizontal multi-beam SSB scheme. Without affecting the coverage performance, the overhead of access resources can be reduced, thus more service channel resources can be made available. In addition, the time slot duty ratio of SSB beams is reduced, and the energy consumption of devices can be further reduced when symbol shutdown is enabled during low-load periods.

❸ Effective interference avoidance

Single wide beam SSB with enhanced transmit power is staggered in time domain to effectively solve the problem of mutual interference between the serving cell and adjacent interference cells. As mentioned before, neighboring cells can coordinate their horizontal wide beams in the time domain to effectively mitigate inter-cell interference.

Tests in a commercial network area with high-rise buildings and streets showed that while the horizontal coverage of power-enhanced wide beam SSB could reach the same level of horizontal 8-beam SSB, the high-rise building coverage was improved by more than 30%. This innovative solution, compared with horizontal 8-beam solution, can offer 30% more access capacity and 5% more service capacity when traffic load was high, and 10% less power consumption when traffic load was low.

Efficient automatic optimization of 5G SSB

As there are tens of thousands of possible combinations of the five key parameters of SSB configuration, cell and cell clusters, the greater flexibility of Massive MIMO technology does come with greater complexity of network configuration and optimization. As soon as the physical deployment of a 5G base station is completed, Massive MIMO parameters need to be optimized based on cell user distribution, traffic pattern, and status of overlapping coverage, weak coverage and cell overshooting. In order to achieve this, advanced smart algorithm based on artificial intelligence and big data can help achieve highly efficient and automatic optimization of SSB beams with the optimal set of parameters.

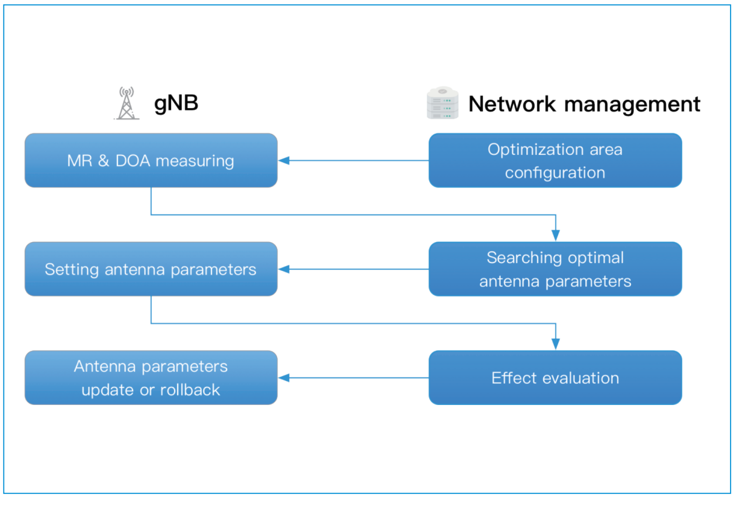


Figure 4 SSB antenna parameters intelligent optimization flow

SU-MIMO and enhanced scenario-based algorithm enhance user experience wherever and whenever needed

SU-MIMO helps realize the ultimate experience of a single user

SU-MIMO improves the uplink and downlink performance for a single user through space division multiplexing of uplink and downlink multi-layer. For 2T4R commercial terminals, a maximum of 4 layers of downlink PDSCH service channels and 2 layers of uplink PUSCH service channels can be supported in commercial networks. By maximizing the number of layers and the spectrum efficiency per layer, SU-MIMO helps achieve the ultimate performance for a single user.

Guaranteed user experience anytime and anywhere

With the ongoing development of mobile network technologies and increase of demands on the network, the network needs to ensure good user perception and good service experience anytime and anywhere, for example, even at cell edge with poor coverage or users with high-speed mobility.

Enhance user experience at cell edge

At the edge of a cell, the SSB of the serving cell and its neighboring cells form a relatively complex interference environment. Interference also exists between the beamforming service channels of UEs in the cell edge area. Therefore, at the cell edge with weak signals, it is critical to mitigate the beamforming interference between SSB and service channels to improve cell edge user experience.

At the near and middle points of a cell where the radio channel conditions are good, the limited uplink transmit power of a UE does not cause any issue, and the uplink SRS can be well received by the base station. Therefore, based on the reciprocity of the SRS channel, the downlink service channel beamforming can provide better single-user downlink performance. However, at the far points, the uplink SRS of the UE cannot be received by the base station with acceptable quality. In this case, it is necessary to adapt to the PMI closed-loop feedback to implement beamforming of the downlink service channel. The terminal uses the CSI-RS reference signal received from the base station to calculate the CSI (including PMI, CQI and number of streams), and then sends it back. Then the base station completes the beamforming of downlink service channel. It is clear that PMI-based closed-loop feedback for beamforming has better performance at the cell edge area than SRS-based mechanism. Therefore, the base station needs to determine the location and radio conditions of the UE, and to introduce the adaptive SRS/PMI downlink beamforming mechanism to achieve the best single user performance across the entire cell.

In addition, multiple algorithms can be used to reduce interference:

1

The downlink service beam interference among neighboring cells can be mitigated through adjustment of antenna parameters and beam shapes. For example, shrinking the side lobe can reduce the overall interference level to neighboring cells, or setting the gain to zero in the direction of the interfered users to reduce interference.

2

The uplink service beam interference among neighboring cells can be mitigated also through adjustment of antenna parameters and beam shapes. For example, shrinking the side lobe to reduce the interference introduced by neighboring cells, or set the gain to zero in the direction of the interfering users to reduce the interference introduced by the said users.

Guarantee user experience in high-speed mobile scenario

As 5G also aims at offering better mobility performance, Massive MIMO can contribute as well. Taking the moving speed supported by SRS with a period of 5 ms as a baseline, the SRS feedback period can be adjusted in accordance with UE's moving speed. For example, SRS with 2.5 ms and with 1 ms can support UE speed twice and five times faster respectively.

Compared with fixed DMRS in 4G networks, 5G DMRS can be dynamically adjusted to shorten the feedback period of channel status and support higher movement speed. Based on the preset DMRS supporting the speed of 30 km/h, adding from one to three DMRS can support the speed of 30-120 km/h, 120-300 km/h and 300-500 km/h respectively.

In addition, the following algorithms can be used to improve user service perception in high-speed movement scenarios:

Relatively stable inner-circle policy:	Fixed cyclic codebook:
A stable scheduling policy is used for mobile users to increase the success rate of one-time data transmission and improve mobile performance.	For high-speed users, the channel status is difficult to trace. Using a fixed cyclic antenna parameters codebook can obtain relatively stable performance.

Wide beam optimization:	Channel estimation correction:
Compared with narrow beams, wider beams can offset – to some extent – the performance degradation caused by beam loss in high-speed movement scenarios.	The current channel estimation result is corrected based on the historical moving track and channel information to improve the beamforming performance in the mobility scenario.

MU-MIMO SDMA pairing algorithm and QoS intelligent scheduling help enhance system capacity and capability

MU-MIMO is the basis for multi-user and multi-layer pairing optimization and enhancement of system capacity

MU-MIMO space division multiplexing includes multi-user space division multiplexing of PDCCH control channel and of PDSCH and PUSCH service channels:

PDCCH MU-MIMO space division scheduling can significantly increase the maximum number of users that can access the network.	MU-MIMO space division multiplexing capability for both PDSCH and PUSCH is fundamental to maximize network capacity and spectral efficiency.

In medium- and high-load scenarios, the following algorithms can be used to improve the efficiency and success rate of SDMA pairing, increase the number of streams for SDMA pairing, and enhance the cell throughput.

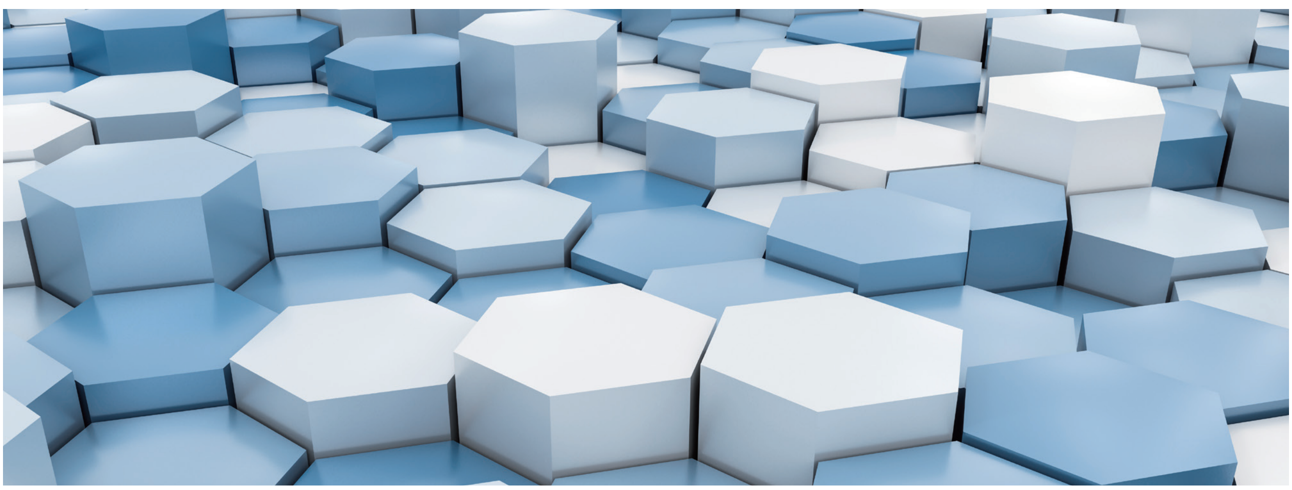
Optimization of the pairing between large packets and small packets:
As the types of 5G services are diverse, so are the sizes of the service packets. The optimization allows UEs with packets of different sizes to perform space division pairing for higher system capacity.

Rapid pairing optimization of UEs with high spatial isolation with one another:
Using user correlation information based on beam information related to the users and historical data of successful paring, direct space division pairing can be done for users under beams with relatively high isolation, so as to simplify and speed up the computing process of space division pairing, enhance the success rate of space division paring and thus the system capacity.

Intelligent downlink power distribution:
Among the MU-MIMO spatially multiplexed UEs, the near-point UEs can lend its extra power to the cell-edge UEs to improve their performance, thereby increasing the success rate of space division pairing.

QoS-based intelligent scheduling

Intelligent QoS scheduling enables different users or services to use different scheduling policies. For example, for VIP users and latency- or reliability-sensitive services, SU-MIMO transmission can be a preferable option, or using MU-MIMO transmission is also doable but strict SDM threshold needs to be in place to improve the success rate of SDM with guaranteeing the QoS of GBR users. On the other hand, MU-MIMO space division scheduling is preferable for enhancing system capacity and spectral efficiency for the services with lower requirements on latency or reliability.



Digital twin can help Massive MIMO realize intelligent value evolution of physical networks

With the introduction of the Massive MIMO technology, the coverage and capacity of wireless network in a three-dimensional space have been greatly improved with much improved flexibility as well. Many things are consequently more complex and therefore more difficult to predict, such as radio propagation, user distribution, service and traffic pattern, beam measurement and beamforming, which poses challenges for network problem identification, solution validation, and new feature introduction and optimization. How to predict the problems and find the optimal solutions even before the problems really happen? "Digital twin" can give us probably the biggest hope for finding the ultimate solution.

"Digital twin" is a term that first came out in the 1990s but the underlying idea and its practice actually were started much earlier than that. A digital twin is a digital replica of a physical entity. It leverages a wide variety of technologies, including internet of things, artificial intelligence, machine learning, big data, etc. to create digital simulation models that change as the physical entity changes. It constantly learns from the sources connecting to the physical entity, from historical knowledge and also from other systems, and updates itself accordingly in real time. It then provides feedback and insight on how the physical world can be optimized. Digital twin has its most popular application fields in manufacturing, automotive, healthcare, environment industry, etc.

Applying digital twin in 5G Massive MIMO can have basically three stages:

1. Network portraying:

   5G can collect more measurement data than ever before, such as DOA, RSRP/SINR, network load and service characteristics. Digital modeling of the external environment of network elements and service characteristics of to form portraits of network elements and users, and then a portrait of the network, mapping everything of the network into a digital model.

2. Twin simulation:

   The core algorithm of 5G products and even the codes are completely modeled on the digital twin simulation platform which is to be fed with real data stream input from the network portrait. The real performance of the network is replicated to the highest extent possible.

3. Intelligent closed loop:

   The closed loop between reality and simulation at every level is the essense of digital twin. It does not follow the traditional way that goes from modeling to simulation and to feedback, but instead offers real time and interactive capabilities. The digital twin can learn and correct all on itself, and give valuable feedback to the real physical world in real time. The digital world exists to serve the physical world. The physical world becomes more efficient and capable because of the digital world.

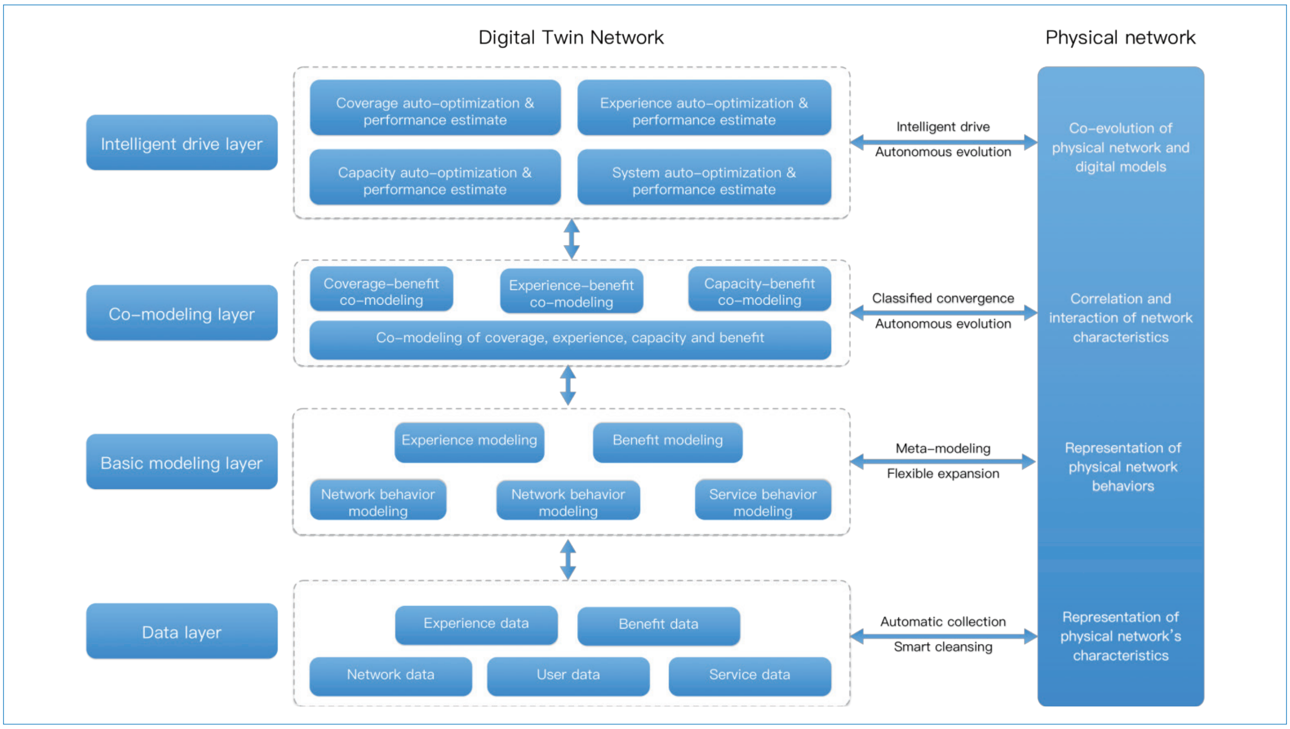


Figure 5 Mapping model of digital twin network and physical network

Digital network and physical network are integrated and interact with each other in real time. They work together to optimize the network design and deployment with respect to Massive MIMO.

1. The basic data layer of the digital twin needs to extract and collect data in both entire time and space domain, then form a model layer upwards after data cleansing.
2. The model layer is a key part of the simulation. It can be divided into a basic model layer and a model aggregation layer. The model aggregation layer centers around the three most critical performance dimensions of Massive MIMO: coverage, experience and capacity. It is closely linked to the operator benefit model to form a new paradigm of network operation. Any changes to the network will be evaluated against the new paradigm of network operations in the model aggregation layer, so that the network performance can be visualized, quantified, and evaluated.
3. Based on massive real-network data and self-optimized model, AI can be introduced to from a "intelligent drive" layer, which acts as a brain of both the digital and physical networks and constantly drives mutual verification of the two worlds with seamless integration. It can pave the way for creating more values for network operation, setting the right evolution path of the network, and making reliable predictions of network development.

The combination of Massive MIMO and digital twin can give us a brighter future, but there are huge technical challenges to address, including collecting and cleansing of massive data, prediction of user environment and service behavior, integration of real product algorithms or code models, and subtle yet critical changes of the network device characteristics. On the other hand, the very nature of this complexity of Massive MIMO network makes its coupling with digital twin an even greater potential. The supporting technologies of digital twin are also developing, including network data collection, big data, link and system simulation, network simulator, and automatic control system. With the implementation of digital twin, these tools will continue to evolve and converge with the platform to realize the intelligent value evolution of the Massive MIMO network.

Summary and expectation

With its powerful beamforming capability, the Massive MIMO technology has become a core technology of 5G. Massive MIMO plays an important role in all key aspects, including network coverage, user experience and network capability of 5G network, to guarantee the development and value operation of the network.

Meanwhile, with the introduction of digital twin concept, the behavior pattern of network, service, terminal, and algorithm in the physical world can be accurately modeled to enable parameter adjustment, solution customization, and automatic evaluation, which helps allocate network resources to the most critical and/or valuable users and services, with maximized utilization efficiency. For example, comprehensive modeling analysis and value evaluation based on coverage, traffic, user behavior patterns can automatically focus coverage capabilities to the areas with the highest value. Via the closed-loop interaction of the physical world and the digital simulation, quick iteration and evolution of solution and service capabilities can be achieved.

Looking ahead, higher network capacity, better performance experience and more network capabilities will all rely on having more spectrum resources and/or more efficient use of the existing spectrum resources, for which Massive MIMO will still play a key role. 3GPP has extended the scope of 5G system frequency bands to the millimeter-wave frequency band of 6 to 100 GHz. In this frequency range, a large number of continuous frequency bands are available, yet achieving good network coverage and performance over these bands can be challenging. This requires the use of Massive MIMO to form high directional and high gain beams under the constraints of factors such as complexity, cost and power consumption. The ever-growing number of new services enabled by 5G and future generations of mobile network technologies will continue to have higher requirements on network capacity and performance. Massive MIMO has already been adopted on a large scale in the 5G network and will surely play a key role in network development and evolution.

Glossary

CQI	Channel Quality Indicator
CSI-RS	Channel State Information Reference Signal
DMRS	Demodulation Reference Signal
DOA	Direction of Arrival
GBR	Guaranteed Bit Rate
MU-MIMO	Multi User MIMO
PDSCH	Physical Downlink Shared Channel
PMI	Precoding Matrix Indicator
PUSCH	Physical Uplink Shared Channel
QoS	Quality of Service
SDMA	Space Division Multiple Access
RSRP	Reference Signal Received Power
SINR	Signal to Interference plus Noise Ratio
SRS	Sounding Reference Signal
SSB	Synchronization Signal and PBCH block
SU-MIMO	Single User MIMO
3GPP	3^{rd} Generation Partnership Project

中兴通讯股份有限公司
ZTE CORPORATION

NO.55, Hi-tech Road South, ShenZhen,P.R. China
Postcode:518057
Website: www. zte. com. cn
Tel:+86-755-26770000
Fax:+86-755-26771999