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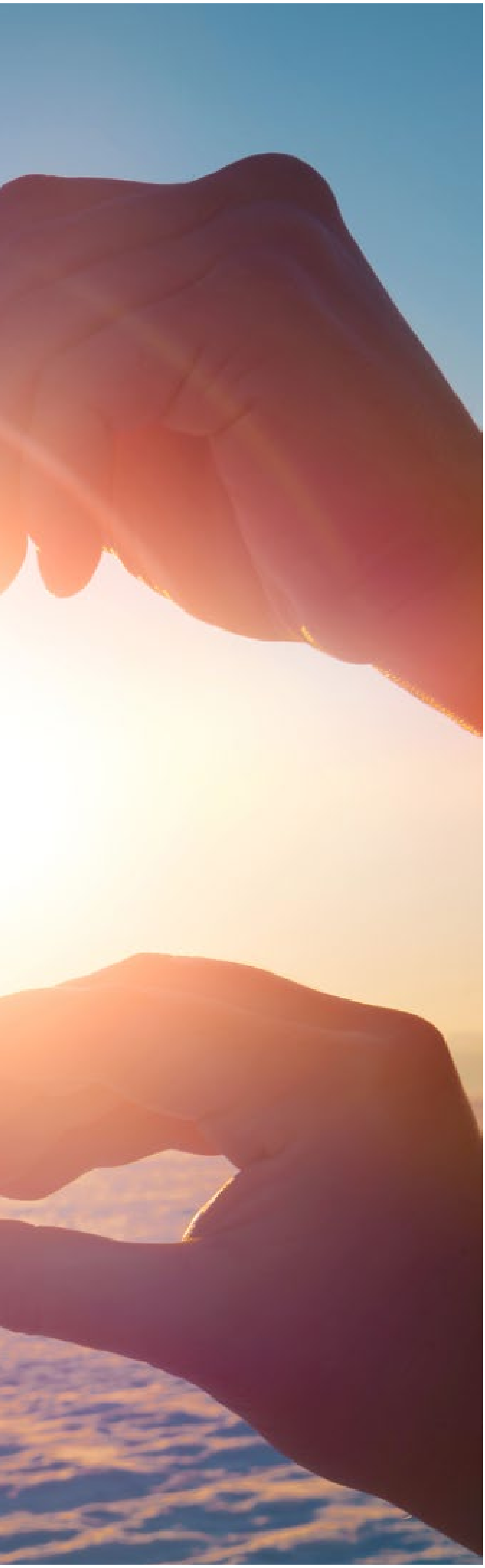
Huawei 5G Wireless Network Planning Solution White Paper



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1.1 3GPP Visions & 5G Use Cases

Mobile communications has brought about profound changes in people's lives. In order to cope with a burst of traffic growth in 2020, the industry is witnessing the arrival of massive device connections, and emerging new services and scenarios, and celebrating the fifth generation of mobile communications.

The future 5G mobile applications defined by the International Telecommunication Union (ITU) in June 2015 are categorized into three types:

- Enhanced Mobile Broadband (eMBB): Facilitating people-to-people exchange is the fundamental requirement set out for mobile communications. eMBB featuring larger bandwidth and shorter latency focuses on the improvement of a user's perceived experience.
- Massive Machine Type Communication (mMTC): With everything increasingly interconnected, Internet of Things (IoT) and other vertical industries will bring about a large number of wireless sensor networks, posing high requirements on network access quantities and power consumption efficiency.
- Ultra-Reliable and Low-Latency Communication (uRLLC): Automated driving, telemedicine, smart grid, and other vertical industries require high reliability and low latency.

3GPP Technical Specification Group, Service and System Aspects (TSG-SA) have studied potential 5G services, markets, application scenarios, and possible enabling technologies. Based on the three scenarios defined by the ITU, the scope of application for 5G is further summarized as follows: enhanced mobile broadband, industrial control and communications, large-scale IoT, and enhanced Internet of Vehicles (IoV).

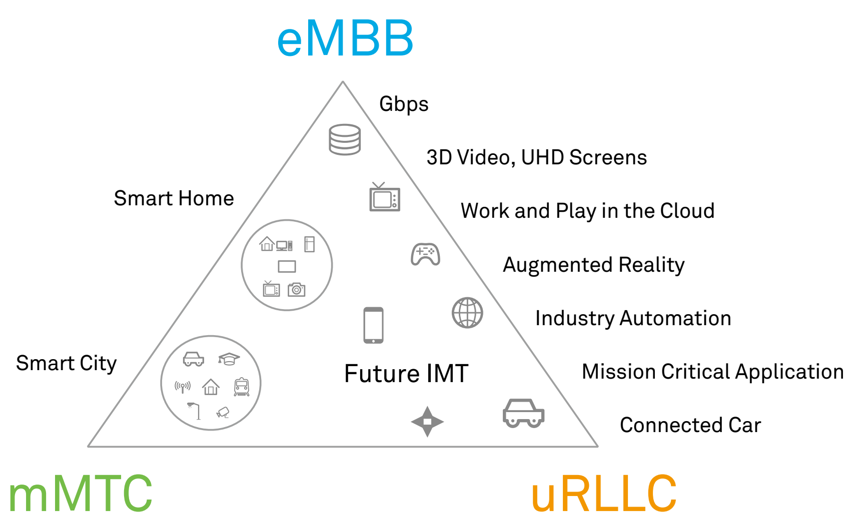
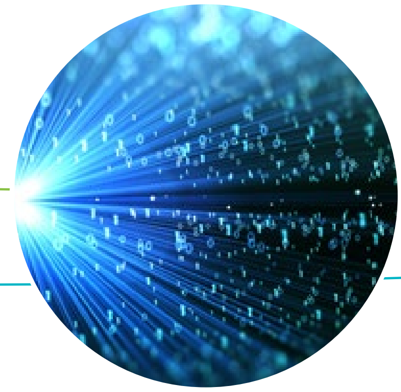


Figure 1-1 Three types of 5G application scenarios



1.2 Challenges Faced by 5G Wireless Network Planning

New cross-generation standards in terms of spectrum, new radio, and network architecture have been developed to support a myriad of future 5G application scenarios. However, these new standards and technologies also pose several challenges to 5G wireless network planning.

1.2.1 Challenges Raised by New Frequency Bands

In order to meet the requirements of massive connections and ultra-high data rates, 5G networks are designed to be deployed in high frequency bands, such as 28 GHz and 39 GHz (attracting industrywide attention) in addition to sub-6 GHz bands. Compared with the radio propagation features of low frequency bands, the signals in high frequency bands are more susceptible to issues such as architecture materials, vegetation, rain attenuation, and oxygen attenuation. For instance,

» In the line of sight (LOS) and non-line-of-sight (NLOS) scenarios, the link loss in high bands is 16–24 dB and 10–18 dB, respectively higher than that in low bands.
» In the same frequency band, the link loss caused in NLOS scenarios is 15–30 dB more than that in the LOS scenarios.
» In the High Loss and Low Loss scenarios, the penetration loss in high bands is 10–18 dB and 5–10 dB, respectively higher than that in low bands.

On top of that, the spectrum usage rules and constraints (such as licensing and admission policies) vary with different frequency bands, which further complicates the process of spectrum planning.

Based on the preceding premise, new research topics brought by the new frequency band are as follows.

» Establish a basic database regarding the propagation features of high frequency bands, and identify a coverage capability baseline.
» Build adaptive propagation models that adhere to different materials and classify scenarios based on the high-precision of electronic maps.
» Develop accurate and efficient ray-tracing propagation models applicable to high and low frequency bands.
» Develop intelligent spectrum planning to utilize various types of available spectrum resources.

In addition, higher accuracy of site location and engineering parameter planning is required to compensate for the limited coverage scope of a 5G high-frequency network. The high-precision of 3D modeling and ray-tracing propagation models can accommodate for the demanding technicalities involved in the many different stages of planning. However, these technologies can inadvertently reduce simulation efficiency and increase overall engineering costs.

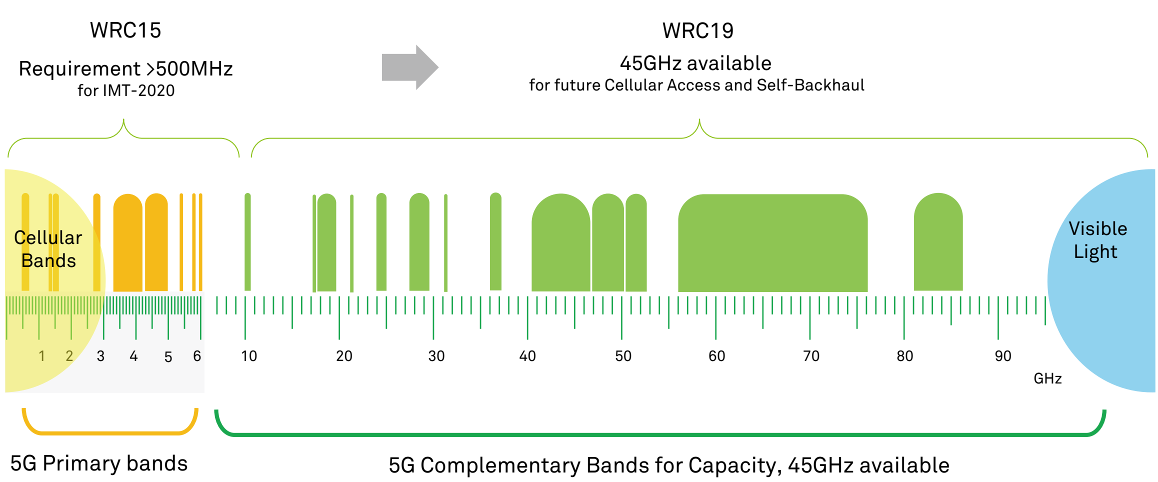


Figure 1-2 5G full-spectrum access

1.2.2 Challenges Raised by 5G New Radio

Massive MIMO is one of the most important 5G technologies. It will significantly change the traditional network planning, which is based on sector-level wide beams. The antenna pattern of Massive MIMO is no longer a sector-level fixed wide beam, but has been replaced with user-centric dynamic narrow beams instead. In order to improve spectral efficiency, MU MIMO is introduced to simultaneously enable multiple users with low beam correlation to share the same frequency.

It is growing increasingly obvious that traditional network planning cannot meet the Massive MIMO requirements on planning and prediction of coverage, data rate and capacity. Therefore, in response to such mounting requirements, it is necessary to pursue the following areas of further research and design. 3D precise modeling of the Massive MIMO antennas: beam modeling for channels such as SSB, CSI, and PDSCH

» Simulation modeling of network coverage and data rate: electrical level, inter-cell interference, mobility speed, and single-user (SU) MIMO Network capacity and user experience modeling: correlation between users and its impact on MU pairing probability and link performance, as well as the experience rate modeling for multiple users
» Scenario-based Massive MIMO pattern planning and optimization: Improve network performance by identifying the most effective and optimal pattern.

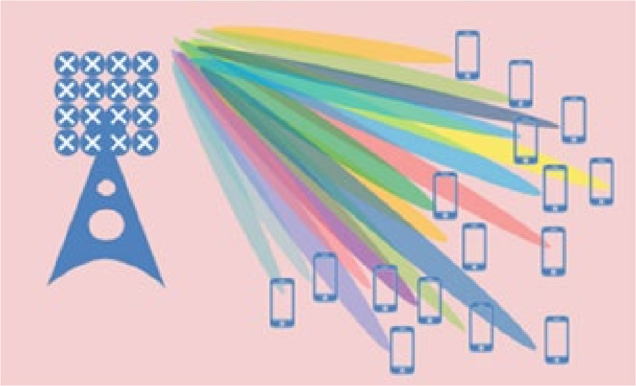


Figure 1-3 Patterns of Massive MIMO antenna

1.2.3 Challenges Raised by 5G Services

User experience-centric network construction is gaining support and has received widespread consensus throughout the industry. xMbps, video coverage, and other construction methods that prioritize user experience have been widely applied for 3G/4G networks. User experience-centric network construction aims to satisfy user experience requirements. The key functions involved in network planning are service identification, experience evaluation, gap analysis, and simulation and planning. According to the characteristics of service experience requirements, different 5G services have different requirements.

- uRLLC services have high requirements on latency (1 ms) and reliability (99.999%).
- mMTC services have high requirements on connection quantity, power consumption, and standby time.
- eMBB services require that the mobile network provide a favorable user experience for new services such as augmented reality (AR) and virtual reality (VR).

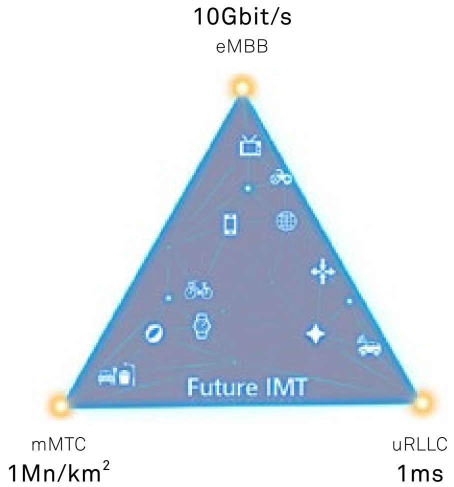
In terms of the experience requirements of new 5G services in standby, latency, and reliability, the evaluation method, planning solution, and simulation prediction are currently unavailable or in the very early initial stages. Therefore, it is rather difficult to satisfy the experience requirements at this current level of development.

1.2.4 Challenges Raised by 5G Applications

Since a large number of new services are introduced, the application scope of 5G networks has been extended to a larger extent than that of traditional mobile networks. New 5G applications are as follows.

- Mobile hotspot: The data rate of eMBB services can increase to 100 Mbps or higher and the huge influx of crowds and people flowing through such areas will create a need for a larger number of mobile hotspot scenarios. To address the situation, planning solutions that support ultra-dense networking is required.
- IoT: New IoT services are provided for various vertical industries, such as smart meter reading, smart parking, and Industry 4.0. The applications have extended far beyond the scope of human daily activities.
- Low-altitude or high-altitude coverage: Many countries have clearly proposed to provide coverage and supervision for low-altitude drones through mobile communications networks. 5G can be deployed to provide high-speed data services and network coverage for aircrafts on high-altitude routes.

For these applications, propagation characteristics and networking solutions are still not being touched upon and related research must be carried out.



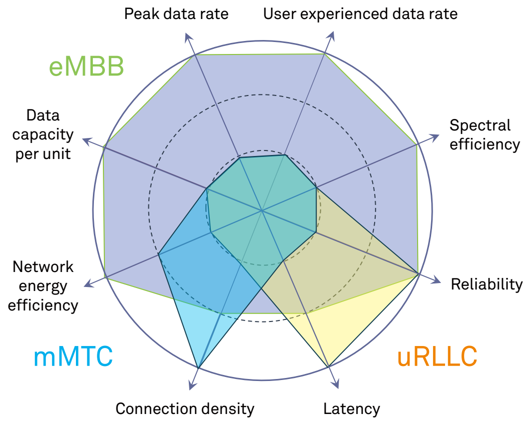


Figure 1-4 Technical requirement differences brought by diversified 5G services

1.2.5 Challenges Raised by 5G Network Architectures

With the growing focus on user experience, networking planning has undergone an evolution from network-centric coverage and capacity planning to user-centric experience planning. The network architecture is also developing towards cloudification. In addition to using network slices for quick service orchestration and deployment, real-time resource configuration and scheduling are also newly introduced features. However, these new capabilities will require a great deal of improvement in terms of network planning.

- Network slice-based network planning (single and multi-slices)
- User-centric dynamic network topology design, planning, and simulation
- User-centric channel resource cloudification modeling, and planning of dynamic topologies and coordination-based features for ultra-dense networks

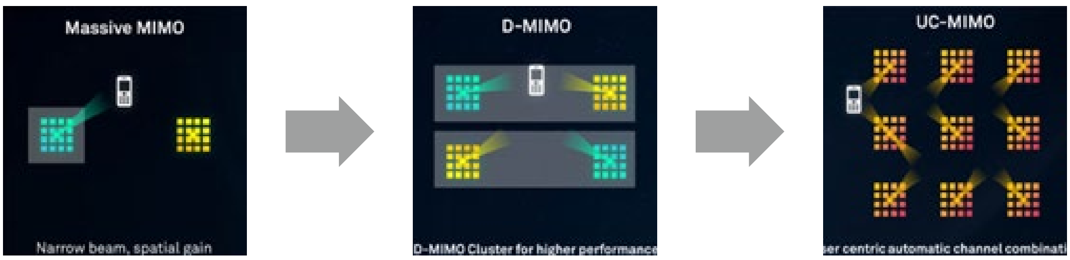


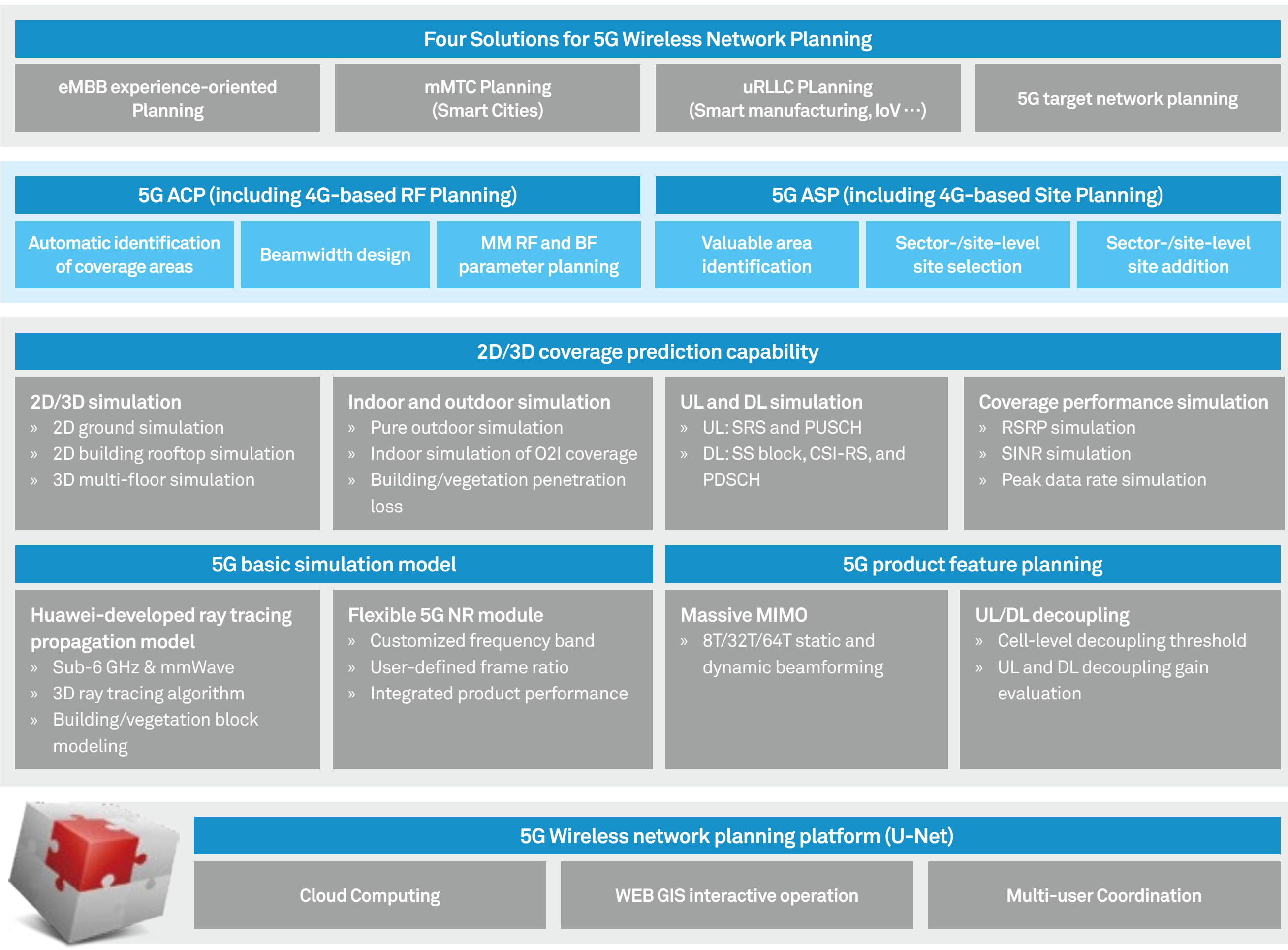
Figure 1-5 User-centric dynamic network topology design and planning

02 Huawei 5G Wireless Network Planning Solution

2.1 5G Wireless Network Planning Solution

Huawei has launched research into new 5G technologies, services, and scenarios, and built several network planning solutions and key technical capabilities to support the construction of efficient and cost-effective wireless networks.

Figure 2-1 Huawei 5G wireless network planning solution



2.2 Key Capabilities

2.2.1 High-Precision 5G Propagation Model

Ray-Tracing Propagation Model

Compared with traditional 3G/4G networks, 5G networks will be more complex. With the emergence of Massive MIMO and beam forming technologies, multipath modeling is of greater importance. However, due to the lack of multipath information at a high level of granularity, the accuracy of network planning is hard to guarantee. Therefore, a ray-tracing propagation model established upon high-precision electronic maps and multipath modeling plays an irreplaceable role in 5G wireless network planning.

The beam-based ray-tracing propagation model (independently developed by Huawei) includes the following types of features.

- Direct radiation: The transmitter and receiver are not affected by tall buildings or dense vegetation in the first Fresnel zone. The direct radiation power constitutes the main power source of the received signals. The power of the signals reflected by grounds or walls can be ignored.
- Reflection: When reflection occurs, the incident ray, reflection ray, and reflection point are in the same plane. The angle between the incident ray and the reflection point is equal to the angle between the reflection ray and the normal line of the reflection point. The ray-tracing reflection model is established based on the preceding description.
- Diffraction: The condition of diffraction concurrence is related to the wavelength of the electromagnetic wave and the size of the obstacle edge. Diffraction can bring great propagation power in sub-6 GHz bands. However, when the frequency band is 10 GHz or higher, the number of edges that can produce diffraction is reduced, and so is the resulting power generated by diffraction.
- Signal transmission: The transmission and reflection of electromagnetic waves occur at the junction of two kinds of media. The transmission energy is related to the dielectric constant and permeability of the penetrated material.
- Combined paths (diffraction after reflection and reflection after diffraction): The transmission mode of multiple paths combined cannot be marginalized. It is also a potential candidate power propagation method that can be used for the ray-tracing propagation model.

The Huawei ray-tracing propagation model can automatically identify the preceding electromagnetic wave propagation paths based on the high-precision electronic map and the position of the receiver. This can lead to higher accuracy during network planning.

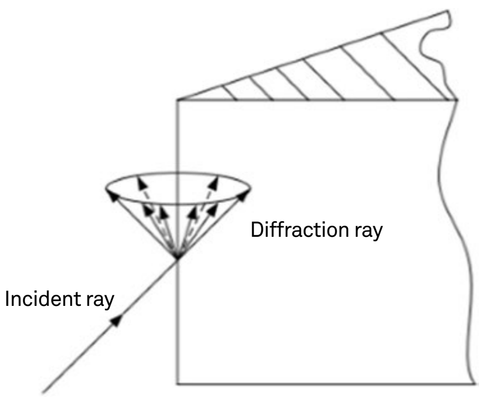


Figure 2-2 Schematic of the edge diffraction of the ray-tracing propagation model

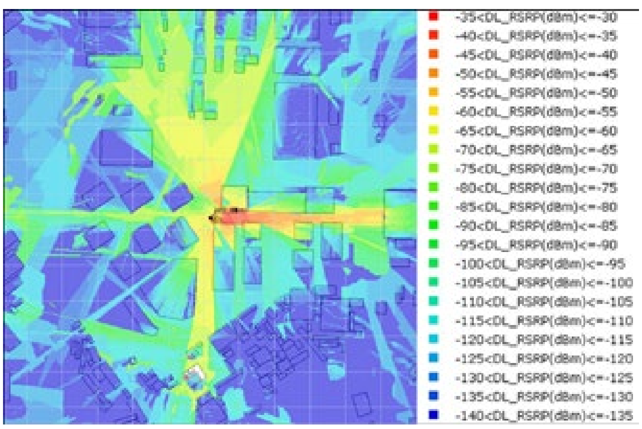


Figure 2-3 Coverage prediction effect of Huawei ray-tracing propagation model

UMI and UMA Propagation Models

The high-frequency and experience-centric propagation model released by 3GPP does not include environmental features. These include the height of transmitters and buildings, and road width, nor does it consider signal loss caused by trees, oxygen attenuation, rain attenuation and other factors. In addition, the range determined by the receiver's height is still relatively small and limiting.

In order to develop a high-frequency propagation model featuring higher simulation efficiency and accuracy, Huawei has studied radio propagation characteristics of different frequency bands across different scenarios. Compared with the model released by 3GPP, the Huawei release has taken more factors into account and has worked hard to improve upon many areas of network planning. This includes important aspects such as the height coefficient of the receiver/transmitter, location features of the receiver, and outdoor-to-indoor (O2I) penetration loss.

2.2.2 High-Fidelity Modeling of Product Features

Massive MIMO Modeling

Massive MIMO, one of the main 5G features, uses beamforming to form extremely precise user-centric ultra-narrow beams. It aims to project power to user locations, thereby improving coverage and reducing inter-cell interference. Through in-depth research, Huawei has implemented high-fidelity modeling for Massive MIMO. This will help ensure that the coverage simulation effects are as close to actual scenarios as possible.

Massive MIMO antenna beams are classified into static and dynamic beams. Static beams: Beams can be generated in advance based on the antenna structure and beamforming weight to facilitate planning and simulation.

Dynamic beams: Multipath identification can be implemented by using the ray-tracing propagation model. User-centric dynamic beams are formed based on multiple paths and measurement results, which is similar to onsite scenarios.

- Multi-path identification: The propagation path between transceivers is calculated using the ray-tracing propagation model to identify multiple paths. Then, the propagation loss is calculated for each individual path.
- Dynamic beamforming: Dynamic weight matrices are calculated based on the measurement results of the multiple paths. Different beams are directed to different UEs based on the calculation results.
- MU space division multiplexing: Spatial multiplexing and related calculations are supported to maximize system capacity.

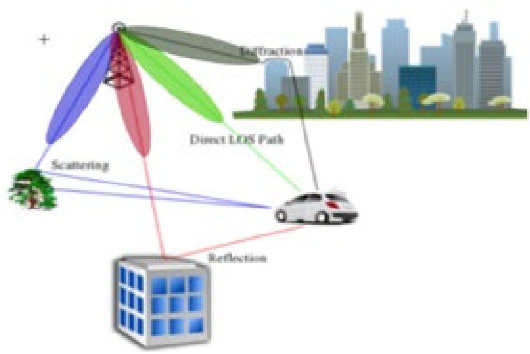


Figure 2-4 Dynamic beam

SUL Modeling

Radio network coverage is determined by both the uplink and downlink. Therefore, the uplink and downlink must be balanced. Generally speaking, the transmit antenna gain of the base station is large and its power amplifier consumes high levels of power. However, because of the limited volume of terminals, the antenna and the power amplifier cannot be set to high specifications, which results in constrained uplink coverage in most cases. The uplink and downlink decoupling feature intends to separate uplink and downlink of 5G networks onto different frequency bands. It is allowed to configure a low frequency band for the uplink to resolve the issue of limited uplink coverage.

Based on the actual measurement and research of the uplink and downlink decoupling feature, Huawei designs a complete coverage simulation and RF parameter planning solution for the feature.

2.2.3 Refined Coverage Prediction

Overview

Coverage prediction is the most commonly used approach to evaluating network coverage, as well as the foundation of network planning. Currently, Huawei is capable of simulating network coverage for typical 5G services and scenarios (such as eMBB) and many others:

» Coverage in frequency bands including 3.5/4.5/28/39 GHz
» WTTx, outdoor hotspot scenarios, and so on

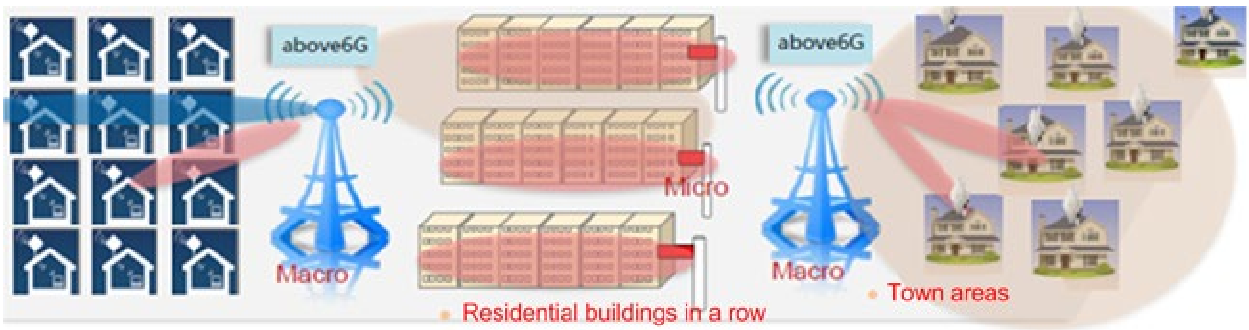


Figure 2-5 WTTx scenarios

» Propagation models, such as Huawei ray-tracing propagation model, and UMI and UMA propagation models
» Static beamforming and dynamic beamforming of Massive MIMO
» Signal level, interference, signal quality, and uplink and downlink throughput of the pilot, broadcast, control, and traffic channels

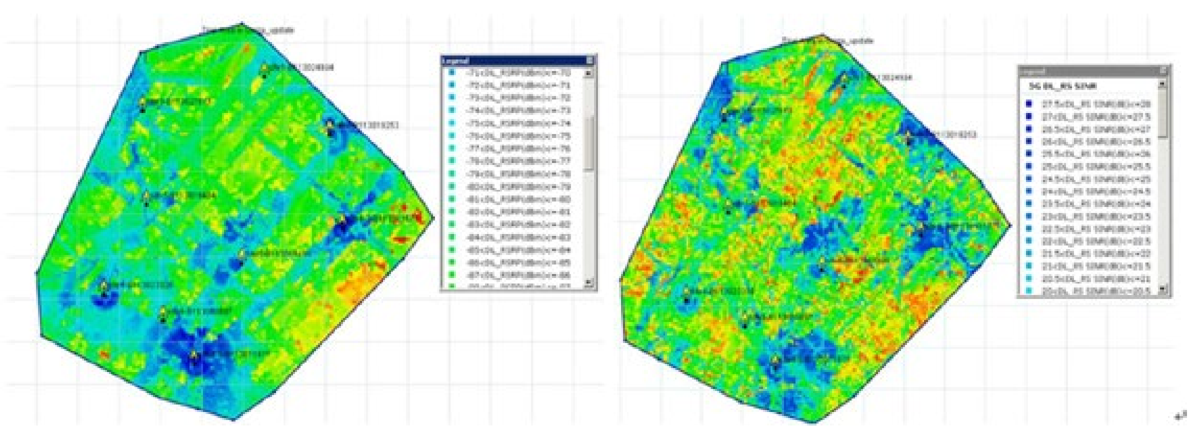


Figure 2-6 Prediction results of DL RSRP and DL SINR provided by U-Net

» Inter-site and inter-UE interference caused by different uplink-downlink frame setting in a cell
» Coverage prediction after the penetration loss caused by an unspecified number of different materials is taken into consideration

3D Coverage Prediction

In the future, more and more traffic will occur indoors. Therefore, 3D planning and simulation technologies are crucial to 5G network construction. Huawei has developed the 3D coverage prediction function to extend the simulation range from a traditional 2D plane to a 3D space. Multiple coverage indicators on different floors can be displayed.

» 3D space modeling: Use an electronic map providing important information for large structures (location, silhouette, and height) to construct a 3D model.
» 3D propagation model: 3D simulation and 2D outdoor simulation differ greatly in terms of the radio signal propagation environment. Therefore, the traditional propagation models cannot be used and the modeling of radio signal penetration and transceiver height need to be established.
» 3D prediction: signal level, interference, signal quality, throughput and others of the pilot as well as the traffic channels can be predicted in 3D scenarios.

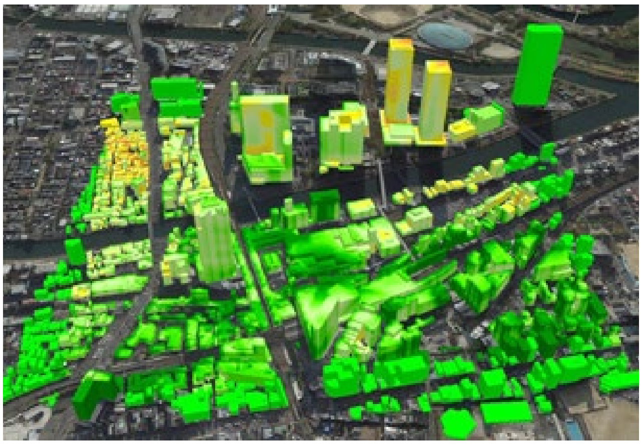


Figure 2-7 3D coverage prediction result provided by Huawei U-Net

2.2.4 Automatic Cell Planning (ACP)

Massive MIMO is one of the main 5G features. Precise planning of radio frequency (RF) and beamforming (BF) parameters plays a crucial role in 5G network construction.

Figure 2-8 Traditional antenna pattern & Massive MIMO

Massive MIMO antenna beams are classified into static and dynamic beams. 5G static broadcast beams cover the entire cell using the narrow-beam polling mode. Narrow beams are transmitted over proper time-frequency resources, while broadcast beams can be configured based on the coverage scenario.

Huawei's ACP solution is equipped with the following capabilities to help plan RF and BF parameters for Massive MIMO antennas.

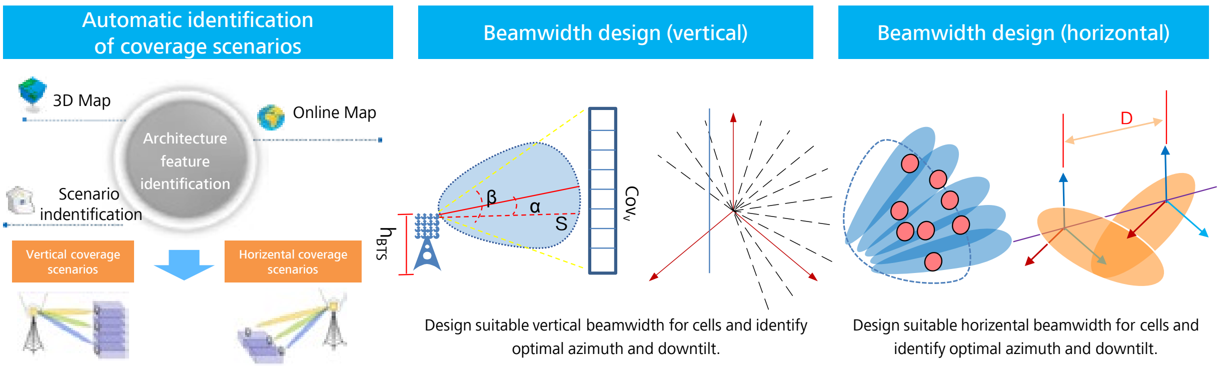


Figure 2-9 ACP functions for precise RF parameter planning

» Accurately identifies building scenarios based on high-precision digital maps or online maps (optional).
» Determines the optimal height, azimuth, and downtilt angle of Massive MIMO antennas after collecting all curve statistics and checking whether buildings at such a height will block signals. Identifies the vertical and horizontal beamwidth based on the building silhouette, height, and traffic distribution to ensure that traffic is evenly distributed on horizontal beams.
» Repeatedly generates the best set of RF and BF parameters for new sites.
» Supports simulation and grid-level geographical displays of coverage based on the latest planning results.

2.2.5 Accurate Site Planning (ASP)

In the 5G era, sites are growing more and more densely deployed. Customers are in urgent need of accurate site planning solutions to help slash network construction costs. During the initial stages of network deployment, existing 3G/4G sites are preferentially recommended as the candidate sites for 5G networks. Then, it is necessary to identify the specific sites according to the use of target networks. For example, in areas where existing sites fail to meet the current requirements for network construction, further planning of new sites is required.

The ASP solution provided by Huawei supports customers in selecting candidate sites or designing new sites in efforts to realize network construction objectives (such as coverage and throughput). The solution's functions are including but not limited to the following.

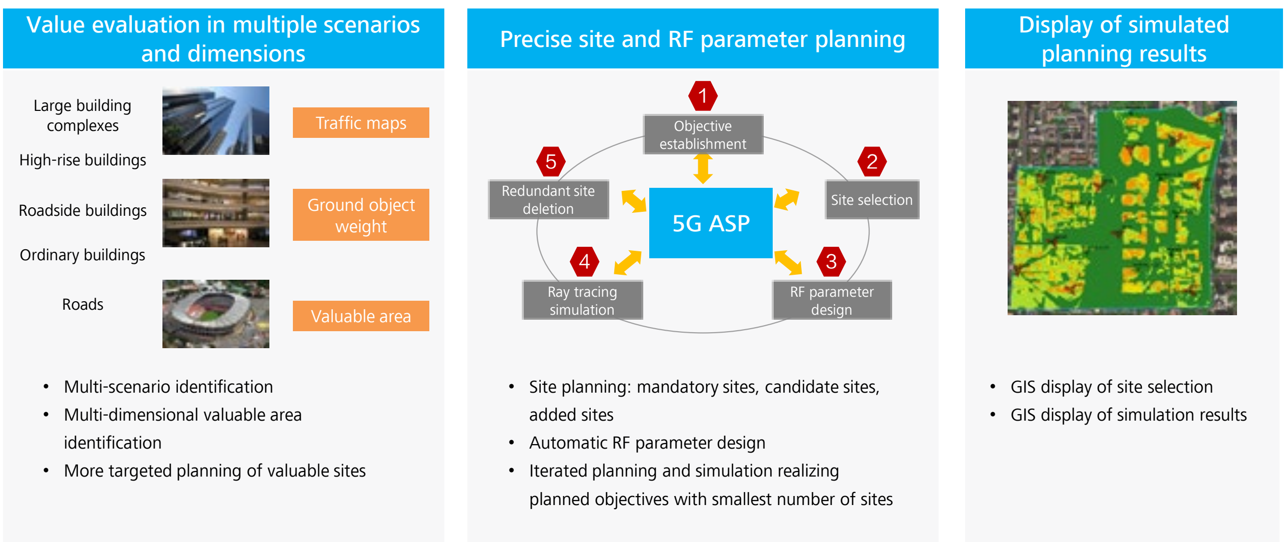


Figure 2-10 ASP functions for precise site planning

» Supports sector/site-level site selection based on the precise identification of scenarios and value.
» Supports sector/site-level new site planning based on precise identification of scenarios and value.
» Predicts the gains that uplink and downlink decoupling generates for 5G new sites and specifies the decoupling threshold of cells.

2.2.6 Research on Network Planning for New Service Experience

According to 3GPP specifications, three types of 5G services (eMBB, mMTC, and uRLLC) will emerge in the future. uRLLC services have high requirements on latency and reliability. mMTC services require a high level of connections, power consumption, and standby time, while eMBB services are best supported by high data rates. In order to meet user experience requirements in terms of standby time, latency, reliability, and connections, Huawei has studied the features of 5G new services (such as VR, smart driving, and drones) and their requirements on wireless networks.

VR

The 360° VR service provides real-time video streaming over multiple paths. The required network bandwidth varies according to the experience level. In order to offer the ultimate experience rate, the minimum network data rate must be as high as 4.2 Gbps. The following table lists VR technical requirements on network bandwidth.

During the stages of 5G network planning and construction, it is of paramount importance to ensure that the indoor network coverage can meet the user experience requirements of 360° VR services.

	Preliminary	Basic	Supreme
Resolution per eye	5037x5707ppi	5037x5707ppi	5037x5707ppi
Frame rate	25~30 fps	50~60 fps	100~120 fps
Bit/pixel	8 bit	10 bit	12 bit
Half-screen	Approx. 70 Mbps	Approx. 175 Mbps	Approx. 350 Mbps
360°VR	Approx. 840 Mbps	Approx. 2.1 Gbps	Approx. 4.2 Gbps

Table 2-1 VR requirements on network bandwidth

Smart Driving

Smart automobiles and driving are emerging trends against the background of a new round of scientific and technological revolution. Smart driving has great potential in reducing traffic accidents, improving road and vehicle utilization, while helping to cut operating expense. It has become a very important new service and application scenario for 5G networks. However, the E2E transmission delay varies with the degree of driving automation. The following table lists the specific key performance indicators. Smart driving poses high requirements on the transmission latency, reliability, and data rate of 5G networks. In smart driving scenarios, 5G network coverage can be affected by various factors, such as road conditions, other vehicles, and travelling speed. This describes an urgent need for more complex and refined scenario-based planning solutions.

Level	Automation Degree	Transmission Latency (ms)	Transmission Rate per Vehicle (Mbps)
1	Assisted driving	100-1000	0.2
2	Partially automated	20-100	0.5
3	Conditionally automated	10-20	16
4&5	Highly/fully automated	1-10	100

Table 2-2 Technical requirements for smart driving

03 Application Cases

North America, Japan, Korea, China, and the European Union (EU) are very positive about the large-scale commercial use of 5G. A number of operators from these countries have already begun the small-scale construction and verification of pre-commercial networks. As a major 5G equipment supplier, Huawei has cooperated extensively with several of these operators in the new field of 5G wireless network planning.

3.1 Low-Band Networking and Planning Case

Challenges Faced by Customers

In the 4G era, operators have quickly provided 4G services to achieve a significant growth in market share. With the advent of the 5G era, operators will constantly strive to maintain a leading position in the market. By deploying continuous-coverage 5G networks ahead of their rivals, operators are able to offer subscribers a high-speed 5G eMBB experience, while continuing to improve both company brand and market position. Compared with 4G networks, 5G networks have been greatly enhanced, which requires further exploration into the most current and up-to-date network planning experience and methods. Customer executives have even been known to comment that network planning technology is a troubling issue, a great concern to the entire industry. These executives have expressed high hopes that further cooperation with Huawei will lead to the pursuit of greater research and development.

Huawei's Network Planning Capabilities and Solutions

In the field of trial network construction, Huawei provides a software platform (U-Net) and planning solutions to help customers quickly build 5G networks.

» Based on the high-precision ray-tracing propagation model and the coverage prediction functions (solely developed by Huawei), U-Net can accurately simulate the coverage effect in different scenarios. This includes examples such as central business districts, densely populated urban areas, residential areas, and high-speed railways. It is a useful solution to help customers evaluate network performance of different networking solutions, and will go a long way towards substantially slashing customers' costs.

» The Huawei ASP solution is capable of selecting 5G site position based on 4G sites and providing invaluable guidance on the most ideal configuration of antenna azimuth and downtilt. This can ensure the best network topology and network coverage.

» The distributed computing technology of the U-Net software platform can help complete the network planning and simulation of increasingly complex and ultra-dense scenarios. The combination of electronic maps (with the high precision of 1 m), ray-tracing propagation model, Massive MIMO narrow beams, and inter-beam interference calculation will contribute to further higher efficiency in computing and network construction.

In January 2018, customers and Huawei jointly initiated the construction of 100 AAU trial networks in C-band and were successful in completing the network planning and deployment for five scenarios in three areas.

Based on Huawei's network planning solutions and U-Net platform, 5G site selection, RF parameter planning, and coverage evaluation in the test area have been confirmed. In addition, these tests have proven important in helping to generate new-found momentum with the verification of more than 20 AAUs currently underway.

According to the test results of the trial network, the accuracy of Huawei's 5G wireless network planning solutions is highly recognized. The RMSE and average error are within acceptable expectations, which consolidates Huawei's leadership position, especially in terms of accuracy.

3.2 High-Band Networking and Planning Case

Challenges Faced by Customers

A typical multi-dwelling unit (MDU) covered by operators' networks is shown in the following figure. A unit often has 10 to 30 floors, with 6 to 20 families living on each floor. The occupancy and user density is fairly high at about 400 users per building.

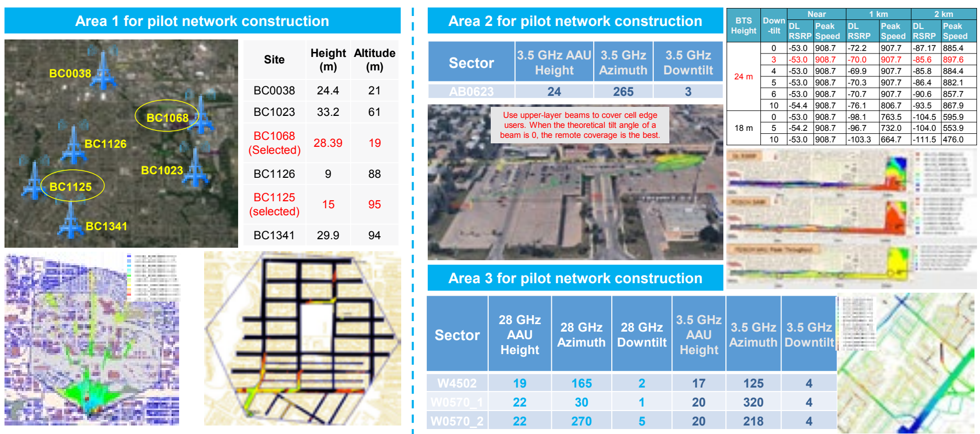
The network coverage for such high-capacity buildings is normally provided by digital subscriber lines (DSL) or cables. However, the installation of fiber optic cables tends to be hindered by architectural regulations and other real-estate related issues. Huawei has endeavored to switch to a more user-centric focus and has developed wireless to the x (WTTx) as an alternative viable solution. Based on Huawei's customer's requirements, the downlink peak rate of the WTTx network is as high as 1,000 Mbps and the average user throughput in the downlink can reach 25 Mbps during peak hours.

Figure 3-1 MDU coverage scenario

Huawei's Network Planning Capabilities and Solutions

» Prior to network construction, Huawei can help plan the candidate sites and RF parameters based on customers' requirements and provide coverage simulation results to efficiently reduce the total cost of experimental network construction.

Site Selection & RF Parameter Design: Simulation Facilitates Field Project Construction



Site	Height (m)	Altitude (m)
BC0038	24.4	21
BC1023	33.2	61
BC1068 (Selected)	28.39	19
BC1126	9	88
BC1125 (selected)	15	95
BC1341	29.9	94

Sector	3.5 GHz AAU Height	3.5 GHz Azimuth	3.5 GHz Downtilt
AB0623	24	265	3

BTS Height	Down-tilt	Near DL RSRP	Near Peak Speed	1 km DL RSRP	1 km Peak Speed	2 km DL RSRP	2 km Peak Speed
24 m	0	-53.0	908.7	-72.2	907.7	-87.17	885.4
	3	-53.0	908.7	-70.0	907.7	-85.6	897.6
	4	-53.0	908.7	-69.9	907.7	-85.8	884.4
	5	-53.0	908.7	-70.3	907.7	-86.4	882.1
	6	-53.0	908.7	-70.7	907.7	-90.6	857.7
	10	-54.4	908.7	-76.1	806.7	-93.5	867.9
18 m	0	-53.0	908.7	-98.1	763.5	-104.5	595.9
	5	-54.2	908.7	-96.7	732.0	-104.0	553.9
	10	-53.0	908.7	-103.3	664.7	-111.5	476.0

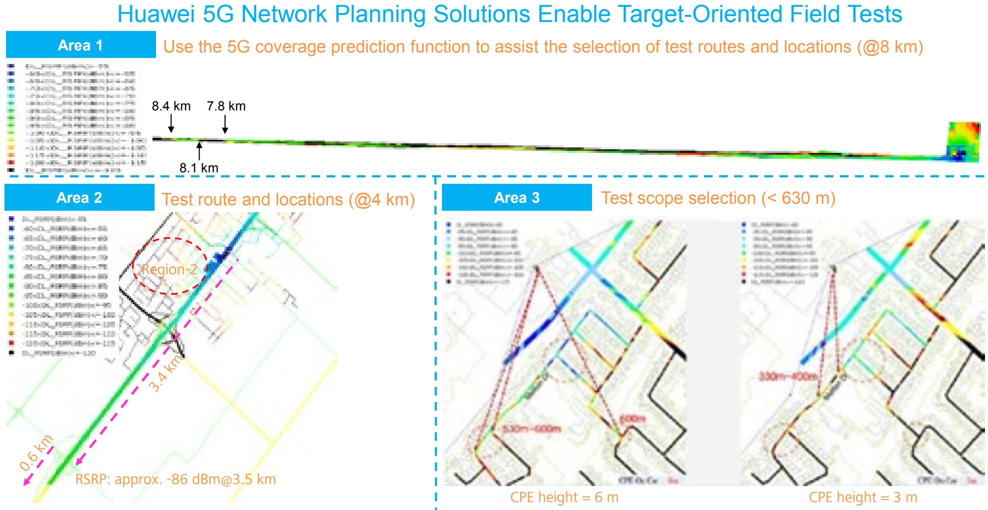
Sector	28 GHz AAU Height	28 GHz Azimuth	28 GHz Downtilt	3.5 GHz AAU Height	3.5 GHz Azimuth	3.5 GHz Downtilt
W4502	19	165	2	17	125	4
W0570_1	22	30	1	20	320	4
W0570_2	22	270	5	20	218	4

ASP and coverage simulation based on customers' network construction objectives

Precise ACP and coverage simulation

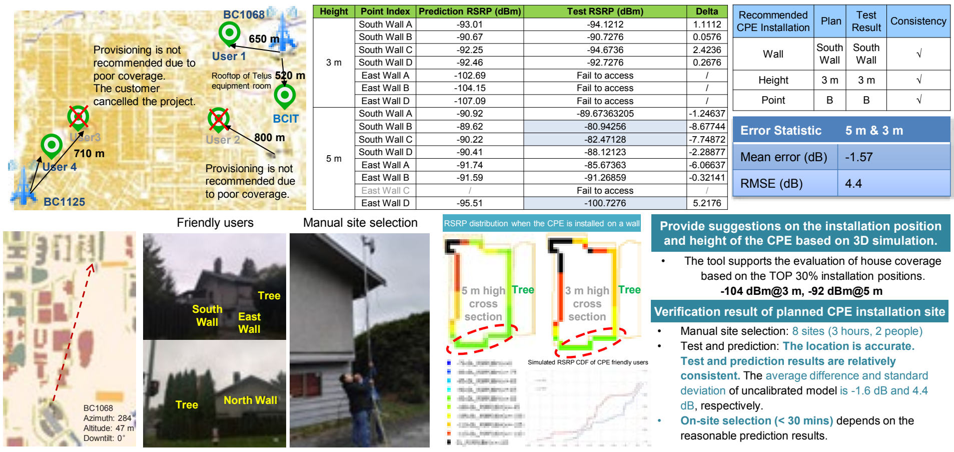
» After the network construction is complete, Huawei can utilize its coverage simulation capabilities to assist customers in selecting the best test routes or test locations. In such cases, invalid tests and verification of experimental networks will be reduced, as well as overall test costs.

Huawei 5G Network Planning Solutions Enable Target-Oriented Field Tests



» Furthermore, Huawei's 5G coverage prediction solution can help customers identify users with the highest data and determine the most ideal installation positions for CPE. The installation time of a single CPE is reduced from three hours to 30 minutes.

5G 3D Coverage Prediction: Accurately Locate Provisioning Positions and Facilitate Installation Site Selection (3 Hours Reduced to Less than 0.5 Hours)



Height	Point Index	Prediction RSRP (dBm)	Test RSRP (dBm)	Delta
3 m	South Wall A	-93.01	-94.1212	1.1112
	South Wall B	-90.67	-90.7276	0.0576
	South Wall C	-92.25	-94.6736	2.4236
	South Wall D	-92.46	-92.7276	0.2676
	East Wall A	-102.69	Fail to access	/
	East Wall B	-104.15	Fail to access	/
	East Wall D	-107.09	Fail to access	/
5 m	South Wall A	-90.92	-89.67363205	-1.24637
	South Wall B	-89.62	-80.94256	-8.67744
	South Wall C	-90.22	-82.47128	-7.74872
	South Wall D	-90.41	-88.12123	-2.28877
	East Wall A	-91.74	-85.67363	-6.06637
	East Wall B	-91.59	-91.26859	-0.32141
	East Wall C	/	Fail to access	/
	East Wall D	-95.51	-100.7276	5.2176

Recommended CPE Installation	Plan	Test Result	Consistency
Wall	South Wall	South Wall	√
Height	3 m	3 m	√
Point	B	B	√

Error Statistic	5 m & 3 m
Mean error (dB)	-1.57
RMSE (dB)	4.4

04 Conclusion

5G services in the future will be more diverse. Users can not only enjoy the ultra-high peak rate access through services such as WTTx, mobile ultra-high-definition videos, and VR/AR, but also have a taste of "zero" latency experience scenarios (smart driving and automatic industrial control). On top of that, massive connections (smart city, smart meter, and many more) enabled by 5G networks can help make people's daily lives more convenient and intelligent.

In order to meet multiple service requirements, 5G networks must be completely innovated in terms of frame structure, multiple access, channel coding, spectrum, and architecture. The entire process of network planning must be revolutionized and updated.

The first 5G pilot networks were constructed in Canada, Korea, and China from 2017 to 2018. Thanks to long-term technical research, Huawei has mastered the core technologies related to 5G network planning, such as propagation features and coverage simulation. In addition, Huawei has accumulated rich networking and planning experience through the construction of experimental 5G networks, and has been able to provide industry-leading 5G wireless network planning solutions.

5G standards, products, and service application scenarios are undergoing further exploration and development. Huawei's 5G solution team will continue to improve key technical capabilities, providing customers with the most comprehensive, efficient, and accurate solutions.

05 Terms

Acronyms/Abbreviations	Description
eMBB	Enhanced Mobile Broadband
mMTC	Massive Machine-Type Communications
uRLLC	Ultra-Reliable and Low-Latency Communications
LOS	Line of sight
NLOS	Non-line of sight
MM	Massive MIMO
O2I	Outdoor-to-Indoor
RF	Radio frequency
WTTx	Wireless to the x
BF	Beamforming
VR	Virtual reality
CBD	Central business district
AAU	Active antenna unit
UHD	Ultra-high-definition
AR	Augmented reality

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