GTI 5G Low-Cost Series Products -5G Femto Technical Requirements White Paper

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Document History

Date	Meeting #	Version #	Revision Contents
2023.8.30		V1.0	Initial Version

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Abbreviations

Abbreviation	Explanation
2G/3G	The 2nd/3rd Generation Telecommunication Technology
3GPP	The 3rd Generation Partnership Project
4G	The 4th Generation Telecommunication Technology
5G	The 5th Generation Telecommunication Technology
BS	Base Station
AI	Artificial Intelligence
DL	Downlink
UL	Uplink
LTE	Long-Term Evolution
NR	New Radio
MIMO	Multiple-Input Multiple-Output
CCSA	China Communications Standards Association
OMC	Operation and Maintenance Center
TDD	Time Division Duplexing
ARPU	AverageRevenuePerUser
SON	Self-Organizing Network
DSL	Digital Subscriber Line
CSG	closed subscriber group
IPsec	Internet Protocol Security
RRC	Radio Resource Control
PON	Passive Optical Network
PTN	Packet Transport Network
SPN	Service Provider Network
OAM	Operation Administration and Maintenance
ANR	Automatic Neighbor Relations
BARS	Broadband Remote Access Server

Introduction

5G, as a crucial infrastructure supporting the digitalization, networking, and intelligent transformation of the economy and society, plays a vital role in driving high-quality economic and social development. The construction of 5G networks is gradually transition to deepness and precise division, along with the continuous expansion of user scale and business application. Other than crowded places such as transportation hubs and bustling shopping malls, lots of indoor scenarios are not sensitive to capacity while strong demand on lower cost. For outdoor scenarios, the investment return rate on traditional macro site is too low for rural, mountainous and border areas where have a sparse population. The cost-effectiveness of 5G network construction in these scenarios needs to be improved immediately. In recent years, main problem in telecommunications industry is related on how to plan the performance of 5G network reasonably, how to relieve investment pressure, and how to improve the cost-effectiveness of 5G network construction. 5G network operators and equipment vendors focus on refinement and and cost-effective of network products, active on continuous innovation, develop a series of low-cost product solutions gradually, and build a ubiquitous and boutique 5G network.

Some typical scenarios of medium and low capacity, like residential buildings, small and medium-sized shops, etc., also face difficulties in property coordination and transmission construction. The 5G Femto has the characteristics of convenience and flexibility, plug and play, and controllable management, making it a cost-effective coverage solution.

This whitepaper delves into the development process of Femto cell, provides an overview of the industry's current state, analyzes the demand for key application scenarios, outlines the technical requirements for 5G Femto, and showcases typical demonstration applications. GTI aims to lead the high-quality development of the 5G Femto industry, accelerate industry innovation, strengthen fine-grained 5G network coverage, and drive the robust growth of the digital economy.

1. Overview

1.1. 5G Femto Development Process

3GPP divides 5G NR base stations into Wide Area Base Stations, Medium Range Base Stations, and Local Area Base Stations.

Table 1-1 Classification of 5G base stations

classification	Minimum coupling loss from base station to terminal（MCL）	Minimum coverage distance	Maximum transmission power
Wide Area Base Stations	70 dB	35 meters	/
Medium Range Base Stations	53 dB	5 meters	38dBm/per channel
Local Area Base Stations	45 dB	2 meters	24dBm/per channel

The 5G Femto described in this white paper is an local area base station,It can utilize fixed broadband or other IP networks transmission, plug and play, to achieve 5G deep coverage in indoor places such as homes, shops, small and medium-sized enterprises, and can also utilize satellite transmission to achieve continuous coverage of 5G signals in special scenarios such as sea areas, mountainous areas, and emergency situations at low cost and high efficiency, providing users with stable, safe, and high-quality wireless communication services.

Femto cell, also called home base station, originated from 3G. It is mainly proposed to address the indoor coverage shortage caused by the higher frequency band of 3G systems compared to 2G systems, as well as the challenge of diverting voice and data services from WiFi technology. The Femto Cell can access operator’s network by utilizing DSL, cables, or fiber, thereby enhancing indoor signal and data transmission rates. Compared with traditional base stations, Femto Cell is inexpensive and has become an important solution for improving indoor signals.

4G wireless data traffic has rapid growth, with 70% of business occurring in indoor scenarios. The rapid popularization of high-speed multimedia services has put forward higher requirements for network coverage and capacity. The traditional cellular network, which mainly relies on the coverage of macro stations, is prone to blind spots or insufficient coverage in some discrete indoor scenarios. The construction and operation costs of using macro stations are relatively high, and the difficulty of building property coordination using indoor distribution systems is high, resulting in large construction and renovation costs. As a new force in indoor coverage, 4G Femto

can make up for the lack of deep coverage in macro cells, increase the ARPU value of single users, and reduce the OPEX and CAPEX of operators. They have achieved rapid development in the 4G period.

in the 5G era, with the gradual popularization of applications such as ultra-high definition live streaming, video conferencing, online education, home monitoring, as well as cloud games and virtual reality, high-speed and low latency applications have become increasingly rigid demands, 5G Femto integrates new generation wireless communication technology, which can provide wireless communication services with higher speed, lower latency, and larger capacity. Combined with excellent network slicing and QoS guarantee capabilities, it can better meet the diverse network needs of various industries. At the same time, with the development of green energy conservation in the communication industry and the current global carbon neutrality background, low-power Femto can achieve network coverage and capacity through plug and play, which is more acceptable to users and has a broader development prospect.

1.2. 5G Femto Industrial Status

As a kind of cost-effective solution for indoor coverage enhancement, 5G Femto solution has reach the consensus of ICT industry. At first, the industry heat is now emerging. Secondly, industrial standard is gradually constructed and improved. Thirdly, chipset solutions are becoming more and more diverse. 5G Femto Products have matured and the industrial ecology is gradually prospering.

1.2.1. Standard Specification

3GPP began to work on the Femto base station (HNB) standard in 2007. Later, 3GPP 4G LTE named Femto base station as HeNB, and broadcast HeNB information to mark the type of HeNB station in the radio interface. It introduced the concept of CSG (Closed Subscriber Group) to support black and white name list based access and features of interoperability. At the same time, the optional HeNB GW function is introduced into wireless architecture to adapt to different backhauling network scenarios. In the 3GPP 5G NR standard, RAN4 has included the Femto RF index in the definition of Local area base station.

CCSA in China has developed a series of standards for TD-LTE Femto cell in the 4G era. In

2022, It has completed the technical research for 5G Femtocell , then launched the 5G Femtocell industry standard project in 2023. China Mobile has formulated enterprise standards for 5G Femtocell and gateway in 2023.

1.2.2. Chipset Solution

In the 4G era, There are mature chipset solutions, Broadcom, Qualcomm, Intel and other small base station chipsets have been widely used. 5G chip industry is in a high-speed development stage, and many manufacturers are committed to developing high-performance chipset supporting 5G technology to meet the needs of high-speed data transmission and low-latency communication.

At present, Qualcomm and NXP have mature chipsets for 5G Femto, and their chipsets and software have reached the commercial state. In addition, several chipset schemes of Smart Logic,Picocom and Ultichip in China have products or are under development. 5G Femto chipsets show a trend of increasing integration, evolving to a one-piece solution that supports multi-mode, multi-band and covers baseband and high-level protocol stack functions, making the equipment more compact and energy-saving, providing higher performance and capacity, and supporting various communication technologies to provide users with more comprehensive coverage and services. It is believed that with the development of 5G technology and semiconductor industry, more manufacturers may emerge in the future to launch new solutions.

1.2.3. Products

The miniaturization and flexibility of the 5G Femto make it an ideal low-cost solution to fill the coverage gap and provide high-speed data services. Operators and equipment manufacturers have announced corresponding solutions and products to embrace this expected market.

In 2022, China Mobile officially released the world's first 2.6GHz 5G Femto, and further released 4G/5G dual-mode commercial Femto product in 2023, which can achieve DL 800Mbps and UL 230Mbps throughput. NOKIA, SAMSUNG, T&W, SAGERAN, Baicells and other operators and equipment vendors have also released their 5G Femto series products. In addition, more and more vendors such as Comba and Ruijie have also joined the research and development program, promoting the further development of technology and equipment cost reduction.

2. Requirements Analysis

2.1. Residential Scenarios

As previously discussed, there are dual challenges in current residential scenarios. On the one hand, certain residential settings experience issues of weak coverage and blind spots. On the other hand, with the gradual widespread adoption of applications such as ultra-high-definition livestreaming, video conferencing, online education, cloud gaming, and even virtual reality, the demand for networks with high data rates, low latency, and extensive capacity has become an essential requirement.

Considering the inconvenience associated with deploying transmission lines within residential environments and the variable placement of devices, there is a notable demand for equipment deployment that is flexible, convenient, environmentally friendly, and energy-efficient. 5G Femto have the capability to leverage existing residential broadband networks for Backhaul, and enable the Plug and Play feature,they significantly mitigate the challenges and costs of deployment. This allows for the rapid attainment of comprehensive indoor coverage, while boasting attributes such as compact and aesthetically pleasing designs, low power consumption, and the capacity for effective management and control. As such, they stand as a preferred and optimal solution.

2.2. Retail Scenarios

With the widespread adoption of mobile smart terminals such as smartphones and tablets, along with the rapid proliferation of services like mobile payments, short-form video content, cloud gaming, and extended reality (XR), there is a pronounced demand for high-quality networks in various contexts. This demand extends to traditional retail spaces like shops, restaurants, and and business halls, as well as emerging venues like immersive gaming experiences and temporary

e-Sports competitions. These establishments seek robust network connectivity to enhance their brand image and provide finely-tailored customer services, thus unlocking additional avenues for business growth.

The retail environment is characterized by its inherent complexity and numerous internal partitions. It is susceptible to signal attenuation due to architectural obstructions and geographical barriers, leading to significant signal penetration losses and the emergence of signal dead zones within. In commercial zones with high foot traffic, wireless signal congestion can occur, significantly compromising the user experience. Addressing these discrete areas of weak coverage and blind spots using a distributed small cell approach often requires substantial investment. Moreover, installation work such as laying cables and drilling holes can disrupt the aesthetic appeal of store interiors, causing inconveniences for business owners.

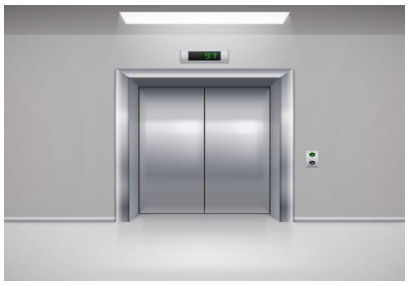
5G Femto does not require new transmission lines. by utilizing the existing broadband infrastructure, it's possible to achieve comprehensive coverage of retail spaces quickly and at a low cost, and deliver high-speed, stable, secure, and high-capacity networks, ultimately enhancing the user experience. 5G Femto with mmWave is attractive to offload traffic by co-channel deployment in this scenario, because the inter-cell interference is mitigated naturally by large penetration loss.

2.3. Isolated Island Scenarios

Limited spaces such as elevators and basements are enclosing environment, and outdoor macro and indoor base station signals can't penetrate in, so it is easy to become wireless signal coverage of the island blind area. In such regions, there is a strong user perception for uninterrupted coverage, making them frequent sources of network complaints. These scenarios typically involve fewer users, short stay durations, and lower data demands, thus emphasizing the need for cost-effective coverage solutions. Additionally, the closure of limited space is not

conducive to device heat dissipation, and there is also a high demand for device miniaturization and low power consumption.

5G Femto can be rapidly deployed within enclosed island scenarios, offering a stable signal strength without signal loss, thereby enhancing the user experience. Simultaneously, their features of low cost, compact size, and energy efficiency make them well-suited to effectively meet the demands of such scenarios.



2.4. Special Scenarios

With the large-scale deployment and application of 5G, the demand for coverage in unique settings such as sea areas and mountainous regions is becoming increasingly urgent. Determining how to accomplish 5G coverage in these specialized scenarios with minimal resources and investments has become a key area of focus.

Typical application scenarios encompass a wide range, including low-traffic expansive areas like oceans, mountainous regions, and plateaus; hazardous environments like oil, gas, petrochemical, and coal mining sites; and emergency situations such as firefighting, rescue operations, and disaster relief. Diverse scenarios present distinct requirements for network equipment.

5G Femto,due to their advantages of being cost-effective, energy-efficient, easy to deploy and maintain, and capable of plug-and-play operation through existing fixed broadband or satellite backhaul, are well-positioned to promptly and effectively fulfill these varying demands.

- Wide-Area Low-Traffic Scenarios

The defining characteristic of wide-area low-traffic scenarios such as sea are, mountainous regions, and plateaus is the overall low traffic volume spread across these areas. These scenarios exhibit a heightened demand for seamless coverage communication, particularly critical in

emergency situations, yet sporadic instances of elevated traffic demands can also arise. Challenges encompass both transmission and power supply in such environments, and there is a substantial need for base station equipment with low power consumption and flexible backhaul methods.

- Hazardous Environments

The intelligent construction within hazardous environments, such as oil and gas, petrochemical, and coal mining sites, underscores a compelling demand for high-quality 5G communication. These environments are characterized by adverse conditions, often featuring elevated temperatures, high humidity, and substantial dust levels. On-site situations are complex, characterized by high uncertainty and significant danger factors. Furthermore, these scenarios encounter limitations in available space. As such, there is an urgent requirement for base station equipment with a simplified network structure that allows for agile deployment and straightforward maintenance. These stations must not only meet safety requirements for explosion-proofing but also minimize deployment complexities and maintenance workloads. This dual focus on safety and efficiency is essential in achieving secure and effective operations within such high-risk environments.

- Emergency Scenarios

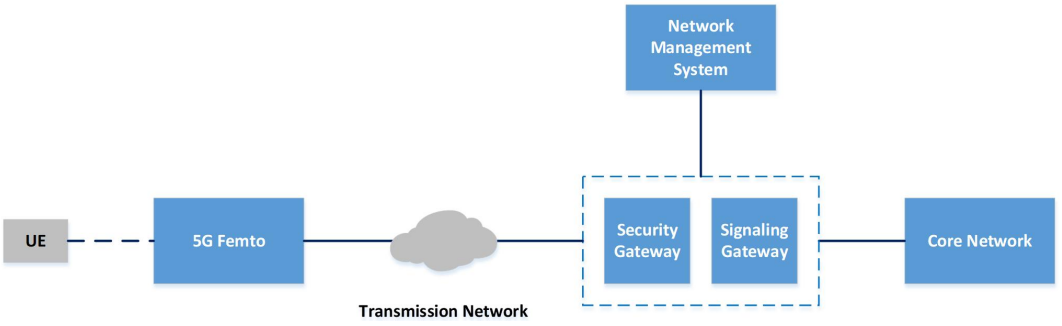
Within emergency scenarios like firefighting, rescue operations, and disaster relief, the demand for communication is not longer limited to the voice intercom for key communication.With real-time image and data transmission becoming pivotal for frontline command decisions, the role of intelligent emergency robots has transcended human limitations, allowing them to operate within perilous environments and perform various tasks. Such contexts call for base station equipment that is readily deployable without the need for installation, capable of quickly providing communication services and real-time image transmission.

3. Technical Requirement

3.1. Network Requirement

3.1.1. Network Architecture

5G Femto network architecture diagram is as follows. The main network elements include 5G Femto,security gateway,signaling gateway, and network management system. 5G Femto can access the core network through the dedicated transmission networks for operator, which belongs to the trusted domain network. The security gateway is an optional network element in this case. It can also access the core network through fixed broadband or other IP networks, which belongs to the untrusted domain network. In this case, the security gateway is a mandatory element. The 5G Femto and security gateway establish IPsec tunnels to encrypt data packets and protect data security.



Fig

Figure 3-1 5G Femto Network Architecture

The functions of the main devices in the 5G Femto network architecture are as follows:

- 5G Femto: Implements complete base station functionality.
- Security gateway: Performs mutual authentication with the 5G Femto on behalf of the core network.
- Signaling gateway: Aggregates signaling between 5G Femto and the core network.
- Network management system: Performs location verification of 5G Femto, device management for 5G Femto, security gateways, and signaling gateways, and achieves system manageability and controllability.

3.1.2. Synchronization Technology

Synchronization is a necessary requirement for TDD mobile networks. Unsynchronized clocks

can affect base station handover and increase interference risks, resulting in issues such as dropped calls and poor user experience. Synchronization includes frequency synchronization and time synchronization. The synchronization technologies for 5G Femto mainly include air interface synchronization, GNSS synchronization, and IEEE 1588v2 synchronization.

Considering that 5G Femto is mainly deployed in indoor environments, GNSS synchronization has higher costs and installation difficulties, while implementing IEEE 1588v2 synchronization requires upgrading and modifying the transmission network equipment. Therefore, air interface synchronization is the preferred solution. It involves listening to the synchronization and broadcast signals of surrounding base stations to obtain the frame offset information between 5G Femto and macro base stations, ensuring synchronization between neighboring cell clusters.

Table3-1 Comparison of synchronization technologies

Technology	Backhaul Requirements	Environment Requirements	Extra Costs	Implementation Difficulty	Reliability
Air interface synchronization	No	Need macro base station network around	No	Low	Medium
GNSS synchronization	No	Can receive GNSS signal	Increase GNSS module costs	High	Medium
IEEE 1588v2 synchronization	Support 1588v2	No	No	Low	High
GNSS-1588v2 hybrid synchronization	Support 1588v2	No	No	Low	High

3.1.3. SON

Traditional network configuration and optimization typically require a large amount of manual intervention and adjustment, consuming time and resources. Self-Organizing Network (SON), as an automated network management technology, can automatically perform system parameter configuration and optimization through self-configuration, self-optimization, and self-healing. This reduces manual intervention, improves network deployment and maintenance efficiency, and has been widely applied in mobile communication network systems.

Due to the large number of deployments and the private and flexible locations of 5G Femto,

it is more necessary to rely on SON to avoid dependence on manual network configuration and optimization. Through wireless network intelligence and automation management, 5G Femto can achieve “plug and play” functionality, improving network efficiency, performance, and stability, reducing operational costs, and providing users with a better communication service experience. 5G Femto need to support the following SON technologies at least:

- Self-starting: Automatically obtain an IP address, detect network management system, and establish an OAM channel. Automatically detect the gateway/core network and establish NG/S1 interface. Download and install relevant software and configuration parameters from the network management system to achieve automatic configuration of system parameters.
- PCI self-configuration and self-optimization: Automatically configure PCI during cell establishment based on the principle of no conflicts or confusion, and optimize PCI when there are changes in the network topology, minimizing the probability of interference.
- ANR (Automatic Neighbor Relations): Automatically obtain the initial neighbor relations by listening to the wireless network environment during cell establishment. Update neighbor relations through UE measurement reports, handover statistics data, Xn/X2 signaling interaction, etc., during device operation to achieve automatic maintenance of neighbor cell list, improving the completeness and accuracy of the neighbor cell list, and increasing handover success rate.

3.1.4. IPSec

For non-trusted domain backhaul, such as connecting to fixed broadband networks, an IPSec tunnel is established between the 5G Femto and the security gateway to encrypt the data packets and ensure data security. Communication parties use IPSec at the IP layer to encrypt data packets, perform integrity checks, and authenticate data sources, ensuring confidentiality and integrity of IP data packets transmitted on the network. It also provides features to resist replay attacks, supports certificate and EAP-AKA authentication methods.

- Data source authentication: The receiver verifies the legitimacy of the sender’s identity.
- Data encryption: The sender encrypts the data and transmits it over the Internet in

ciphertext form. The receiver decrypts the received data for processing or forwarding.

- Data integrity: The receiver verifies the received data to determine if the packet has been tampered with during transmission.
- Resistance to replay attacks: The receiver rejects old and duplicate packets to prevent malicious users from launching attacks using captured and replayed packets.

3.2. Product Requirements

3.2.1. Hardware Requirements

1. Operating bands

The operating bands used should comply with the relevant regulations of the radio management departments of each country.

2. Channel bandwidth

Supports normal operation under the following channel bandwidth configurations: 100MHz/80MHz/60MHz.

3. Number of RF channels

Supports 2 transmitter channels and 2 receiver channels.

4. Output power

Meets the requirements for Local Area BS type as specified in 3GPP TS38.104.

5. Antenna pattern

Selects either built-in omnidirectional antenna or directional antenna based on the installation method.

6. Synchronization method

Supports Air interface synchronization, GNSS synchronization and IEEE 1588v2 synchronization.

7. Heat dissipation method

Adopt natural heat dissipation and silent operation.

8. Power consumption

The whole device power consumption should be less than 35W.

9. Indicator light

Should have at least the following indicator functionalities: power supply switch status indication, transmission link status indication, NR cell status indication, error or alarm indication.

10. RF Performance Requirement

Meets the requirements for Local Area BS type as specified in 3GPP TS38.104.

11. Environmental adaptability

- Operating temperature: -5℃ to +45℃
- Relative humidity: 10% to 95%
- Protection level: IP30
- Electromagnetic compatibility: Complies with 3GPP TS 38.113 (2017-12 R15)

3.2.2. Software Requirements

1. Modulation scheme

Supports the following modulation schemes for downlink: QPSK, 16QAM, 64QAM, 256QAM. And for uplink: QPSK, 16QAM, 64QAM, 256QAM.

2. MIMO mode

2x2 MIMO for downlink and uplink.

3. Peak rate

The peak rate requirements for a single user are shown in the table below.

DL/UL	Modulation	Peak rate	Peak rate (Mbps)
DL	256QAM	2	≥750
UL	256QAM	2	≥230

NOTE: The bandwidth is 100MHz. The frame structure is DDDDD DDSUU. And the special time slot configuration is 6:4:4.

4. Number of RRC connected users

Supports 64 RRC connected users with 100MHz bandwidth.

5. Number of RRC active users

Supports 32 RRC active users (with data uplink or downlink within 100ms) with 100MHz bandwidth.

6. Number of VoNR users

Supports 16 VoNR users (using high-definition voice at 24.4kbps) with 100MHz bandwidth.

7. Mobility management

Support intra-RAT and inter-RAT mobility interoperability of data and voice services.

8. SON

Support base station self-starting, PCI self-configuration and self-optimization, and ANR optimization.

3.2.3. Security Requirements

1. The backhaul network adopts IPSec technology and supports certificate and EAP-AKA authentication methods.
2. The device complies with the following security requirements:

- Mechanical safety: The product's mechanical structure and housing have sufficient strength and rigidity to withstand normal operating conditions, loads, and impacts, protecting users from mechanical harm.
- Electrical safety: The product's electrical structure and circuits have sufficient insulation, voltage resistance, and overcurrent protection capabilities to ensure user safety from electrical hazards.
- Fire safety: The materials and structure of the product are not easily ignitable and can prevent fires caused by arcs and overcurrent, ensuring the safety of users and the environment.
- Radiation safety: The product's radiation capability complies with relevant national standards and does not cause harm to human beings and the surrounding environment.
- Chemical safety: The materials used in the product do not contain harmful substances, comply with relevant national standards, and do not pose any hazards to users and the environment.

4. Demonstration Applications

4.1. Residential Scenario

The total residential area of the user is about 150 square meters. Because it is far away from the macro base station, the indoor signal is very weak, which cannot meet the needs of basic voice calls and data services. Deploy an integrated small base station and connect it to the core network through the small station gateway system, as shown in Figure 4-1. The integrated base station is deployed in the living room, as shown in Figure 4-2.

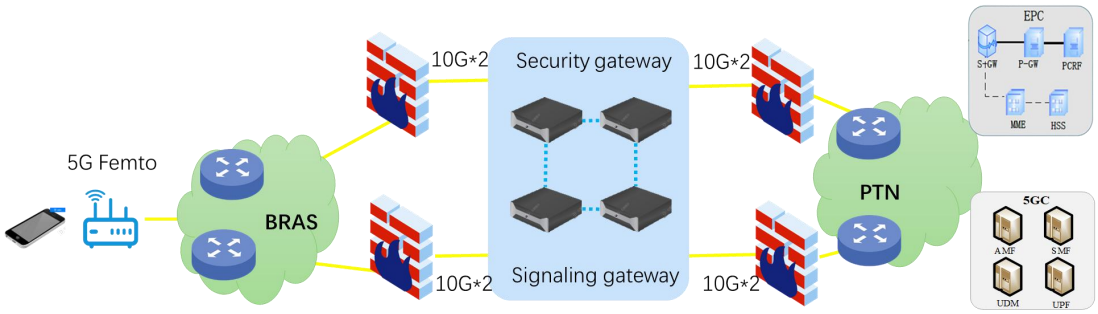


Figure 4-1 Networking Scheme

Figure 4-2 Residential Deployment Diagram

After the deployment, the domestic signal coverage is obviously improved, and all rooms have good signals, and the signal strength is between -70dBm and -117dBm, which can well meet the needs of users such as voice calls and video browsing. With the Gigabit Ethernet, the average downlink rate is about 800Mbps, the average uplink rate is 110Mbps.

4.2. Restaurant Scenario

A restaurant along the street has a total area of about 1200 square meters. Due to the poor signal coverage of the macro base station, some dining positions cannot meet the needs of

customers' voice and data services, and the existing signal coverage affects consumers' needs and dining experience. The deployment of the 5G Femto, using the existing broadband in the restaurant for backhaul and connecting to the core network through the small base station gateway system. Network is shown as Figure 4-3. The station is installed at the cashier position, as shown in Figure 4-3.

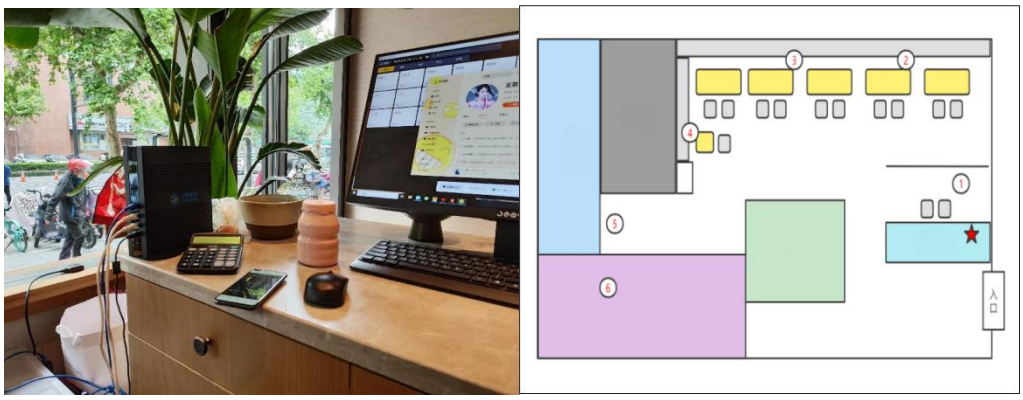


Figure 4-3 Restaurant Deployment Diagram

Before the deployment, the signal intensity of the restaurant table was between -55dBm and -110dBm, and after the deployment of the small base station, the signal intensity was increased to between -55dBm and -94dBm, and the signal intensity was obviously enhanced, both the VoNR call and the video call were normal. Under the condition of broadband of 300Mbps, the download rate of all points is above 200Mbps, which can meet the needs of consumers such as surfing the Internet and video browsing. At the same time, the 5G Femto can switch and reselect with the outdoor macro station normally.

4.3. XR Experience

New services such as XR have a high demand for stable large bandwidth and low latency. By deploying 5G Femto and 5G lightweight core network, and connecting local service servers, the latency and speed requirements of XR services in end-to-end collaboration can be met. The network scheme is shown in Figure 4-4.

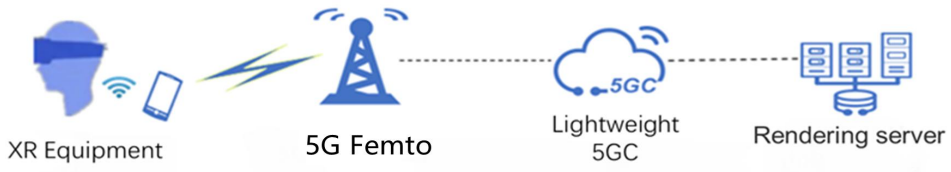


Figure 4-4 5G Femto+XR Networking Diagram

5G Femto can meet the requirements of 100Mbps single-user rate and less than 20ms round-trip delay of XR service and can successfully experience XR games. The user wears the XR head-mounted display device and holds the induction control terminal, presenting the XR demonstration content, and the game screen is smooth and the experience effect is good. For multi-user XR games, larger bandwidth may be required, e.g., by utilizing mmWave band, to strive higher sum data rate for all the XR users.

Figure 4-5 XR Experience

4.4. Elevator Scenario

In the elevator scene of a residential area, the outdoor macro base station signal cannot be covered, so it is difficult to carry out basic communication services in the elevator. In this residential area, the elevator has 34 floors above ground and 2 floors underground. The product scheme of 5G Femto and wireless bridge is adopted, and the remote unit (including 5G Femto) is deployed at the top of the elevator car and the near unit is deployed at the top of the elevator shaft. The two units communicate with each other through Wi-Fi, and the network is shown in

Figure 4-6.

After the deployment, the signal coverage in the elevator is good and the voice data service is smooth. Because the 5G Femto is deployed at the top of the car, the signal strength in the car is stable when the elevator runs up and down normally, and there is no obvious difference in the speed between different floors. Under the condition of 400Mbps broadband backhaul, the downlink speed is basically stable above 300Mbps.

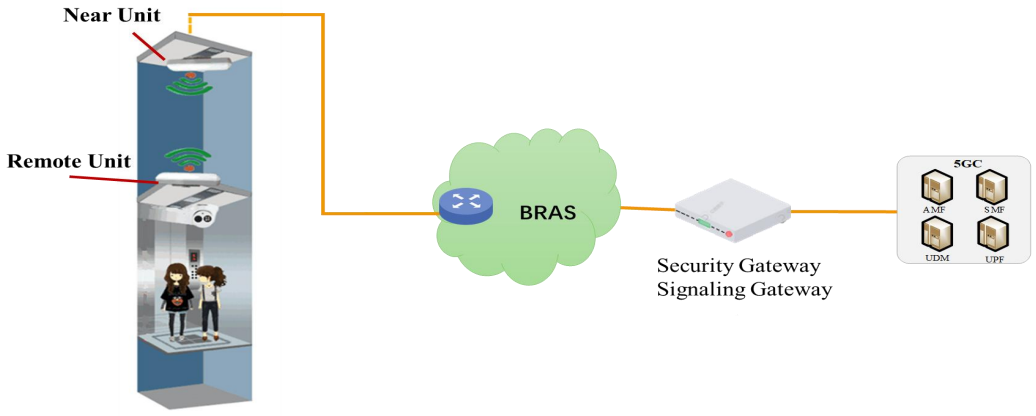


Figure 4-6 Elevator Network Diagram

4.5. Sea Area Scenario

The signal coverage of base stations near the coastline is limited, which cannot meet the signal coverage requirements of deep-sea areas. At present, most long-distance ships use satellite to communicate, and satellite terminals are expensive and not widely available, so it is difficult to meet the communication needs of users on board. The 5G Femto is deployed in the cockpit and connected to the terrestrial core network through satellite broadband to complete the 5G network coverage on board.

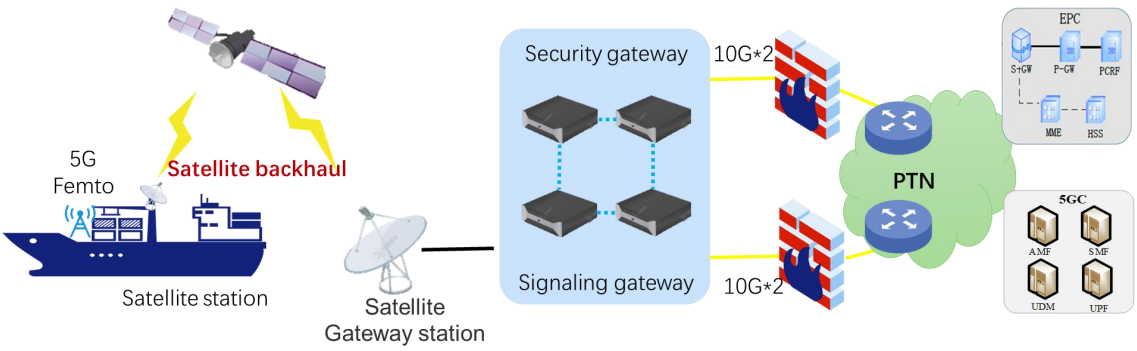


Figure 4-7 Network Diagram

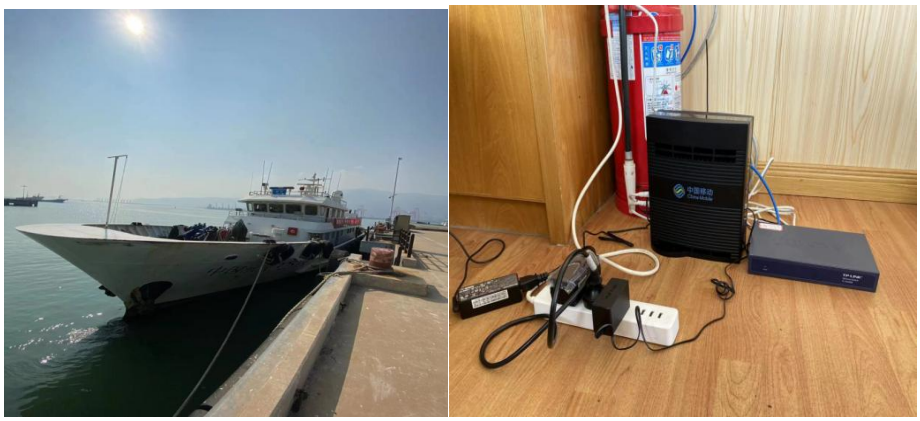


Figure 4-8 Deployment Diagram

After deploying 5G Femto, the test ship can sail to 30 nautical miles at the longest distance, and the mobile phone downlink rate can reach about 70Mbps with the satellite's backhaul capacity of about 75M. It supports phone calls, send and receive short messages, voice chat and video conference normally, and there is no jam, frame loss and dropped calls in the communication process. In the reselection test of the onshore base station, there was no network disconnection.

4.6. Smart Mine Scenario

Some coal mines have established a 10 Gigabit industrial ring network, mine broadcasting system, fixed telephony system, Wi-Fi communication system, etc., which has a high level of informatization and digitization. However, the correlation between the various systems is not robust enough which exists certain degree of information island effect. There is a need to upgrade the fixed telephony and Wi-Fi system to an unified 5G communication system, hoping to meet network requirements of intelligent applications such as remote control of working level tunneling machine, remote control of the integrated collecting, and visual inspection of main coal flow machine in parallel. 5G Femto which is directly connected to the industrial ring network is suitable for deployment according to the requirements.

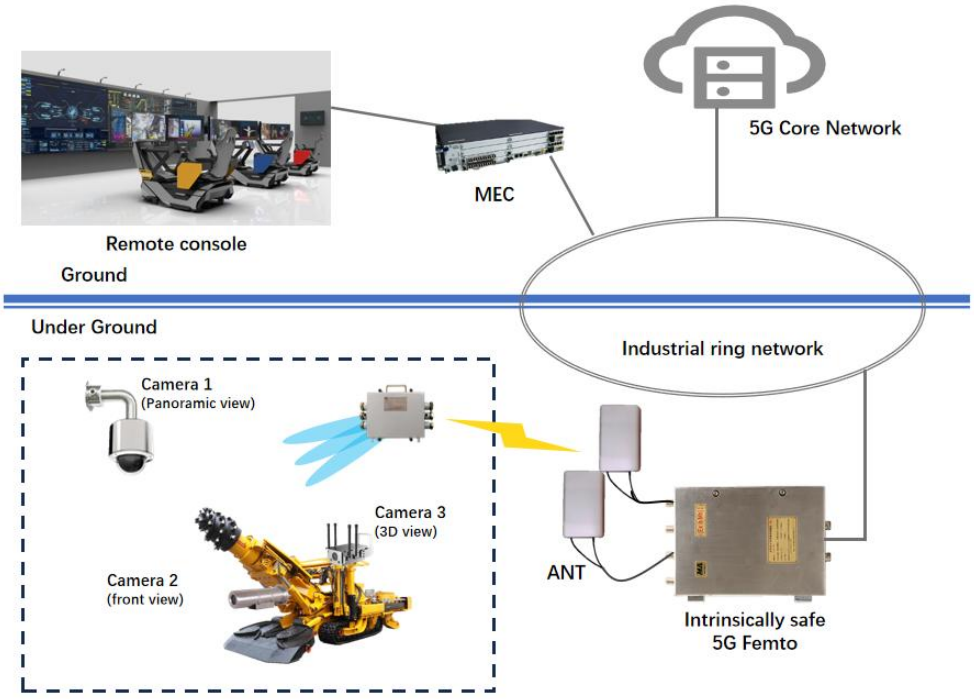


Figure 4-9 Network Diagram

Figure 4-10 Site deployment diagram

In this project, the mine dedicated network is built through a 5G Femto which provides high bandwidth, low latency, and massive access to highly reliable 5G network services for coal mines, as well as effectively solves problems of multiple wireless signal blind spots and limited system bandwidth previously faced by wireless AP. 5G Femto based dedicated network realizes full chain interconnection and interconnection of the mining process, mining equipment, underground personnel, various materials, etc. improves productivity and production safety level. Summary in one sentence, 5G Femto assists in creating a Full-Connectivity intelligent mine industry.

5. Forward Vision

The deployment of 5G is focusing from providing ubiquitous coverage to delivering precise coverage. 5G Femto, with features of cost control, agile deployment, user-friendly operation, and energy saving, are serving as catalysts for the rapid development of 5G and will continue to play an increasingly significant role in the future. With the continuous enhancement of indoor users' diverse entertainment and lifestyle demands, along with the gradual popularization of emerging technologies like XR, 5G Femto will also evolve into more intelligent solutions. It will incorporate more applications, acting as intelligent nodes that connect indoor 5G devices and enable a more convenient and digitally enhanced lifestyle.

Looking ahead, GTI is committed to driving technological advancements, setting standards, and fostering industrial growth in the ecosystem for 5G Femto. This commitment will accelerate their large-scale deployment, providing users with a low-cost, flexible, and efficient 5G network. Consequently, helping unlock new possibilities for social development and industry innovation.