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5G+ Proximity Network Architecture Based on Digital Twin White Paper

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1 Digital twin is the future direction of industry development

1.1 Three-tier architecture and key technologies of digital twin

Digital twin technology describes the changes of physical objects in the real world and simulates the behavior and influence of physical objects in the real environment through the digital mirroring of physical objects, so as to realize functions such as condition monitoring, fault diagnosis, trend prediction and comprehensive optimization. According to ISO/DIS 23247: Digital Twin framework for manufacturing, the first architecture standard in the digital twin field released by ISO, The digital twin system consists of three layers: First, the data collection and control layer, which mainly covers sensing, control, identification and other technologies, and undertakes the collection of uplink sensing data between the twin and physical objects and the execution of downlink control instructions, which connects the physical layer and the core layer, sometimes considered part of the entity layer. The second is the core layer. It relies on general support technologies to realize functions such as model construction and fusion, data integration, simulation analysis, and system expansion. It is the main carrier for generating twins and expanding applications. The third is the user entity, which is mainly based on visualization technology and virtual reality technology, and undertakes the function of human-computer interaction, which belongs to the category of application layer. In addition, cross-domain entities spanning the above three levels are required as internal support to undertake data exchange and security assurance functions between various entity levels.

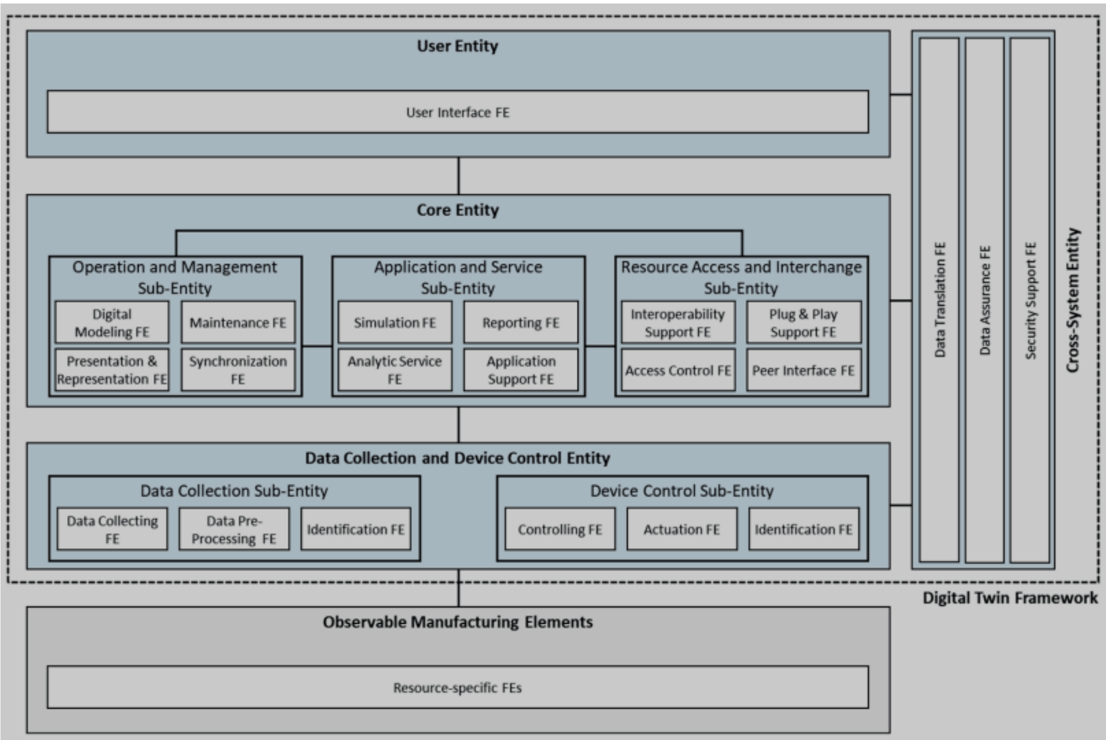

Figure 1-1 ISO digital twin architecture

In order to build a digital image and achieve the above goals, it is necessary to integrate basic supporting technologies such as sensing, modeling, and simulation through a platform-based architecture to build a closed loop of information interaction from the physical world to the twin space.

(1) Sensing technology

Sensing is the underlying foundation of the digital twin system architecture, and an important part of realizing the accurate mapping and real-time interaction of all elements, all services, and all processes between physical objects and digital twin systems. Therefore, the digital twin system puts forward higher requirements for sensing technology. In order to establish a global and all-time IoT sensing system and realize multi-dimensional and multi-level accurate monitoring of the running situation of physical objects, sensing technology not only requires more accurate and reliable physical measurement technology , it is also necessary to consider the collaborative interaction between sensing data, clarify the spatial location and unique identification of objects in the whole domain, and ensure that the device is credible and controllable.

(2) Modeling technology

Model construction technology realizes the mapping of entities in physical space to virtual space twins, and through analysis and decision-making in virtual space, interactive instructions are formed to intervene and control the physical space, so that the entire physical system maintains a good operating state. The digital twin model includes geometric model, information model and mechanism model.

(3) Simulation Technology

As an online digital simulation technology, the simulation in the digital twin system converts the model containing deterministic laws and complete mechanisms into software to simulate the physical world. As long as the model is correct and has complete input information and environmental data, it can basically correctly reflect the characteristics and parameters of the physical world, and verify and confirm the correctness and validity of the understanding of the physical world or problems. From the perspective of simulation, the simulation in digital twin technology belongs to an online digital simulation technology. Digital twin can be understood as: establishing a corresponding virtual model for a physical entity and simulating the behavior of the physical entity in the real environment.

1.2 Development Trend of Digital Twin

Digital twin is a new stage in the development of the Internet of Things. The popularization of the application of the digital twin will promote the evolution of the traditional Internet of Things with the goal of "Internet of Everything" to the next-generation Internet of Things with the goal of "Intelligent Connection of Everything". The complex business requirements and the need for accurate sensing data pose higher challenges to the communication network including the industry proximity network.

Digital twins are in the rising stage of development, with the continuous improvement of the technical system, the continuous acceleration of industrial integration, and the accelerated penetration of industrial applications. In the future, with the development of new ICT technologies and advanced manufacturing technologies, digital twins will continue to be further improved in data collection, modeling, interoperability, visualization, and platforms. Digital twin technology will optimize itself while exploring and experimenting

2 The concept and key technology of proximity network

Proximity network is a communication and management technology used for data intercommunication field devices, field devices and external devices, devices and platforms. Proximity network is the application of IoT technology in the enterprise intranet. In order to meet the needs of the enterprise's digital and intelligent transformation, its research scope of proximity network is constantly expanding. The concept of Proximity Network was proposed in ISO.23247 digital twin standard in 2013. After in-depth analysis and extensive research, GTI improve the concept and overall solution of the proximity network, and strengthened the technical synergy between the field network equipment connection technology and 5G+AICDE.

2.1 5G+ Proximity Network Architecture and Key Technologies

5G + industry proximity network is centered on the gateway. In the south direction, the connection and communication between field and devices are realized through proximity network technologies such as passive IoT, short distance communication, and deterministic transmission. In the north direction, the industry field production and management data are transmitted to the platform through 5G. It can serve the industrial production site and meet the differentiated requirements of various businesses in verticals.

The key technologies of the industry proximity network mainly include passive IoT for automatic asset inventory; short-range communication technologies for ultra-low latency and ultra-high reliable device intercommunication; deterministic transmission technology for high-reliability and deterministic transmission of data. On the one hand, the integration between proximity network and 5G can meet the field communication requirements of different industries and different scenarios, and further improve the management and operation and maintenance capabilities of enterprise network. On the other hand, it can combine edge computing, computing power sensing and other capabilities to improve the intelligent ability of the network.

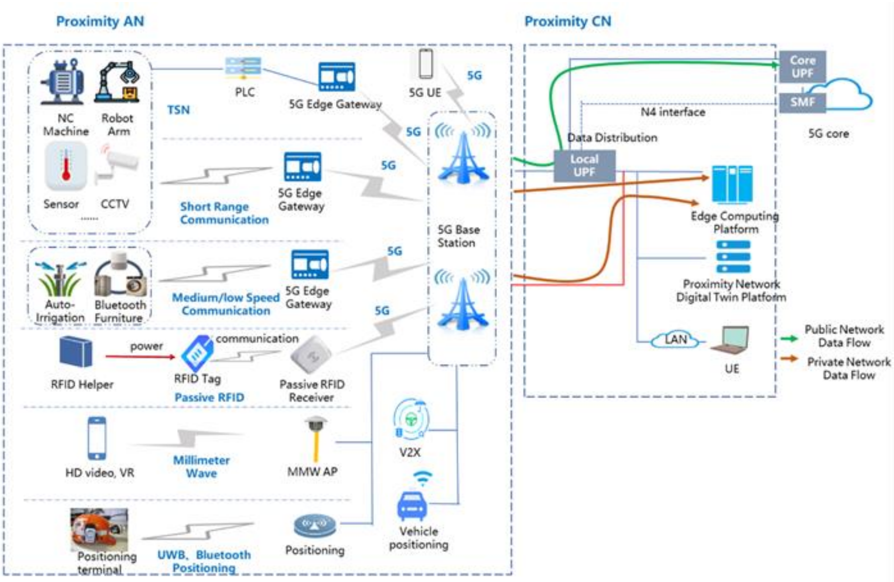

Figure 2-1 5G+industry proximity network architecture

2.2 Typical scenarios of 5G + Proximity network

1--Automatic asset inventory: Based on the low cost and zero power consumption characteristics, traditional RFID systems with integrated transceivers are widely used in the new retail field. With the digital transformation and business expansion of the industry, the expansion of the warehouse area and the increase of assets number raise new requirements for automated inventory. With separation architecture of signal reception and transmission, passive IoT could effectively solves the problem of system interference and improves the excitation and reception distance. The; integration of 5G and passive IoT could further improves the automated operation and maintenance management capabilities of the IoT system, which can meet the requirements of long distance data transmission and automatic assets management in the industry.

2--Intercommunication between mobile devices: Replacing people with machines can effectively improve the production efficiency and reduce labor costs for verticals. Many logistics and manufacturing companies use AGVs to transport goods on the production site. However, with the expansion of new business of flexible manufacturing, the requirements for flexibility and coordination of equipment movement have increased, and the requirements for communication between experiments have also been further strict. The Sparklink short-distance communication is based on an optimized frame structure, wihch could achieve microsecond-level communication delay, thus making it possible to efficiently collaborate between mobile devices in the industry.

3--Wireless deterministic transmission: For example, the high-temperature molten iron loaded in the molten iron tank of a steel plant needs to periodically and deterministically report the temperature, pressure and other data of the molten iron tank, and realize the rapid transmission of fault data, so as to realize safety warning and rapid problem processing, and prevent production accident happens. Based on 5G + deterministic transmission, deterministic transmission of production management data and priority transmission of fault data can be achieved through precise time synchronization, traffic scheduling, etc., to ensure production safety.

3 5G+Proximity network architecture for digital twin

In terms of digital twins, we propose the 5G+proximity network architecture of "Cube 365". Among them, "3" represents the three-layer architecture of the digital twin-oriented industry proximity network, including entity layer, capability layer, and application layer; "6" contains two meanings, one of which is six development trends, including flattening, wireless, IP-based, more intelligent, more controllable and more refined. The second is the 6 major field proximity network technology systems, with six technical dimensions of "sensing, communication, computing, data, intelligence, and application"; "5" represents the five connection technologies for the digital twin industry proximity network: 5G + passive IoT, 5G+Spark-link short-range communication, 5G+deterministic transmission, 5G+high-precision positioning, 5G and medium and low speed communication.

In this architecture, "sensing" and "communication" correspond to the entity layer, "computing", "data", and "intelligence" correspond to the capability layer, and "applications scenarios" corresponds to the application layer. And the entire proximity network architecture is also developing towards flat, wireless, IP-based, intelligent, controllable, and precise.

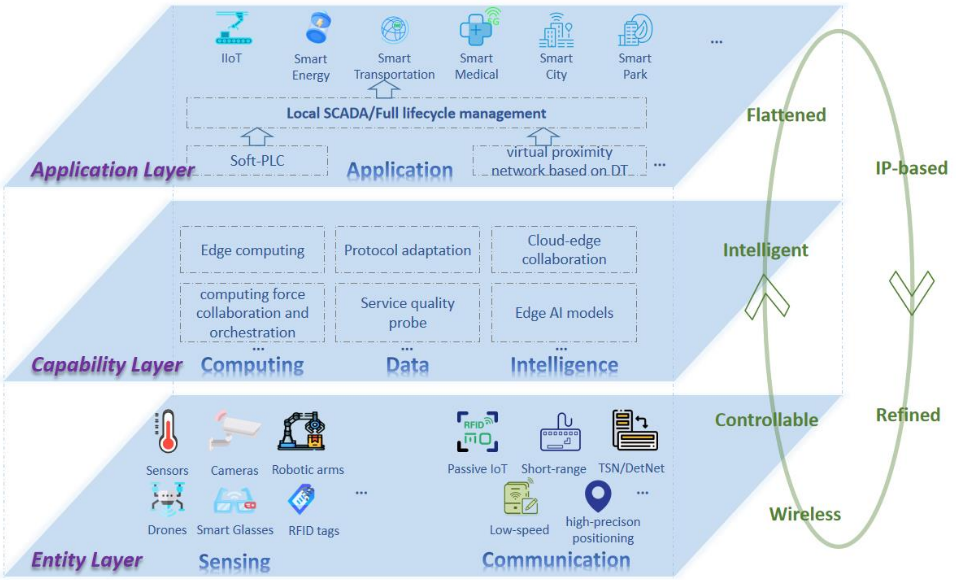

Figure 3-1 Digital twin-oriented field network architecture (Cube 365)

3.1 5G+proximity network three-tier architecture for digital twin

The digital twin system provides six technical dimensions of "sensing, communication, computing, data, intelligence, and application" for the rigid needs of the industry through functional entities and core technologies in the three-layer architecture of entity layer, capability layer, and application layer.

The bottom layer is the entity layer, which can provide "sensing" and "communication" capabilities through data collection entities and data transmission entities. Data collection entities include on-site production and management physical terminals such as sensors, cameras, robotic arms, passive IoT labels, etc., which can collect environmental data such as temperature and dust, production line equipment operation data, material information and location data or equipment defects, which can effectively reflect the working conditions of machines operate in the physical world. The data acquisition entity and the new passive, new short-range, deterministic transmission, medium and low-speed transmission, high-precision positioning and other digital data transmission entities are the link between the northbound transmission of sensing data and the southbound transmission of control instructions.

The middle is the capability layer, which can provide the physical entities at the lower layer and the applications at the upper layer with three capabilities of "computing", "data" and "intelligence" through edge computing, protocol adaptation, AI and other technologies, so as to realize data integration, simulation analysis, intelligent processing, twin model construction and fusion, etc.

The upper layer is the application layer, which can provide more efficient and convenient network and business life cycle management services for industry applications through technologies such as digital twins.

3.2 Six development trends and six technical dimensions of 5G+field network

With the continuous advancement of the digital transformation of the industry, the customized production requirements of industry customers are gradually emerging, and the network and platform are evolving towards a flat, wireless, IP-based, intelligent, controllable and precise direction.

First, the network architecture is more flattened. The traditional industrial network structure is complex, with a variety of field-bus protocols, Ethernet protocols and industrial wireless protocols. Different communication protocols and systems cannot interconnection between each other. A flatten network architecture is conducive to the normalized management of data, which requires data to be collected and transmitted according to a unified protocol

Second, the network connection is more wireless. For global industrial network market sharing in 2020, wired network accounts for 94% and wireless accounts for 6%. As industry business require more flexibility and mobility increase, such as dark factory, the demand for wireless communication is getting stronger. While wireless replacing wired networks brings convenience, it also introduces unreliable factors, causing enterprises to be more cautious about introducing wireless communication in production. 5G+field network technology is expected to combine the advantages of the two to promote the development of network connections to wireless.

Third, network transmission is more IP-based. Traditional industrial networks are mostly point-to-point Layer 2 communications, which temporarily cannot achieve data traceability, flexible routing, and refined business network management. However, industrial production puts forward high demands on the scalability, high quality, operability, reliability, stability and security of the network, and the requirement of IP transformation of the network has become more and more urgent. IPv6 has abundant address resources and can assign IP addresses to each network device. IPv6 also provides management capabilities for traffic and services, facilitating network SLA assurance.

Fourth, industrial applications are more intelligent. At the present stage, the intelligent analysis capability mainly relies on the cloud platform. Some industrial scenarios, such as safety production and industrial quality inspection, have high requirements for large bandwidth, low latency and data privacy, and high. business response speed to ensure business continuity. Using edge intelligence technology, intelligent services such as predictive maintenance, fault detection, face recognition, and industrial quality inspection can be processed at the proximity edge, which could be deployed on the industrial gateway.

Fifth, the proximity network is more controllable. The traditional network management system cannot monitor network parameters on the client side in real time. By deploying quality probes on the terminal side, it provides monitoring, analysis and alarms of key information such as device status, network coverage, and service quality at the field level, effectively making up for the lack of network management data, making the terminal side no longer a black box, and helping quickly locate and delimit faults to ensure network awareness of on-site customers.

Sixth, equipment control is more precise. With the development of 5G and deterministic network technology, network latency and jitter are greatly shortened, making it possible to deploy devices in a distributed manner and to manage centralized control. In scenarios such as remote device control and equipment collaboration, on-site data is collected and transmitted through the 5G network, and industrial control functions and equipment remote precise control are realized based on software.

In view of the six major development trends of flattening, wireless, IP-based, intelligence, controllability and precision, it is necessary to build a comprehensive 5G+proximity network technology system of " sensing, communication, computing, data, intelligence, and application ". Which provide standard software and hardware interfaces, and modularize technologies such as field network, protocol adaptation, edge intelligence, and quality probe to meet the diverse needs of the industry.

3.2.1 Sensing

The entity layer of "sensing" in the three-layer digital twin architecture represents sensors and is the source of industry field information. Traditional production lines have problems such as unconnected sensing units and difficulty in realizing full automation. According to the requirements of intelligent and wireless sensing in intelligent manufacturing, through intelligent sensor technology, real-time and dynamic collection of Internet of Things data is realized, and multi-source and heterogeneous industry field data is aggregated to the industry gateway. Provide data support for edge-side data processing, business analysis, and upward deterministic transmission.

3.2.2 Communication

The entity layer of "communication" in the three-layer architecture of the digital twin. Taking a factory as an example, it may have tens of thousands of sensors and actuators, which requires massive connection capabilities of the communication network as support, and real-time communication between the workshop and the central cloud control platform, reliable computing of sensors and artificial intelligence platforms, The efficient interaction of the human-machine interface puts forward higher requirements for the wireless of the communication network. According to different network requirements, through 5G+proximity network integration technology, it provides users with low-latency, high-reliability wireless transmission capabilities and data localization and offloading capabilities.

3.2.3 Computing

The capability layer of "computing" in the three-tier architecture of the digital twin. Most of the industrial AI services are based on deep neural network algorithms, which require computing units with high computing power and low power consumption. However, the computing units of the traditional Von Neumann architecture with separate storage and computing have low energy efficiency and cannot meet the computing needs of deep neural networks. Aiming at the storage/computing performance bottleneck, the integrated storage and computing chip technology, computing power coordination and orchestration technology are used to achieve computing acceleration and energy efficiency improvement. Relying on edge intelligence, load balancing, segment routing and other technologies, the computing power of gateways in the region is aggregated into a field-level edge computing resource pool to achieve unified computing power sensing, computing power orchestration, and computing power scheduling.

3.2.4 Data

At present, there are two major problems in the capability layer of "data" in the three-layer digital twin architecture. First, the traditional industrial network is heavily hierarchical, with numerous and incompatible protocols, making it difficult to achieve data interoperability. Second, industry customers need to perceive key information such as field-level device status, network coverage, and service quality in real time. Traditional network management can only perceive the core layer. In response to the industry needs of flexible data access, field equipment and network monitoring, on the one hand, unified docking interfaces, access specifications, and configuration rules, and the cloud platform intelligently identifies southbound protocols and issues plug-ins, enabling device plug-and-play and rapid deployment. On the other hand, through the quality probe technology, the network quality data of the gateway, the data of the gateway and the attached device, and the business data of the attached device are collected. Provide multi-protocol adaptation capabilities for device access, as well as network monitoring and network operation and maintenance autonomy capabilities for 5G and proximity networks.

3.2.5 Intelligent

The capability layer of "intelligence" in the digital twin three-layer architecture. Traditional cloud computing has problems such as high latency, high energy consumption, and unfavorable data security and privacy. For industrial field big data, low latency, high privacy requirements. Edge intelligence extends computing and intelligence capabilities to industrial sites, and will work with cloud-side intelligence to meet the key needs of industry digitization in real-time business, computing optimization, application intelligence, security and privacy protection. The first is to provide the intelligent deployment function of edge AI models, which can quickly implement model deployment and status monitoring according to the original model and resource requirements; the second is to achieve personalized model updates through cloud-edge collaboration and lightweight continuous learning; the third is to use model splitting and other technologies to intelligently balance communication delay and computing delay, and minimize AI service delay; the fourth is to provide on-site intelligent analysis capabilities through built-in pre-training models for industrial quality inspection, safety monitoring and other scenarios.

3.2.6 Application

The application layer of "application" in the three-tier architecture of the digital twin. In terms of control applications, the traditional PLC adopts a closed software and hardware architecture, which has problems such as high cost, fragmentation, and difficulty in expansion. Cloud PLC is based on open architecture, realizes industrial control logic through software, realizes SCADA sinking, reduces PLC hardware cost, and builds a flexible and scalable industrial control system. In terms of digital applications, the application scenarios of the IoT industry are complex, and network isomerization and customization are common. The digital twin of the field network supports the full life cycle management of the network and services, and provides visibility, management, and control of the network. Through the digital twin platform, it provides twin visual service capabilities and intelligent operation and maintenance capabilities, realizes low-cost trial and error, high-quality operation and maintenance of the network, and intelligently assisted decision-making, and improves user experience.

3.3 Five connection technologies for 5G+proximity network

There are many proximity network connection technologies in the industry. This white paper focuses on five connection technologies that are widely used in the field, such as 5G+new passive communication, 5G+new short-range communication, 5G+ deterministic transmission, 5G+high-precision positioning, 5G with medium and low speed communication.

3.3.1 5G+new passive communication

Passive IoT uses the principle of electromagnetic induction and signal reflection to conduct non-contact data communication through the built-in tag of the item. It consists of a reader, a tag, and an application system: the reader emits electromagnetic waves to the tag, and receives the electromagnetic waves reflected from the tag; the tag is closely combined with the object to be tested, and passive tags do not require external power supply or built-in batteries, relying on electromagnetic wave emitted by the reader starts and reflects the signal to realize data transmission; the application system controls the reader to send and receive, and process the data reported by the tag.

According to the operating frequency, passive IoT is divided into low frequency system (125-134KHz), high frequency system (13.56MHz), ultra-high frequency system (about 900MHz) and microwave system (above 2.4GHz). The interconnection system is based on electromagnetic wave backscattering technology, and the theoretical transmission distance is 1-10 meters. It is the most widely used passive IoT technology in the world. UHF passive IoT was first used in clothing and supermarket retail, and then gradually expanded to asset management, medical care, transportation and other fields. Unless otherwise specified, the following passive IoT refers to UHF passive IoT technology.

The traditional passive IoT reader adopts a full-duplex architecture with integrated transceiver, transmits excitation signals and receives reflected signals at the same time, so there is strong system self-interference and inter-system mutual interference. This results in short reading and writing distance, low recognition accuracy and difficult device management.

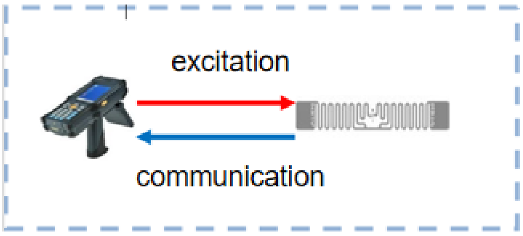

Figure 3-2 Traditional passive IoT framework

The new passive IoT system uses a separate architecture to solve the problems of serious self-interference and difficult network deployment in the traditional integrated architecture. This can realize the continuous coverage and networking of passive systems to meet the needs of automatic inventory of industry assets, fine management of materials, and intelligent logistics tracking.

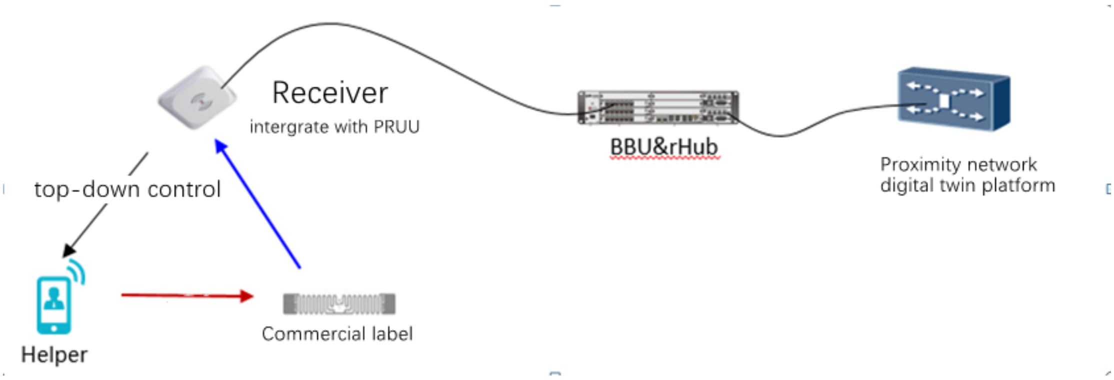

Figure 3-3 Framework of Enhanced Passive IoT

The new passive communication provides more efficient connection service capabilities through the separation of transceivers. After the transceiver is separated, the new passive IoT system divides the reader into two devices: an exciter and a receiver, and solves the interference problem through physical separation, which can not only increase the communication distance, improve the recognition rate of items, but also reduce the Device implementation complexity and R+D costs.

The combination of the new passive IoT system with 5G and other cellular communication technologies will be more conducive to network deployment, reduce network deployment costs, and enhance operation and maintenance management capabilities. Through the built-in module of the passive IoT exciter, the passive IoT receiver is combined with the base station. This can not only achieve indoor continuous coverage for large warehouses, but also realize co-management and operation and maintenance with base stations, enhancing the operation and maintenance management capabilities of passive IoT systems. At the same time, the cellular network can further support passive IoT technology. The base station excites the tag and receives the reflected signal. It can learn from the multi-antenna beamforming, new air interface waveform and coding technology of cellular communication. It is expected to further increase the communication distance and enable passive IoT technology to be applied to outdoor scenarios.

3.3.2 5G+New Short-Range Communication

Short-range wireless communication generally refers to providing point-to-point wireless communication in a small area (usually less than 100 meters). It is a typical industrial proximity network and is mainly used for small-scale interconnection between devices. It has the advantages of simple deployment and low cost.

Wi-Fi, Bluetooth, and Zigbee are widely used short-range wireless communication technologies. They have low deployment and maintenance costs, but limited communication distance, poor stability, networking capability, security, and high-power consumption. With the rapid development of intelligent ubiquitous connectivity, more extreme performance requirements have been put forward for large bandwidth, anti-interference, and highly reliable communication. However, the existing traditional short-distance communication technology cannot guarantee the high stability of channel resources, and it is difficult to achieve microsecond-level low latency, anti-burst interference and other characteristics.

The StarLink Alliance was launched in September 2020 and is committed to promoting the innovation of next-generation short-range communication technology and the globalization of the industrial ecology. The StarLink short-range communication technology developed by the StarLink Alliance is based on a new wireless interface design, which can better support ultra-low latency, high reliability, precise synchronization, high concurrency, high efficiency and high security. This meets the needs of deterministic service quality assurance services in scenarios such as smart manufacturing, smart cars, smart homes, and smart terminals. Specifically, Starlink Short Distance uses an innovative frame structure design, introduces a minimalist protocol stack and a cross-layer transparent transmission mechanism, enables semi-persistent scheduling based on service characteristics, and achieves a one-way user plane transmission delay of less than 20us. At the same time, Polar code and RS code are introduced to optimize for random interference and burst interference. Combined with the fast feedback and retransmission mechanism of the physical layer and the flexible interference detection and avoidance mechanism, high-reliability transmission in complex electromagnetic environments is realized. However, due to the design of the frame structure, the short-range StarLink cannot achieve wide coverage deployment, and the communication is limited to short-range scenarios. It needs to use cellular communication technologies such as 5G to achieve wider deployment.

In the StarLink short-distance technology and 5G network integration deployment solution, the G node (management node) acts as a routing/bridging node to link the T node (communication node) with the 5G network. The 5G core network can perceive the device status of all T nodes through the protocol adaptation layer, including network status, service information, traffic usage, etc. In terms of data format, the system uses the Layer 2 relay method to make an adaptation layer above the data link layer to define the data format and data set of the data plane and control plane protocols. It can be deployed in edge UPF, Home Subscriber Server (HSS) and other locations to realize field-level data migration to the cloud, and to achieve the reachable, Manageable and configurable of 5G networks to G nodes and T nodes in the short-distance and short-distance communication domain of Starlink.

Facing the intelligent manufacturing scenario, China Mobile and its partners have jointly realized the innovative application of 5G &+ StarLink integrated communication technology in motor synchronous control. In this innovative application, the StarLink short-distance technology is used to replace the industrial cable between multiple sets of server servers, and the protocol is transformed at the basic service layer of the StarLink communication node. Not only can it ensure the communication requirements of microsecond-level delay between servo drives, but also can adjust short-distance air interface resources in real time through 5G cloud applications to actively deliver QoS policies such as business priority and delay jitter management. This improves the transmission reliability of the field control data flow, making it possible to achieve higher-order flexible manufacturing.

In the future, the 5G fusion star flash short-range communication system will be further combined with the digital twin, and will also realize the manageable, controllable and visible network of key links in industrial production. In order to meet the demand for flexible, dynamic and rapid deployment of communication connections in production and operation, and promote a breakthrough in the extension of 5G services to the core link of factory production.

3.3.3 5G+Deterministic Network

In order to realize the connection between the 5G TSN logical bridge and the TSN network, the 5G system expands the following three functional modules:

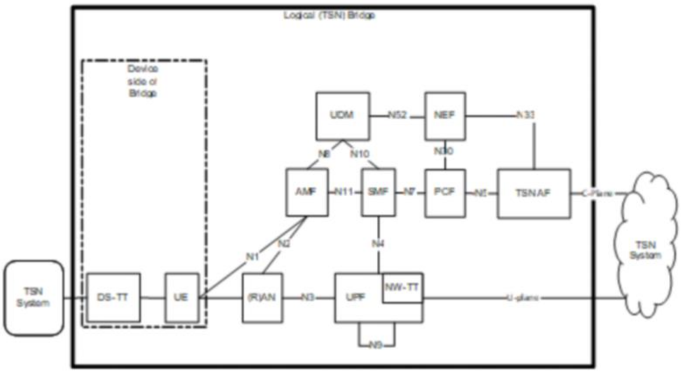

Figure 3-4 TSN logical bridge system architecture defined by 3GPP

1) DS-TT

The Device-side TSN translator is used to connect the TSN system on the terminal side.

2) NW-TT

The network-side TSN translator is used to connect the network-side TSN system.

3) TSN AF

The Application Function of TSN is used to connect the CNC controller of the TSN network.

To a certain extent, 5G+TSN solves the needs of wireless replacement of wired, data interconnection, and deterministic data transmission proposed by the digital and intelligent transformation and development of the industrial Internet, and has certain development prospects.

In order to combine wired and wireless deterministic technologies, simplify system architecture, and promote industrial development, the industry proposes Time Aware Network (TAN) technology for wired LAN deterministic technology. The technology is designed to provide deterministic transport services for industrial applications in a lightweight, plug-and-play manner. Time Clarity Network Protocol is a set of wired LAN evolution enhancement technology for industrial communication, which further expands the special capabilities of network communication on the basis of Ethernet. On the one hand, TAN combines a high-precision clock with Ethernet data communication, and uses the clock as a benchmark to schedule and control data communication, so that data communication has high accuracy and stability. On the other hand, TAN adds a TAN header definition to the Ethernet data format to form a TAN PDU, so that the data has a more complete identification in the communication, thereby improving the scheduling and control capabilities of network multi-service communication. The integration of 5G technology and TAN will further expand the application fields and scenarios of TAN. The specific integration scheme is currently in the testing and verification stage.

5G and TSN/TAN solve the deterministic problem between data transmission layers. The NC-Link launched by China Machine Tool Industry Association and the new generation of OPC standard OPC UA (Unified Architecture) launched by the OPC Foundation. This architecture aims to unify the interoperability interface of the industrial protocol layer, so that information is available to each authorized application and authorized personnel at any time and any place, and solves the problem of interconnection and interoperability in the industrial protocol business layer. This establishes a unified set of standards for the interconnection of industrial CNC equipment. The combination of 5G with TSN/TAN at the transport level and NC-Link/OPC UA at the application level provides a real-time, highly deterministic and truly vendor-independent complete industrial communication solution for wired and wireless coexistence. As the integration and adaptation scheme between technologies becomes more and more mature, it is expected to gradually become the best practice of industrial field communication.

3.3.4 5G+high-precision indoor positioning

It is relatively simple to use the carrier received signal strength for fingerprint database positioning. The RSSI of Wi-Fi or Bluetooth can be used as a reference, and the accuracy is generally 1/3 or 1/4 of the station spacing. The accuracy can be improved by optimizing the algorithm for scene analysis. But its defects are low precision, difficult maintenance, and poor adaptability to environmental changes.

In the future, the 5G-based positioning technology will be explored to achieve a high-precision positioning solution under the condition of limited bandwidth and without affecting existing services. In addition to the commonly used RTT, AOA/AOD, and TDOA, you can also consider referring to GNSS positioning, and perform positioning through the carrier phase information at both ends of the transceiver. Compared with the traditional measurement of time and angle, the wavelength of the 5G carrier wave is shorter. By measuring the phase difference between sending and receiving, theoretically, centimeter-level positioning accuracy can be obtained. Using the carrier phase for positioning, in addition to calculating the absolute position and relative position (distance, angle) of the terminal, it can also directly use the change speed of the carrier phase to quickly calculate the relative speed change rate of the two terminals, which has certain application scenarios.

At the same time, there are also some problems in carrier phase positioning, such as difficulty in first-reach path separation, insufficient phase tracking accuracy, cycle jump, and long cycle ambiguity convergence time, which have a great impact on positioning accuracy and time. Whether it can be quickly applied requires further technical verification.

In addition to the above-mentioned solutions for optimizing positioning accuracy using carrier phase technology, LPHAP (Low Power High Accuracy Positioning) positioning technology optimizes positioning accuracy and power consumption at the same time. LPHAP simplifies the functions of the 5G protocol stack and chip, uses the uplink positioning reference signal in the RRC_INACTIVE state to use the UTDOA and AOA algorithms for positioning, and uses the fingerprint database to compensate in the NLOS scenario, and the target reaches sub-meter positioning accuracy. At the same time, the purpose of reducing power consumption is achieved by quickly switching to the light sleep/deep sleep state to reduce the bottom current and combining network side optimization.

4 Typical applications of 5G+Proximity network industry for digital twin

4.1 Construction machinery manufacturing

The digitization of construction machinery manufacturing is a typical use case for digital twins. Taking mold management as an example, molds are the main production resources of manufacturing enterprises, and important information such as mold start-up time, molding cycle, mold opening and closing times, and abnormal downtime need to be frequently recorded. However, the traditional inventory of molds is carried out by asset managers, using manual search and manual recording methods, which consumes time and manpower, and manual statistics may cause data gaps or errors. Because the existing passive IoT technology adopts the way of integration of excitation and communication, passive IoT tags require short-range power supply from the reader when going up and down. In most cases, the reader still needs to manually scan the code. When the distance is long, the uplink signal-to-noise ratio of the tag is low, so that the reader cannot demodulate the tag signal.

The use of passive IoT technology can break the problem that the communication distance of traditional passive IoT technology is too close. The passive IoT device can periodically read and refresh the current position of the mold, the number of mold clamping times, the forming cycle, the materials and products used, and other information, completely replacing manual code scanning.

The new passive IoT technology can also be combined with the gateway to further extend the communication distance by using the gateway as an active transit node. Reporting core data to the edge cloud through passive IoT tags can meet the localized processing and security requirements of business and data in manufacturing production areas, and the data transfer to the cloud can effectively break through the data gap between the entire production line, workshops, and factories. This can form a unified asset management SaaS platform, realize the management of the entire life cycle of molds from purchase, use, maintenance, scrapping and disposal, and solve many managements blind spots under the existing management model. And it can effectively increase the marginal benefit of investment and improve the utilization rate of assets, and reduce unnecessary equipment investment and idle waste.

4.2 Smart Mining Management

The "integrated management and control" of intelligent mining management is one of the digital twin architectures used in the industry. The industry proximity network plays an important role in the mine proximity network and runs through the entire network layer. The mine-oriented digital twin architecture adopts a distributed, multi-layered architecture, which is divided into five layers from top to bottom: display layer, application layer, platform layer, network layer, and access layer.

Taking the application scenario of unmanned mining in the underground mining business as an example, unmanned mining is to install remote control systems, monitoring equipment and sensing equipment on mining machinery, and realize remote operation and control of mechanical equipment through the console. The current underground mining operation process relies heavily on manual operations, mainly focusing on the inspection of road headers, conveyors, and underground gas sensors. Due to the harsh environment and high-risk during operation, it leads to problems such as difficulty in recruiting, difficult management, high cost, and high risk. The industry urgently needs low-latency, high-reliability, and large-scale connection of unmanned remote control equipment technology to replace on-site manual operation and help mining enterprises to produce safely and efficiently.

At present, the communication mode in the well is relatively backward, and all use the wired way to transmit information. A large number of video surveillance equipment and sensors are installed on the hydraulic support of the working face, and the cables are many and miscellaneous, which are easy to cause cable damage and data interruption during use. In addition, wireless communication methods such as industrial Wi-Fi cannot meet the requirements and are prone to mutual interference. The use of 5G network slicing technology can effectively guarantee remote operation services. According to different mining business scenarios, different business requirements for the industry field network are sorted out. For example, sensor information collection services require high reliability and large bandwidth, and are not sensitive to delay and uplink and downlink rates. In remote control application scenarios, extremely high reliability and ultra-low latency are required. In downhole video surveillance and downhole communication, large bandwidth and high uplink and downlink rates are required.

4.3 Smart Steel Industry Management

In the middle-production process of iron and steel, the iron-making process is a link with high technological complexity in the iron and steel smelting process. The main cost of iron and steel enterprises comes from ironmaking. The traditional ironmaking process has a low level of automation. The process operation mainly relies on manual experience, and the process coordination ability, production stability and cost control are insufficient. Iron and steel enterprises can realize the automation, unmanned and intelligent production process of iron area through the deep integration and innovative application of iron-making process technology and 5G, big data, cloud computing and other technologies, comprehensively improve production efficiency and reduce potential production dangers.

The locomotive positioning accuracy needs to meet the static positioning accuracy of ±2mm, and the dynamic positioning accuracy of ±5mm. Only by ensuring the vehicle position accuracy can remote control accurately judge the locomotive position and collaborate without deviation. At present, 5G can only reach 5-10 meters, which cannot meet the needs of the industry. 5G integrated high-precision indoor positioning technology can meet the millimeter-level positioning needs of four coking vehicles.

The equipment needs to realize the automatic, stable and cooperative operation of the vehicle without human intervention, the communication between the equipment needs to be realized, the service level needs to be guaranteed, and the delay needs to reach the microsecond level. The 5G+Sparklink short-range can support ultra-low latency, high reliability, precise synchronization, high concurrency, high efficiency and high security, etc., to meet the needs of deterministic service quality assurance services in the four major vehicle collaborative operation scenarios.