Passive IoT Typical Scenarios White Paper

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1 Overview of passive IoT

1.1 Development status and trends

Industrial digitization is booming, and the industry's demand for all-factor, all-process and all-life-cycle management of all kinds of objects is becoming increasingly urgent. Existing technologies face challenges in terms of the number of terminal connections, perceived scale and application costs, and the industry calls for new technologies and products for IoT. Passive IoT is a low-power communication technology that realizes the transmission of information to the target node by collecting environmental energy and converting the available radio wave energy, thermal energy, vibration energy and mechanical energy around it into electrical energy that can drive its own circuit, while using the communication mode represented by backscattering. Its most notable feature is that it does not rely on traditional battery power supply, which can well solve the power consumption bottleneck problem and is the key technology for the development of the next generation of Internet of Things. According to the current situation of the industry, market demand and technology evolution trends, the development of passive IoT technology can be divided into three stages: P-IoT I, P-IoT II and P-IoT III (Figure 1).

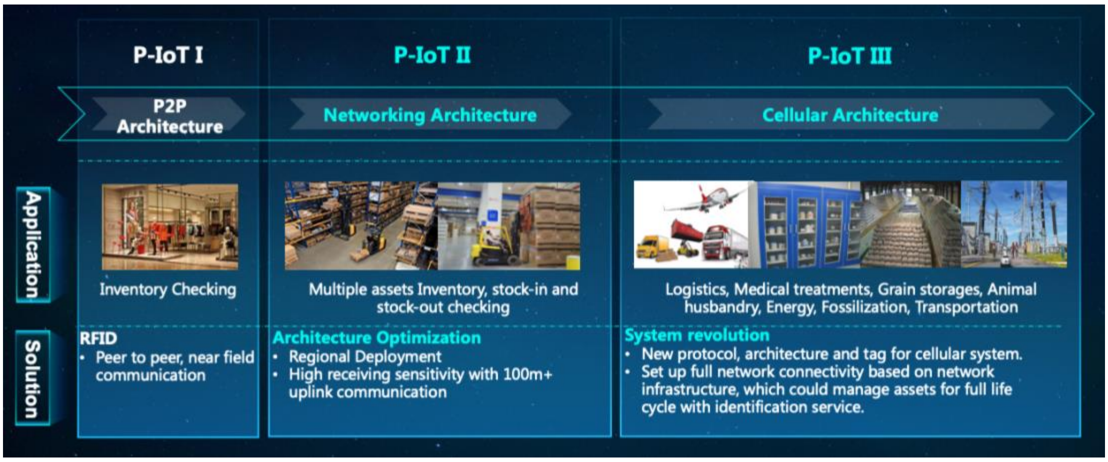

Figure 1 Three stages of passive IoT

P-IoT I adopts single-point architecture, represented by UHF RFID, which contains three parts: passive tag, reader and management platform. The working schematics is that the reader transmits RF signal to activate the passive tag, the tag uses backscattering technology [1] to modulate its own information to the RF signal. The reader receives the tag backscattered signals and demodulation, and uploads the collected information to the back-end management platform to realize the reading and transmission of information. Due to the existence of signal self-interference and inter-reader interference at the reader end, resulting in the communication distance between the read-write and the label is limited. At present, the industry focuses on optimizing the performance of reader and tag to improve the point-to-point identification and short-distance communication capability.

P-IoT II adopts a networked architecture, dividing RFID readers from a single-point architecture into two devices: the helper and the receiver. In the application, the management platform is responsible for starting the request process, unified scheduling of receivers and data analysis with visualization. The receiver is responsible for sending command signals and managing the helper. The helper is responsible for forwarding command signals to the passive tags and supplying energy to activate the tags. The activated tags transmit their own data to the outside world by backscattering [1]. The receiver receives the data and reports it to complete the reading process. P-IoT II decouples the forward link and reverse link by separating the transceiver function, effectively reduces the self-interference problem of the reader, and thus improves the receiver's sensitivity, extending the coverage of the system [2]. At the same time, the receiver needs to support network deployment to optimize the efficiency of the system. Successfully extend the regional coverage from dozens of meters to more than a hundred meters.

P-IoT III adopts new cellular architecture and protocols, and will use base stations or terminal devices to realize the stimulation and information collection of tags, and with the advantages of cellular network upstream and downstream interference suppression, adaptive coding and modulation, flexible resource scheduling, multi-antenna and multi-node joint transmission, and mobility management, it will realize medium to long-range transmission and large-scale coverage. Providing the connectivity capability of "full-process and full-network". 3GPP has already carried out the standardization research of passive IoT. According to the definition of the relevant 3GPP standards, passive IoT supports three types of tags, namely, device A, B and C. The technical characteristics of tags are shown in Table 1. The system can flexibly select label types according to different business requirements, which further improves the applicability of passive IoT in different scenarios. Meanwhile, tags supporting other network architectures or protocols in passive IoT can also be categorized with reference to the above features.

	Device A	Device B	Device C
Features	Backscatter communication. No independent signal generation and amplification capability.	Backscatter communication, with energy storage. No independent signal generation capability, Supports label reverse signal amplification.	With energy storage. Supporting independent signal generation.
Power Consumption	Microwatt power consumption	Between Device A and Device C	Milliwatt power consumption

Table 1 Features of different types of passive IoT tag

P-IoT I can support point-to-point identification within the local area. It has been used for a while in FMCG retailing, small-scale warehousing inventory and other scenarios. However, due to the downlink budget limitation, the coverage distance is less than 10 meters (with a link margin of about 59dB), and it is mostly used for small-scope proximity inventory, making it difficult to meet the needs of large-scale asset management, location tracking, warehousing and other full-process business automation requirements. P-IoT II tag reverse identification distance can exceed 100 meters, with good identification accuracy, and based on network coverage, further expanding antenna-level, depot-level and meter-level low-cost positioning capabilities on the basis of inventory and warehousing business capabilities, it has already been realized for ground application, deployed in large-scale warehousing, asset management scenarios such as single/multiple crossing areas, which can realize the automated large-scale inventory of goods, and is continuously playing a huge role in the value-added of the system. Meanwhile, P-IoT II does not require new tag. The system can reuse the existing resources, to support the seamless connection with the single-point type and the rapid upgrade of business.

In the future, passive IoT will further advance to cellular. Cellular passive IoT can make full use of the cellular network infrastructure and authorized spectrum. Firstly, there will be a substantial increase in communication distance, reliability and security and other communication performance, support for long-distance transmission, lightweight identity authentication, multisensory fusion, and other important capabilities. Secondly, support for cross-domain label management, can achieve end-to-end full business process through, eliminating information silos. Based on the above advantages, passive IoT will realize the “three-transition” management of all kinds of objects, i.e., the visualization, automation and intelligence of all elements, all processes and all life cycles, and realizing sensing for all, connection for all. Throughout all processes control and management, all life cycle data can be connected, thus creating a digital base for the Internet of Everything. Effectively meeting the new needs of industrial digitization, which will help the scale of IoT connection to achieve hundreds of billions or even trillions of dollars. Making the whole life cycle data manageable and controllable, then build the Internet of Everything digital base, effectively meet the new needs of industrial digitization, helping the Internet of Things connectivity scale to achieve hundreds of billions or even trillions of breakthroughs, to create a new industry of the Internet of Everything, to promote the quality of the industry, cost reduction, efficiency, greening and security, and empowering the production of enterprises, people's lives and sustainable social development.

1.2 Application scenario classification

With the in-depth application of IoT technology in various industries, in the face of more flexible and changeable application scenarios, passive IoT is becoming a key enabling technology for realizing the vision of "hundreds of billions or even trillions of IoTs" by virtue of its lower deployment and maintenance costs, no need for traditional battery power supply and other advantages. As shown in Figure 2, the typical scenarios of passive IoT can be categorized into three types: regional inventory, wide-area tracking and full-area management, according to the business aspects and application characteristics of tags in their whole life cycle.

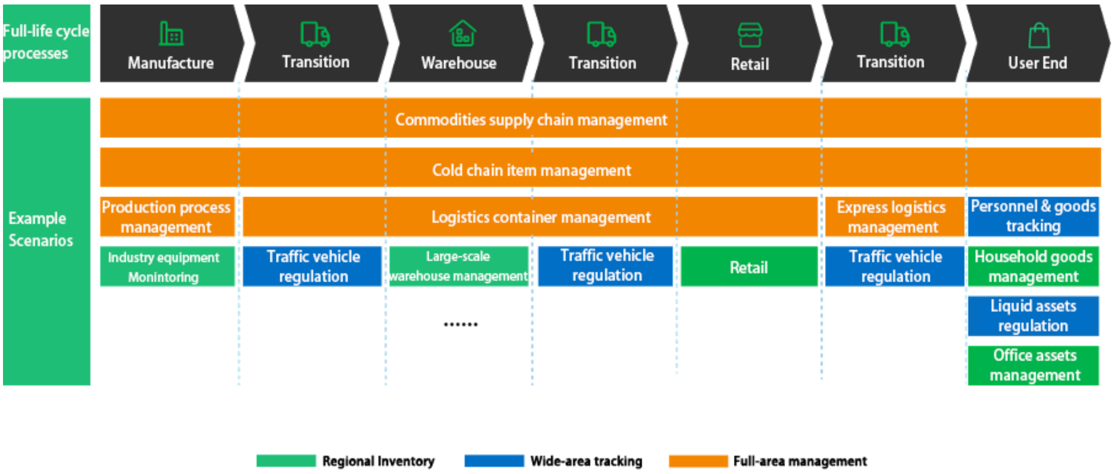

Figure 2 Passive IoT typical application scenario classification and examples

Regional inventory, its application environment is mainly localized, and the application demand is based on the inventory of the labeled objects in a relatively fixed area. Regional inventory focuses on warehouse management, asset management, equipment monitoring, smart family, supermarket retailing and other scenes, automating inventory and management of items in warehouses, parks and family areas, reducing manual inventory costs and error risks, improving inventory efficiency and security, and realizing "one-code identification".

Wide-area tracking, whose application environment is mainly wide-area and the movement of marked objects may be irregular, the application demand is mainly for positioning and tracking of marked objects. Wide-area tracking focuses on personnel and goods tracking, traffic and vehicle supervision, urban movable assets management and other scenarios. Through rapid monitoring, positioning and tracking of important people and goods, it can effectively prevent people or animals from getting lost and goods from being lost, help individual users and urban management units better protect personnel and assets, improve comprehensive management and operation efficiency, reduce losses and risks, and realize "one-code tracking".

In the category of full-area management, the application environment is both local and wide-area, involving multiple business entities, application links and management processes, and the application demand is mainly for end-to-end full-process management and information traceability. The application requirements are mainly end-to-end full-process management and information traceability. The whole domain management category focuses on industry, logistics, cold chain, construction, supply chain management and other fields, and carries out end-to-end supervision of the marking object in its whole life cycle. Taking production process management as an example, starting from the entry of materials into the factory, the supervision and traceability of material warehousing, manufacturing and finished product logistics are carried out to realize the digitization, transparency and intelligence of the whole process of the products, and realize "one-code to the end".

2 Typical scenarios of passive IoT

2.1 Regional inventory “one-code identification”

2.1.1 Large-scale warehouse management

In recent years, with the rapid development of online shopping, cross-border trade, cold chain and pharmaceuticals, and the transformation and upgrading of traditional industries such as manufacturing and retailing, the demand for large-scale warehousing continues to grow. Facing the development trend of informatization, automation and intelligence of large-scale warehousing, passive IoT supports continuous coverage inside and outside the warehouse. Accurate positioning of items and intelligent identification of information can realize efficient inventory and management of large-scale warehousing materials.

At present, large-scale warehousing mainly use the QR code, machine vision, RFID and other technologies combined with manual operation to achieve the daily management of goods in and out of the warehouse and inventory. The level of automation remains low, inventory data is not instantaneously. Inaccurate data and low efficiency of the search for things, etc., which not only consumes a lot of manpower and materials, but also greatly affects the efficiency of warehousing management. In addition, large-scale online shopping, pharmaceuticals and other high-end customers also need to keep abreast of the supply and flow of goods in the warehouse. Traditional management methods are not sufficient to meet the demand.

Passive IoT can extend the coverage of the system, in the warehouse on the goods or packaging containers (such as: cartons, wooden boxes or plastic pallets, etc.) deployment of device A or B tags. Tags and goods information is bounded, and through the warehouse gate, roof, flat storage and vertical storage and other key areas of the distribution of incentive and receiving equipment (Figure 3), can realize the target goods of the rapid inventory, in and out of the warehouse management and positioning and location search and other applications. The tag can be used for quick inventory of target goods, in/out management and locating. When the goods enter or leave the gate, the tag information is read to realize the automatic identification of the entering or leaving. At the same time, the read cargo information will be reported to the management platform, which will be connected to the customer's warehouse management system, thus realizing the automatic updating of the status of goods in and out of the warehouse. When the goods are put on the shelves, the PDA reader deployed on the forklift can identify the goods on the truck and match them with the warehouse information, thus realizing accurate positioning of the goods and timely updating of the information. When the goods are inventoried, the base station equipment deployed in the warehouse can realize minute-level quasi-real-time inventory of the labels, and the inventory efficiency is greatly improved compared with that of manual inventory. When the goods are searched, passive IoT supports antenna-level and warehouse-level accuracy of the warehouse to find the goods, combined with intelligent algorithms to achieve low-cost meter-level positioning.

Figure 3 Schematic of passive IoT deployment in a large warehouse

China's smart warehousing market is large and there is still room for growth in both stock and incremental market in the medium to long term. Passive IoT can be used to deploy equipment at the warehouse site, and combined with the management platform to carry out remote automatic inventory and meter-level positioning; on the one hand, can improve the convenience of warehouse management, and further save manpower costs; on the other hand, can improve the accuracy of the information of the goods in the warehouse, to solve the discrepancies in the warehouse management and other problems, and better meet the comprehensive management needs of large-scale warehousing.

2.1.2 Office asset management

Office assets include office supplies, communication equipment and special equipment, etc. Office assets in enterprise parks are generally characterized by multiple types, large quantities, frequent flows and high usage frequency, which urgently require efficient, accurate and convenient ways to meet the management requirements of enterprises in terms of approving, checking, inventory and tracking of assets. Passive IoT realizes the automated collection of all elements of asset information in the region through the continuous coverage of office areas, warehouses and outdoor parks.

At present, the daily management of assets in the park is mainly realized by online sheet, QR codes, machine vision and other methods combined with manual inventory, but there are still some problems. Firstly, manual inventory takes a long time, which is inefficient and prone to errors, the real-time nature of asset management is poor and it is impossible to realize on-demand inventory, and it is easy to shirk responsibility when problems occur. Secondly, some assets are characterized by high borrowing frequency and frequent movement of location, so it is difficult to detect changes in assets in time and realize rapid recovery of assets with the current management method. Thirdly, as different categories of office assets are highly differentiated, it is difficult to collect all elements of information on the characteristics of the assets in the existing methods, and it is not possible to achieve refined management. Fourth, the existing method is greatly affected by the environment, and it is difficult to play a role in dark environments at night.

Based on passive IoT, device A or B tags are deployed on assets such as computers, printers, filing cabinets, desks and chairs to give office assets a unique "ID card" (Figure 4). Cellular passive base stations are deployed in key areas such as offices, warehouses or entrances and exits in enterprise parks, and the management platform relates to the internal information system of the enterprise. The management platform is connected with the enterprise's internal information system, which can effectively realize the collection of detailed information (e.g. color, function, usage, procurement time, usage cycle and user, etc.) and automated comprehensive management of the entire lifecycle of office assets in the park from procurement, distribution, usage, daily inventory to disposal. Passive IoT can not only greatly reduce the time of asset inventory in the region, solve the management problem of "once a year, take a year", but also combine with positioning technology to realize antenna-level precision positioning, facilitate the rapid recovery of lost assets, and further solve the problems of unclear quantity of assets, unclear ownership and inconsistency between accounts and facts that exist in the day-to-day management of enterprises. Especially in the outdoor environment of the park. Based on the continuous coverage of the cellular base station, it can still realize the rapid positioning of assets. In addition to asset inventory, passive IoT combined with electronic fence technology can also realize the management of personnel in the park, such as automatic ID for personnel entering and leaving the park.

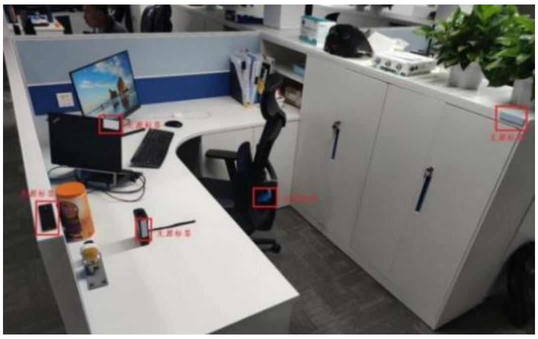

Figure 4 *Deployment of passive IoT in the office asset management scenario of the park*

The number of office assets in the park is large and facing difficulties to manage. Passive IoT has the advantages of fast inventory, regional positioning and continuous indoor and outdoor coverage, which can further meet the requirements of enterprises for the refinement, automation and intelligentization of office assets management in the park, and has great potential for market development.

2.1.3 Industry equipment monitoring

Fields like industry and energy are the basic support for economic and social development, and digitalization, intelligence and green development are the important directions of the new industrial and energy systems. At present, the level of automation and complexity of various types of equipment in the industry are constantly increasing. Effective condition monitoring and fault diagnosis of equipment are required to meet the needs of safe production. Take the electric power industry as an example, power transmission and substation are the core link to realize long-distance transmission of electric power, and there is a demand for periodic monitoring of the operating status of working facilities and working environment. Passive IoT can provide the industry with a more efficient and convenient way to monitor the condition of equipment throughout its life cycle.

Industries such as modern manufacturing and electric power typically use a large number of sensor nodes, manual handheld monitoring devices (e.g., infrared thermometers), or drone inspections to monitor work facilities and environments, but there is a lack of real-time and cost-effective means to do so. At the same time, some monitoring equipment may be deployed in harsh environments (e.g., high/low temperatures, high humidity, or prone to electromagnetic breakdown, etc.), special location spaces (e.g., underground pipeline corridors, etc.), or hazardous environments (e.g., high-speed moving or rotating equipment, etc.), which leads to many inconveniences in the existing monitoring methods.

Take the electric power industry as an example, in the environment of underground pipeline corridors and other environments, underground power transmission cables are mostly buried in the space of 1 meter or less from the ground at the top, and the uppermost cover is concrete or asphalt pavement, which is characterized by a small working space and weak communication signals, and so on. Using passive IoT, device B or C tags with sensing capability are installed at the locations where parameters such as temperature, humidity and water level need to be monitored, and relay equipment is deployed to enhance signal coverage (Figure 5). The sensing tags are self-powered by efficiently harvesting environmental energy such as electromagnetic energy, light (fluorescent lamps) and heat. The base station or relay device can periodically read the tag sensing data, and the platform can filter, curve and analyze the data by combining multiple environmental quantities. By filtering, mapping and analyzing the data in combination with multiple environmental quantities, the platform achieves low-cost and high real-time environmental monitoring based on the point location. Timely discovers the conditions of heat, abnormal vibration, high humidity and waterlogging of the line, and locates the fault points to ensure the safe operation of underground transmission cables. In the outdoor monitoring environment, the working voltage of the primary power equipment ranges from 800kV to 0.4kV, which has the problems of wide operating range, difficult to get power and possible electromagnetic breakdown. Device B tags, which are capable of sensing and resisting high-voltage breakdown, can be mounted at the contact points of the equipment to be measured (Figure 6). The tag can use solar energy to achieve environmental energy supply, the base station periodically reads the sensing data of the temperature measurement point, and the platform uses the collected temperature data to analyze the operating status of the equipment, thus realizing low-cost and maintenance-free monitoring of the operating status of primary equipment. At the same time, in actual deployment, the existing cellular base stations in the park can be reused for tag information reading and sensing monitoring, so as to realize multi-functionality of one network.

Figure 5 *Schematics of passive IoT application in equipment monitoring of underground pipeline*

Figure 6 *Schematics of passive IoT application in primary substation equipment monitoring*

In summary, passive IoT has the advantages of long communication distance and reusable existing communication resources, which can meet the monitoring needs of various types of equipment and environment in vertical industries with high quality, better solve the crucial problems of difficult to obtain power for monitoring equipment and high cost of manual inspection and operation and maintenance, and provide cost-effective and real-time equipment digital monitoring new technological means for the industry. Provide the industry with cost-effective and real-time equipment digital monitoring abilities.

2.1.4 Household goods management

As the standard of living rises, the variety of personal and household items becomes more diverse, for small or important items such as keys, passports, bank cards, wallets, books, and children's toys, people may often forget where they are or be unsure if they are still at home, so there is a growing demand for household items to be found and valuables to be managed. Passive IoT can support the refined management of household items by utilizing cellular base stations, home network devices, and mobile terminals such as cell phones.

Currently, household goods management is mostly realized by Bluetooth or UWB positioning terminals, but these terminals have problems of high energy consumption and high cost. By using passive IoT, some passive tags are placed on fixed positions such as doors, walls, tables, sofas, lamps and beds to serve as reference points for assisted positioning, and some passive tags are pasted on easily lost or valuable items to realize the management of mobile items. In the smart home environment, home network devices like cell phones and other terminals can be used as relay devices to further expand the coverage of passive IoT in the home [3], realize applications such as quick search of items, abnormal alarms, and monitoring of the status of items. Using tags, home network devices and mobile terminals, it is possible to quickly locate and search for items to avoid loss or forgetfulness. At the same time, passive IoT can record information such as the length and frequency of use of an item, which can help users plan their lives better and carry out maintenance or repair in a timely manner.

For example, when users are looking for a certain item at home, they can receive signals from passive tags (tags affixed to the items to be searched and some fixed location tags) at home by means of signal processing algorithm. When the user is looking for an object at home, he can receive the signal sent by passive tags at home (tags pasted on the object to be searched and tags in fixed positions), and locate the object through signal processing algorithms. When the user is located outdoors, if he finds that his personal belongings (such as keys, bank cards, etc.) are not around, he can use his cell phone to interact with the base station to remotely establish a connection with the network equipment at home, triggering the equipment to search for the belongings, so as to confirm whether the belongings are at home or not (as shown in Figure 7).

Figure 7 *Schematics of household goods management*

Passive IoT is used in household goods management scenarios, and has the advantages of ultra-low power consumption, maintenance-free, easy installation, extremely low cost, and integrated sensing capabilities. In terms of ultra-low power consumption and maintenance-free, tags can be powered by harvesting energy from the environment, eliminating the need for traditional batteries or power supplies and greatly reducing maintenance costs. Taking RF energy as an example, gateway devices, routers and CPEs in the home, as well as personal smart devices such as cell phones, can all send RF signals, which can be reused or deployed as dedicated RF equipment to power the tags. In terms of ease of installation, the tags can be extremely small in size, flexible and foldable, oxidation-resistant and washable, and require no wiring or power connections, allowing them to be placed in the home or affixed to household items with greater flexibility. In terms of extremely low cost, tags are usually less expensive than GPS, Bluetooth and UWB positioning devices, and because they don't require embedded batteries and wires, they reduce hardware overhead and maintenance costs. In terms of integrated sensing capability, the tag can integrate temperature and humidity sensors to collect environmental data, so as to monitor the status of household items and provide abnormal alarms in a timely manner, which has great potential for future applications.

2.1.5 Summary

Regional inventory scenarios are based on the needs for inventory and searching of items within a localized area, but the existing technical solutions are only geared to provide services for industrial applications and are difficult to be applied to outdoor open areas. In the future, passive IoT will achieve high-performance and low-power communication with massive tags, as well as full-area and multi-dimensional fusion sensing, with advantages of continuous indoor and outdoor network coverage, automated inventory, access and low-cost meter positioning, etc., which will provide a better solution for regional inventory scenarios, and further expand the applications for individuals and families to efficiently realize the regional inventory of "one-code identification."

2.2 Wide-area tracking “one-code tracking”

2.2.1 Personnel and goods tracking

In recent years, people's outdoor activities have become more and more abundant, and the safety of personal belongings in the outdoor environment has been increasingly concerned. At the same time, the elderly, children and pets at home also have the possibility of getting lost in the outdoor environment, and there is a need to know the current location of people and pets in time, so the demand for localization and tracking is increasing. Passive IoT, with its high real-time performance and support for wide-area continuous coverage, can provide new ideas for the tracking of people and goods.

Currently, the positioning and tracking of people and goods are mostly realized by GPS or Bluetooth devices, but there are still some drawbacks. GPS trackers can only be used outdoors and have disadvantages such as high power consumption and low security. Bluetooth positioning and tracking device only supports data transmission in close range, although the positioning accuracy is high, but it cannot be used individually for wide-area personnel and goods tracking, often need to resort to crowdsourcing and other means, to a certain extent, there are problems of poor real-time performance and low security.

For the positioning and tracking needs of personnel and goods, device C tags can be deployed on personnel (e.g., the elderly, children, etc.) and important goods (e.g., luggage, keys, cards, etc.). The tag supports regular active reporting of information, using the interaction between the tag and the cellular base station to achieve accurate positioning and tracking of the target bound to the tag. The result can be displayed on the cell phone side to achieve low-cost and rapid search. When the user obtains the tag, he or she can activate the tag and bind personal information, and the tag periodically reports heartbeat signals to the cellular network. The mobile application can display the current location of the tag. In the event of a lost person or item, the user can click “find” button on the application, and the cellular network quickly locates the tag bound to the person or item and displays the location information from which the user can retrieve the person or item. The application of passive IoT in people and objects tracking scenarios is characterized by low power consumption, high security and high real-time performance, and the tag's features of environmental energy harvesting and low-power communication can support its long-time standby and use. The information interaction of cellular network can provide high security and effectively protect user privacy. Based on the characteristics of cellular network wide-area continuous coverage, tags can be found wherever there is a base station, and are not restricted by indoor or outdoor environments, so that the tracking will have no “dead spots”.

In the future, with the continuous development and expansion of passive IoT industry, tags will further reduce costs and integrate multiple positioning methods to improve positioning accuracy, thus continuously enhancing the application advantages of passive IoT in wide-area tracking scenarios.

2.2.2 Traffic vehicle regulation

With the acceleration of urbanization, traffic vehicle management is facing more and more challenges, how to improve the efficiency of transportation supervision and enhance traffic safety without affecting the operational efficiency of urban traffic has become an urgent problem for urban road traffic management departments. Passive IoT is characterized by massive data sensing, ultra-low cost deployment and maintenance-free operation, which will provide new technical methods for vehicle and traffic safety management.

The current traffic vehicle supervision mainly relies on the deployment of cameras in certain areas combined with manual checkpoints; however, on the one hand, the shooting of the camera is greatly affected by the environment, and it is impossible to obtain high-quality visual evidence when there is dirt, obstruction or dim light; on the other hand, the mobility of the vehicle is strong and the range of the camera's field of vision is limited, so that the collected images or videos only show the current location. It is nearly impossible to continuously locate and track vehicles. On the other hand, because of the high mobility of vehicles and the limited field of view of the camera, the images or videos collected only show the current location, making it impossible to continuously locate and track the vehicles, and thus failing to meet the need for rapid tracing of abnormal vehicles.

To meet the needs of traffic vehicle supervision, the digital management of vehicles can be realized by deploying passive IoT device C tags on vehicles to form electronic license plates and combining with cellular passive base stations deployed in a wide area in the city. The tag stores the identification and basic information of the vehicle, such as the VIN number, license plate number, model, color and annual inspection information, etc., which can realize paperless, automated and intelligent management of traffic documents. Minimize the fraudulent use, misappropriation and imitation of documents. The tag regularly reports vehicle information to the base station and combined with the image information provided by the camera, it can help the traffic control department to improve management efficiency. On

the one hand, passive IoT combined with cameras can automatically monitor illegal behaviors such as driving in the opposite direction, driving not according to the lane, prohibited detection, speeding, overloading and over-limit, etc. In case of traffic accidents, it can quickly locate and track the vehicles involved in the accidents, and assist rescuers in quickly obtaining the accident location and vehicle information, improve the speed of emergency response, and reduce the difficulty in tracing the traffic violations. On the other hand, by analyzing the road traffic information collected by passive IoT, the management department can quickly understand the comprehensive traffic load, arrange vehicle routes and travel time according to the analysis results, adjust the traffic signal timing according to the needs, make full use of the traffic resources, alleviate the traffic congestion and improve the efficiency of vehicle traffic.
Road supervision involves a wide range and is difficult to manage. In the future, based on the environmental energy collection and low-power communication mode, the network of passive IoT can be promoted to strengthen the construction of road traffic management and continuously promote the informatization and intelligentization of urban road traffic supervision, as well as to promote the informationization and intelligentization of urban road traffic supervision.

2.2.3 Regulation of liquid assets

The supervision of urban assets is an important part of governmental management, and there are a variety of urban assets and a large number of urban assets, some of which are characterized by high mobility, high value, long use cycle, and dispersed use locations, such as automated external defibrillators (AEDs), safety hammers, manhole covers, rain grates, firefighting equipment, and public life jackets, etc. Such mobile assets are difficult to manage and prone to loss, and once lost, they are difficult to retrieve in time, which will bring great potential danger to the life safety of citizens and urban operation and management. Passive IoT can provide innovative solutions for the management of high-value and easy-to-loss mobile assets in cities with its wide-area coverage.

Currently, the management of urban mobile assets mainly includes manual checking, QR code/barcode-based scanning, video surveillance and RFID. Manual records and QR code/barcode-based scanning have the problems of low efficiency and low accuracy, and it is difficult to recover lost assets. Image and video acquisition equipment and recognition algorithms have high deployment costs and dead zones of coverage, which can provide certain clues in case of loss, but still can't realize the rapid recovery of lost objects. RFID technology can realize automated management to a certain extent, but the existing RFID can only support the asset management by gate and indoor small-area coverage, which can't satisfy the demand of rapid positioning and tracking of mobile assets in the city.

Based on passive IoT, it can realize the state monitoring and directional finding of all kinds of urban high-value and easy-to-lost mobile assets. Take manhole cover as an example, its asset value is high, and there are vibration, displacement, pressure and other dimensions of the sensing needs. The sensing ability of the device C tags can be deployed in the manhole cover, to realize its status and location of the regular active reporting. Through the interaction between the tag and the cellular passive base station, on the one hand, the management personnel can check the status of the manhole cover at regular intervals and confirm its location, and if it is lost, it can make use of the cellular base station's wide-area coverage to realize wide-area asset tracking, so as to retrieve the assets quickly. On the other hand, the sensing capability integrated in the tag can be used to monitor the status of the manhole cover at any time, and once the vibration or displacement exceeds the set safety threshold, it can actively report the alarm information to the management platform to assist the relevant personnel to quickly deal with the abnormal situation. Passive IoT supports environmental energy harvesting and low-power communication, thus realizing long-term application in large-scale urban environments. The wide-area coverage of cellular networks can make lost urban mobile assets "invisible" and realize rapid location and recovery.

In the future, with the development of passive IoT technology and industry, the tag form will be more diversified, the cost will be gradually reduced, and the positioning accuracy and real-time performance will be gradually improved. To provide more low-cost, high-precision and high real-time mobile asset management solutions for smart cities, and further meet the needs of management and tracking of the complicated and large number of urban mobile assets.

2.2.4 Summary

In the wide-area tracking scenario, the marked objects are characterized by high mobility and irregular movement, and the existing technical solutions are difficult to meet the application requirements due to the limitations in coverage, communication distance and power consumption. In the future, based on the advantages of passive IoT in terms of wide coverage, high real-time performance and authorized spectrum, the wide-area tracking scenario can be better realized and is expected to become one of the representative scenarios of passive IoT. Passive IoT with high real-time positioning and tracking capability is expected to provide in-depth empowerment for individuals, families and industries, thus supporting efficient, safe and extremely low-power consumption "one-code tracking" wide-area tracking.

2.3 Full-area management “one-code for all”

2.3.1 Production process management

Digital production is the upgrading of traditional production processes through digital technology to realize automated and intelligent production and manufacturing. Under the digital production scenario, it is necessary to supervise the materials, tools and finished products in the whole process of manufacturing and realize the whole process management from materials to finished products. Among them, in the warehouse area, roadway and production line area, manufacturing factories have the demand for quick inventory of materials and finished products. Passive IoT has the ability of medium and long-distance transmission and large-scale coverage, which can solve the business difficulties in the production process management of large factories.

The current production process management mainly relies on manual labor, workers based on paper lists or scanning code inventory materials and products, in the production process, from the main parts on the line, parts assembly, quality inspection of finished products to finished products off the line, are involved in a variety of parts of the check-in and check-out operations, manual operation is cumbersome and inefficient, there are omissions, wrong points, low efficiency and information is not interoperable and other issues, resulting in the production line efficiency is difficult to improve. At the same time, the flow of products lacks effective guidance, low efficiency, warehouse space cannot be effectively utilized, and increased management costs.

Adopting passive IoT, deploying device A tags on production materials, containers, work trucks and finished products, and deploying cellular passive base stations at entrances and exits of warehouses, warehouses and workstations, automated management can be carried out with regard to the types, quantities and locations of management objects. **In the aspect of warehouse in & out management** (Figure 8), when the carrier carrying tags loads relevant materials or finished products and passes by, the road junction automatically recognizes the information of materials or finished products and uploads it to the logistics system of the factory to update the logistics information of the factory in a timely manner, so as to realize the visual management of the logistics paths of the materials or finished products, and achieve the pulling of plans, Kanban boards and waves, so as to avoid the shutdown due to the failure of materials to be delivered in time. **In terms of inventory management**, based on the seamless coverage of cellular network in the warehouse area, the tags quickly report asset information to the upper material and finished product management system, thus realizing high real-time monitoring of the number of assets and inventory status in the warehouse as well as precise positioning of assets, realizing quick access to and from warehouses and asset counting, improving work efficiency, improving the quality of counting and enhancing the utilization rate of warehouses. **In terms of production line information**, the base station automatically reads and uploads information on materials and work-in-progress passing through each workstation, realizing automatic check-in of key parts. At the same time, it can improve production efficiency by recording the operation time consumed at each station and analyzing bottlenecks with big data technology. Automatically performs quality inspection and downstream distribution when products come off the production line. Based on the automatic collection of data from machines passing through each process and analyzing bottlenecks through LOB, the production beat can be improved, and the unmanned, automatic and accurate identification of item-level products on the production line can be completed, thus improving the production efficiency and meeting the needs of automatic production and lean production.

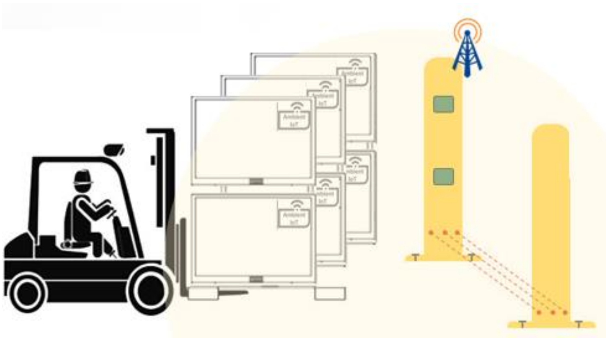

Figure 8 *Schematics of using passive IoT for warehouse in & out management*

In summary, passive IoT can better meet the needs of large-scale factories for automated inventory and automatic identification and reading of materials in the manufacturing process, effectively solve the problems of low efficiency, error-prone and non-transparent information and other pain points in the manufacturing industry, and provide low-cost, highly automated and highly accurate technology means for transparent production monitoring. In the future, the connection scale of passive IoT in the whole process management application scenario of manufacturing is expected to reach ten million per year, and there is much room for development.

2.3.2 Express logistics management

With the rapid growth of e-commerce, consumers' demands for express delivery speed and service quality are increasing, especially for express delivery with more logistics links and high-value express delivery, such as: insured items, bills and documents, cross-border goods, etc., the demand for end-to-end full-process digitalization and intelligent management is becoming more and more prominent. **Passive IoT can pass through the logistics business processes to achieve efficient full life cycle management, with greater development potential.**

At present, for express logistics management, RFID program has been more mature, that is, each express transit bag or other logistics containers pasted or embedded RFID tags, RFID equipment can be used to inventory containers and inventory management. However, RFID can only support equipment scanning in close proximity, by the network deployment cost constraints, reader equipment cannot be deployed on a wide-scale, so RFID-based express logistics cannot be achieved in all aspects of the logistics state of the real-time tracking, it is also difficult to realize the refinement of each piece of express management.

The use of passive IoT technology, device A or B tags deployed in a single piece of express delivery. For particularly important or valuable express delivery, device C tags is also available. Combined with express transfer points, distribution stations and other aspects of the deployment of the honeycomb base station, the use of base station wide-area coverage capabilities, logistics personnel can quickly complete the identification, sorting, storage and distribution, improve the efficiency and accuracy of the logistics of the picking and distribution and to reduce labor, reduce costs, help express logistics enterprises to keep track of the location and use of the express status, significantly reduce the loss rate, to achieve its state in the whole life cycle tracking and full management. At the same time, the label can be integrated with temperature, humidity and pressure and other sensing capabilities, to achieve efficient environmental monitoring of fresh and other perishable commodities and rapid information reporting. In the process of solicitation, the label can be deployed on the express parcel to activate the label and enter the express information. In the sorting process, the cellular passive base station deployed in the sorting center reads the labels on the parcels and automates the sorting of the parcels according to the destination and other information. In the transportation link, by reading the label information, it can understand the number, status and location of express delivery in transit, so as to accurately grasp the expected arrival time and other information. In the transit link, the base station deployed in the transit warehouse reads the label, checks the information of express parcels, and updates the information of the label if the items are damaged. In the distribution link, the label can be used to quickly locate the current position of the express package, which is convenient for the recovery of loss and wrong delivery.

According to statistics, China's express delivery business volume exceeds 100 billion pieces per year, with a large market space and development potential. Passive IoT supports wide-area inventory, low-cost fusion positioning and tag sensing capability integration, which can solve the problems of RFID small-range point coverage cannot be continuous networking, lack of sensing capability and lead to the inability to timely tracking, positioning and access to logistics status, etc., and better support for the express logistics industry's refinement and intelligent management, strengthen the express end-to-end supervision of the whole process, reduce the loss of express delivery, and improve the overall operation and flow efficiency.

In addition to express logistics, supply chain logistics management can also be realized by passive IoT. Combined with cellular base stations with full coverage, relay equipment, terminal equipment and passive tags deployed in supply chain commodities, it realizes rapid and accurate collection of data in all key operational links of the logistics process, provides effective basis for enterprise decision-making, and realizes visualized, refined and differentiated integrated logistics services.

2.3.3 Cold chain item management

Cold chain items refer to items that must be kept in a specific low-temperature environment at all stages of the whole life cycle, such as chilled food, biologically active drugs, and so on. Based on the needs of protecting users' health and improving management level, continuous collection of status information is required in the production, processing, storage, transportation and consumption of cold-chain food or drugs, so as to prevent deterioration or damage of the items, and to ensure that enterprises and individuals can grasp and trace the status of cold-chain items and the flow process in a timely manner. **Passive IoT can meet the management demand for traceability of cold chain items in their whole life cycle and will**

play an important role in cold chain management.

At present, the management of cold chain items represented by medicines is mostly realized by barcode or RFID, which has the problems of single-point operation, decentralized management and data delay, and it is difficult to realize the automatic collection and unified reporting of information on the quantity and status of items, and it is not possible to realize the continuous coverage of the network and the linkage of system information of each link of the whole life cycle of the cold chain, so the management efficiency is low and the maintenance cost is high. Moreover, the security of the existing technical solutions is low, and they cannot effectively realize the anti-counterfeiting and traceability of cold chain articles.

Based on passive IoT technology, device A or B tags with integrated temperature and humidity and other environmental sensing capabilities are deployed on cold chain items, and device C tags can also be used for items with higher value or more stringent management requirements. On the one hand, the interaction between the tags and the cellular base station can be used to realize the functions of positioning, regular inventory and information traceability of cold chain items, and on the other hand, based on the built-in sensing capabilities of the tags, the monitoring of the whole life cycle status of the items can be realized on demand. On the other hand, based on the built-in sensing capability of the tag, it can realize the monitoring of the whole life cycle status of the articles on demand. By multiplexing cellular passive base stations in production workshops, logistics routes, warehouses and sales outlets, continuous end-to-end coverage and full-process data integration can be realized, so as to realize applications such as production management, logistics tracking, rapid inventory, usage statistics and out-of-stock reminders for cold chain items. For special cases such as recall of cold chain items, the location and quantity of problematic items can also be quickly located through labels to improve the recall efficiency, and ultimately realize the closed-loop management of the whole process from production, distribution, sales, use, return and traceability. Meanwhile, passive IoT can effectively solve the problems of article counterfeiting and information alteration due to the characteristics of authorized spectrum and high security of cellular communication, thus further reducing the security risk. In addition, some special articles (e.g. blood, biological pharmaceuticals, etc.) have more stringent requirements for the environment, which not only require the whole cold chain transportation and storage, but also may require that the temperature and humidity of the cold chain environment and other indicators be maintained in a relatively stable value range. For such articles, the use of passive IoT can greatly avoid abnormal environmental factors caused by abnormal cold chain equipment or human negligence, and improve the supervision of cold chain articles.

To sum up, passive IoT can realize the whole life cycle management and traceability of cold chain items by taking advantage of the whole network of base stations and combining with sensing ability, and improve the speed and accuracy of information collection in the whole process. In the future, passive IoT technology will continue to develop and improve, and play an increasingly important role in anti-counterfeiting, traceability and supervision.

2.3.4 Commodity supply chain management

Supply chain management is the main battlefield of passive IoT and the key application field to show comprehensive benefits. Take commodity supply chain management as an example, its end-to-end process can be divided into production, warehousing and logistics, and store sales, and the marking objects cover commodities, logistics containers, vehicles, etc. The focus of supply chain management is to seamlessly connect all business links and unify data between them to enhance overall efficiency. The focus of supply chain management is to seamlessly connect all business segments and unify the data between them to enhance overall efficiency. **Passive IoT can provide full-factor, full-process and full-life-cycle supply chain management capabilities, and further strengthen end-to-end management**.

Existing commodity supply chain management is generally characterized by low management efficiency, difficult to produce on demand, low inventory efficiency, inaccurate inventory and goods anti-counterfeiting and anti-theft problems. Although RFID has been applied in the supply chain management of some retail commodities represented by footwear and apparel, which has alleviated the above problems to a certain extent, there are still problems: First, the communication distance of tags is limited, and in many cases, manual hand-held read/write devices are still required to conduct batch scanning, and the management efficiency is relatively low; second, the existing program needs to deploy read/write devices at key chokepoints in each link of the supply chain, and the deployment cost is higher; and third, the current back-end information systems in different links of the supply chain are generally inefficient in management, difficult to produce on demand, inaccurate inventory and difficult to prevent counterfeiting and theft of goods. Currently, the back-end information systems of different links in the supply chain are often "fighting separately", and it is difficult to interoperate the data between the systems, thus affecting the supply chain efficiency and even the overall competitiveness.

Relying on passive IoT technology, the deployment of device A or B tags in single commodities and device C tags in freight containers or vehicles, combined with the cellular base station with full-area coverage and a unified management platform, can realize seamless docking throughout the entire supply chain of commodities and provide one-stop information services. **In the production process**, information can be connected with commodity labels, truly reflecting the information on materials, processes and product parameters of each commodity, and supporting the efficient flow of commodity information in different processes and between different departments, so that production progress and commodity status can be viewed in a timely manner through shop-floor electronic signboards, computers and industry terminals, and so on. **In warehousing**, cellular network equipment is used to realize automatic batch scanning of commodities entering the warehouse, intelligent sorting and rationalization of the selection of cargo space, rapid positioning of commodities and inventory updating at the time of leaving the warehouse, and accurate recording of information such as the delivery time, flow direction, and attributes of commodities of each commodity to improve the efficiency of delivery**. In logistics**, the device C tags deployed in commodity containers or on vehicles can actively report information to the cellular base stations along the way, so as to timely update the logistics status and location of commodities and realize efficient logistics management. **In the sales process**, passive IoT supports stores to carry out detailed management of commodities based on information such as model, size or color, and supports applications such as commodity inventory, quick checkout, out-of-stock alarm, anti-counterfeiting of commodities, virtual trial, intelligent anti-theft, and statistics of best-selling/lagging products. In addition, based on passive IoT technology, it is expected that the commodity supply chain will be extended to individual users in the future. After purchasing goods, individual users can read the tags through cell phones with integrated read/write capability, obtaining information on the whole process of goods from production to sales, and realizing more personalized applications such as goods traceability, smart closet and smart cooking.

The scale of domestic retail commodities is large, and the annual total volume of commodities can reach hundreds of billions or even trillions, which provides a huge market space for passive IoT. Passive IoT simplifies equipment deployment by reusing the existing cellular infrastructure and opens up various business links, realizing the information integration of the whole chain of the commodity supply chain from end to end and the fine management of the whole process.

In addition to the commodity supply chain, passive IoT also shows great application prospects in industrial applications represented by the construction supply chain. With the accelerated pace of urban lifeline project construction, new urban infrastructure construction, railroad, highway and other transportation infrastructure construction, as well as " the Belt and Road" going out, passive IoT will play a more and more important role in opening up the links in the construction supply chain, and promoting the transformation of the industry in digitalization, greening and intelligentization. increasingly important role.

2.3.5 Summary

The full-area management scenario is characterized by a large number of business subjects and business links, as well as a long management chain, and its application environment is both local and wide-area. At present, information traceability can be realized to a certain extent by deploying read-write devices at key choke points in important links such as production workshops, logistics warehouses and sales stores. However, this approach requires greater control over the whole chain from end to end, and there are problems such as high deployment difficulty and business discontinuity. In the future, passive IoT, with the help of cellular network equipment, spectrum resources, station resources and ecological capabilities, is expected to further reduce the difficulty of deployment of reading and writing facilities, seamlessly connect all aspects of the life cycle of management objects, and truly realize "one-code for all".

3 Conclusion and outlook

Passive IoT integrates the advantages of backscatter communication and cellular communication technologies, and realizes the enhancement of air interface communication performance, the improvement of massive tag management capability and the diversification of system topology through the innovative and efficient design of digital and simultaneous transmission air interface, the minimalist network architecture and protocol stack and other key technologies, and possesses the important advantages of low-power consumption, low-cost, easy deployment and maintenance-free, and is able to provide the entire network and full-area coverage capability as well as the access capability of full-volume terminals. It is capable of providing full network coverage and access to a full range of terminals, efficiently constructing a digital base for the interconnection of everything, realizing rapid information sensing, connecting the physical, digital and commercial worlds, and bringing about revolutionary changes in diversified industrial applications for individuals, families and industries.

For the three typical scenarios of regional inventory, wide-area tracking and full-area management, passive IoT can solve the pain points of existing technical solutions, thus realizing "one-code identification", "one-code tracking" and "one-code for all". For regional inventory scenarios, passive IoT, through the improvement of technical performance and service efficiency, can realize a significant upgrade of inventory efficiency and accuracy, provide better solutions, and further realize the expansion of applications for households and industries. Wide-area tracking and full-area management are two types of scenarios in which passive IoT is advantageous. Passive IoT is able to realize high real-time tracking and full life cycle management of management objects, and further enhance the level of wide-area and cross-domain services, which will continue to open up new market space. With the continuous application requirements and the continuous development of the industry, passive tags as the core will usher in new opportunities, and the communication and sensing capabilities will be continuously improved, gradually evolving to passive intelligent microsystems. However, the development of passive IoT also faces a number of challenges, such as the difficulty of adapting to the existing network architecture, the low efficiency of RF energy collection, and the difficulty of networking topology, etc., and it is necessary to carry out end-to-end technological research and industrial research on core network, wireless air interface and new type of tags. In the future, with the continuous development of technology and industry, passive IoT will be deeply integrated with 6G, helping to build a green, energy-saving, intelligent and efficient next-generation mobile communication network. Truly realizing the "three-transition" management of labeled objects, i.e., realizing the visualization, automation and intelligence of the entire element, process and life cycle, and accelerating the promotion of the smart internet of everything.

4 Abbreviation

Abbreviation	Definition
3GPP	3rd Generation Partnership Project
6G	The sixth generation mobile communication systems
AED	Automated External Defibrillator
CPE	Customer Premise(s) Equipment
GPS	Global Positioning System
LOB	Line of Business
RFID	Radio Frequency Identification
UHF	Ultra High Frequency
UWB	Ultra Wide Band
PDA	Portable Digital Assistant

5 Reference

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