Development and Application Research of 5G Private Network Equipment For Ship Construction

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***Abstract*—At present, the networking rate of equipment and digitization level in the shipbuilding industry is generally lower than that in other industries. The 5G network provides a feasible solution to adapt to the complex manufacturing environment of the shipyard workshop. In order to ensure the reliability and real-time performance of the network at all times, a set of 5G independent private network equipment for the shipbuilding industry is developed, including private network terminal, base station and core network equipment. It is verified that the equipment can meet the requirements of high-performance network for shipbuilding in the laboratory environment. 5G integrated network scheme is designed to meet the needs of low-cost and high-performance network. At the same time, three typical 5G applications for ship construction are studied, including key equipment networking management, intermediate products status tracking and AR-aided ship block assembly based on 5G integrated network, which will improve the efficiency and quality of ship block construction.**

Keywords—5G private network, ship blocks construction, 5G application technology

I. Introduction

The shipbuilding industry is a typical discrete manufacturing industry, which has such practical problems: (a) The shipyard is in high humidity and high salt environment, the signal shielding is serious because of many steel structure parts, there are many mobile operation scenarios, and the real-time performance and reliability of 4G / WiFi and other wireless networks are poor. (b) The ship block workshop has a large number of equipment and parts, and a huge amount of data is generated in the construction process[1]. The existing network could not meet the requirements for the wide coverage and connection of such a large number of elements, and so does not have the basic network conditions for applying big data analysis to improve efficiency. (c) The process of ship block construction is complex, and the quality and accuracy checking mostly depends on manual work and empirical judgment. The efficiency is low and the checking results are uneven[2]. The existing network is difficult to support the application of quality and accuracy checking technology based on high-definition visual recognition. (d) The rework rate of assembly process is high, and the existing network is difficult to carry the application of AR (augmented reality) assisted assembly technology. 5G network has the characteristics of high rate, large connection and low delay, which can meet the application requirements of large data transmission, wide coverage connection and low delay control in shipbuilding, which is difficult to be solved by the existing network.

However, when 5G public network's external use environment is changed, such as user surge and signal interference, the network performance may could not meet the requirements for real-time and large bandwidth in industrial environment. The 5G independent private network is not affected by the external environment, which will enhance the performance of the network in some cases[3]. Therefore, aiming at the harsh working environment of the shipbuilding industry, we study the wireless integration of heterogeneous networks and 5G anti-interference technology in the shipbuilding environment, and develops 5G independent private network equipment, including 5G private network terminal, base station and core network equipment. In the laboratory environment, it is verified that the equipment can meet the requirements of ship construction for network performance. At the same time, the application scenarios based on 5G integrated network that of key equipment interconnection and management, intermediate product status tracking and AR-aided assembly are introduced respectively.

The structure of this paper is as follows: section 2 introduces the deployment scheme of 5G integrated network, section 3 introduces the basic development of 5G independent private network terminal and base station, as well as the laboratory verification of private network equipment, section 4 introduces the design of three 5G application scenarios based on 5G integrated network, and we summarize the research at section 5.

II. 5G Integrated Network Scheme For Shipbuilding Environment

In order to ensure network performance and save cost, the 5G Integrated Network which includes 5G public network, 5G independent private network, WIFI, and cable network is designed. The 5G independent private network can be temporarily deployed in the signal blind area caused by poor radio environment in ship block workshop, which mainly including 5G terminal, base station and core network equipment. Through 5G network, it can improve workshop network coverage, network rate and reduce air interface delay.

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The 5G integrated network deployment scheme of ship block workshop is shown in fig. 1. In which, fixed equipment such as cutting machine and gantry welding equipment are connected to the workshop convergence switch through wired network; Application that do not require high network performance, such as status data viewing of mobile equipment, is access to the workshop convergence switch through WiFi and other wireless networks; Mobile welding machines, high-definition video cameras, AR glasses, 5G PAD and other equipment with high network performance requirements are connected to the convergence switch through 5G public network or private network equipment, and connected to the MEC edge server in the plant area, and connected to the core switch through VPDN special line to aggregate the service data to the application server for data processing and analysis of the service scenario, so as to realize the 5G integrated network for data interconnection and realize the application of equipment interconnection, on-line quality and shipbuilding accuracy checking, AR-aided assembly and other application scenarios.

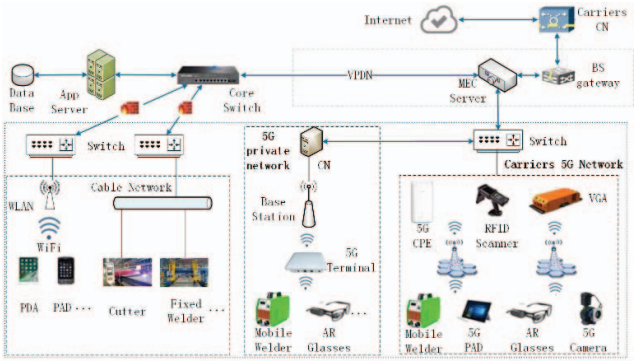

Fig. 1. 5G integrated network architecture.

III. Development of 5G Private Network Terminal and Base Station Equipment

A. 5G Private Network Terminal Equipment

5G independent private network terminal equipment is mainly composed of circuit module and external parts, as shown in fig. 2. The circuit module includes RK3399 core module, 5G communication module, power board and connecting backplane. The RK3399 core module is mainly used for data processing in the communication process. In addition, it also provides WiFi access function. 5G communication module is used for transmitting and receiving 5G wireless signal data. The power module is used to supply power to the whole system. The connecting backplane is used for interconnection and interface expansion between various functional modules. The external part has a protection grade of IP67, which will guarantee the adaptation to the harsh environment of shipbuilding. One type of internal interfaces are used for debugging equipment boards, mainly including SD card interface, UART interface and TF card interface, and the others mainly include RF signal interface, network interface, power interface, key switch and WiFi interface. The RF signal interface is used for transmitting and receiving wireless signals, the network interface is used for the wired network access of 5G independent private network terminal equipment, the power interface is used for the access of external power supply, and the key switch is integrated with the switch indicator, which is used for the indication of equipment working status and the control of power supply. The WiFi interface is used for the access of WIFI antenna for external equipment access through WiFi.

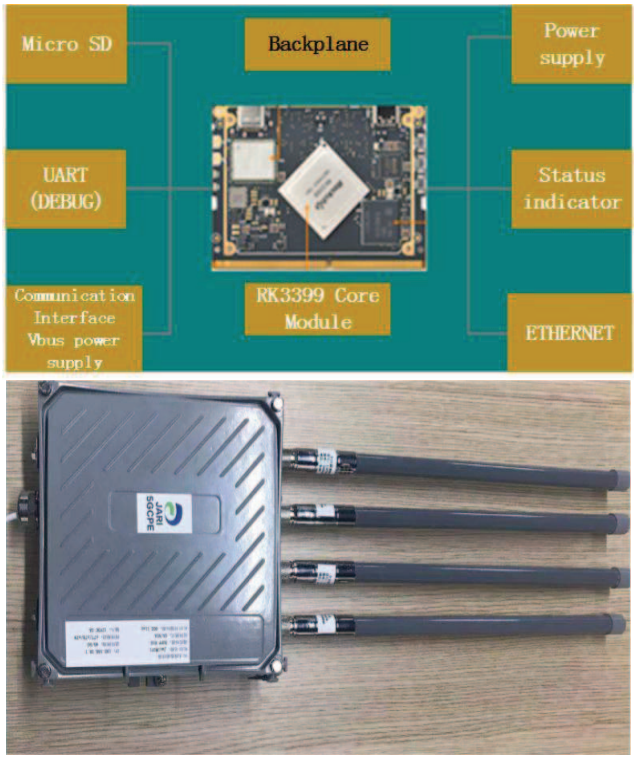

Fig. 2. 5G private network terminal equipment.

B. 5G Private Network Base Station Equipment

5G independent private network base station equipment is mainly composed of circuit module and external part, as shown in fig. 3.

The circuit module includes acceleration board, RF board and CPU board (x86 architecture). The acceleration board is used for transparent transmission between SFP+ interface (RF board side) and PCIE interface (CPU board side), RF board is used for transmitting and receiving wireless signals, serial to parallel conversion of communicated data, and CPU board is used for processing digital signals inside base station equipment. The external part also has a protection grade of IP67. The internal interface mainly include RF signal interface, Gigabit network interface, 10 Gigabit network interface, power interface, USB interface, key switch and indicator light. Among them, RF signal interface is used for transmitting and receiving wireless signals, Gigabit network port is used for system login and debugging and access of external wired equipment, 10 Gigabit network port is used for high-speed communication with core network equipment, power interface is used for access of external power supply, and USB interface is used for access of peripherals, mainly for configuration and debugging of equipment parameters.

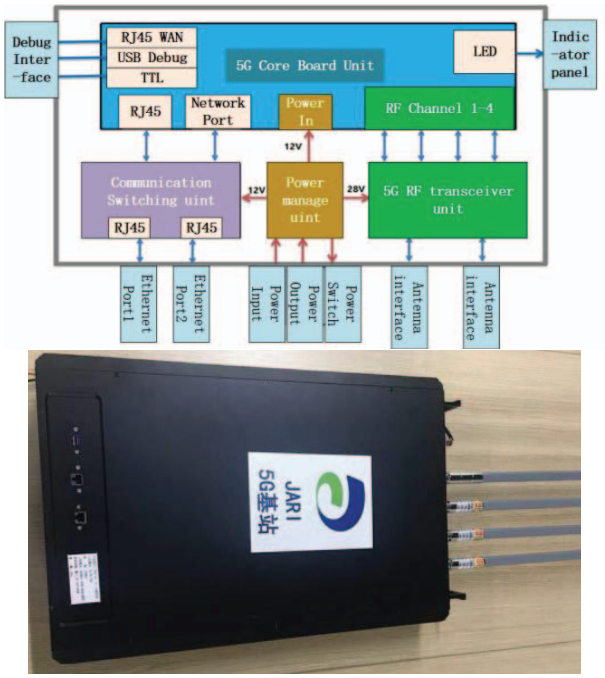

Fig. 3. 5G private network base station equipment.

C. 5G Private Network Equipment Test

In the laboratory, the high-definition image data of visual recognition is simulated through high-definition camera, and the real-time data of welding machine and cutting machine such as current, voltage and temperature are simulated through simulation software, which are connected to the switch through wired network. The real-time status data of equipment and materials collected from the process of shipbuilding intermediate products tracing are simulated through AGV and scanner, and the data of AR auxiliary ship blocks assembly scene is simulated through AR video data. All the data is connected to the application server via 5G private network equipment. We have developed 5G private network performance real-time monitoring software, which can monitor the upstream rate and downstream rate of 5G private network, and the performance of base station and core network equipment, as shown in fig. 4. Through the test, the air interface of 5G independent private network equipment has a downstream rate of 1Gbps, an upstream rate of 150Mbps and a delay of about 20ms, which can meet the requirements for the network bandwidth and delay of the ship block building business.

IV. Overview of the Research on 5G Application for Ship Block Construction

A. Key Equipment Management Based on 5G Network

The welding operation of civil ships accounts for more than 30% of the work hours of shipbuilding[4]. Therefore, it is particularly important to manage and optimize the welding process. At present, it is difficult to trace the welding process information because of low online rate[5]. At the same time, the key equipment, such as the welding and cutting machine, is maintained in the mode of post maintenance and regular maintenance, which could not avoid breakdown.

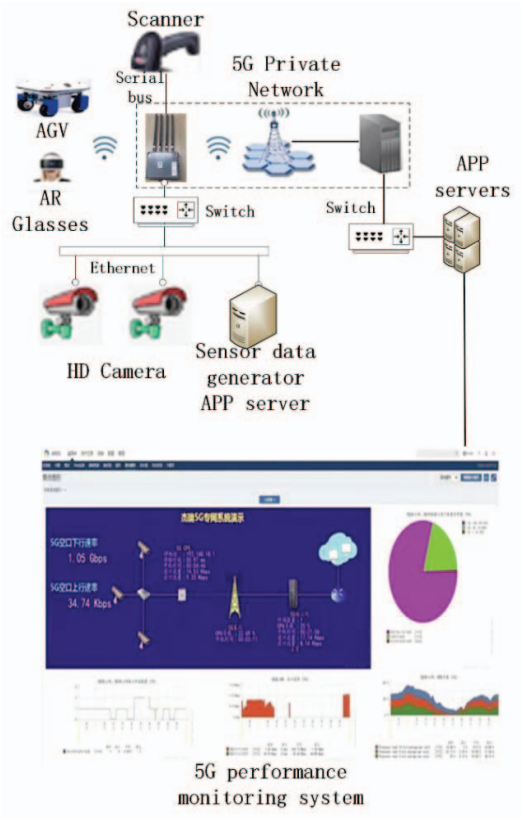

Fig. 4. 5G private network equipment test network architecture.

Based on the characteristics of low time delay and large connection of 5G network, we studied the technologies of low time delay data acquisition and management, fault diagnosis, life estimation and predictive maintenance based of welding machine and cutting machine equipment in ship block workshop, as shown in fig. 5. Data such as the current, voltage, equipment status, operation time, alarm status and other data of the welding machine is collected. The data is transmitted to the server through 5G integrated network to alarm the abnormal welding parameters, accumulate data and optimize the welding process. At the same time, based on predictive maintenance and fault diagnosis model algorithm, the data is analyzed, and compared with the fault database, to verify the fault diagnosis function for the equipment. Based on the performance degradation characteristics and real-time state data, combined with the equipment operation environment, realize the performance evaluation of the key components of the welding machine, which can maintain the key equipment timely to improve equipment utilization.

B. Ship Intermediate Products status tracking

There are many kinds of intermediate products with large quantities in ship block workshop. Whether the intermediate products are delivered efficiently or not between working stations and processes is an important factor affecting the efficiency of block building[6]. Through the 5G integrated network, the status tracking rate of intermediate products in the ship block workshop can be greatly improved, so as to improve the construction efficiency.

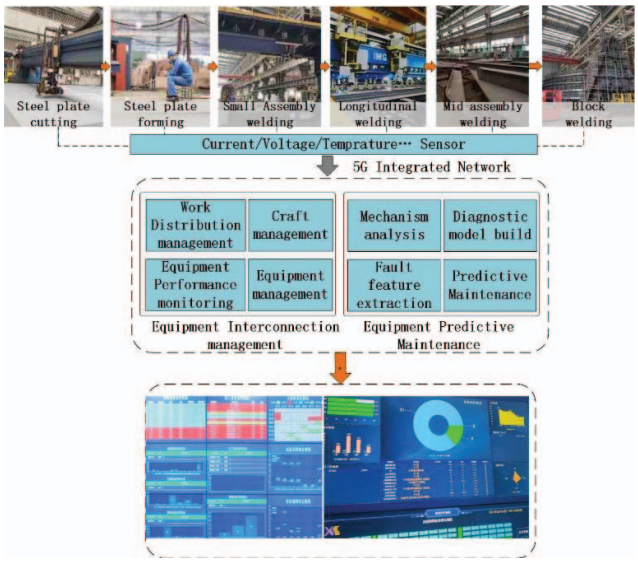

Fig. 5. Key equipment interconnection and management based on 5G integrated network.

Aiming at various intermediate product objects such as assembly parts, plate parts, profile parts and wall parts involved in the production stage from steel plate cutting and small-assembly assembling to mid-assembly welding in the block workshop. Based on the 5G integrated network, we research the state tracking technology of block workshop assembly products and their parts. Firstly, we research the definition of information classification, and the classification definition, identification coding rules and logistics management rules of logistics key elements such as logistics personnel, distribution tools, distribution list BOM, distribution rules and paths, distribution handover documents for the transportation of assembly products and their parts is studied. A coding system suitable for ship block manufacturing workshop is formed.

Then, we research the information identification and rapid collection, and positioning technology, built an intelligent all element information database for intermediate product transportation, and realized the real-time collection, integration and storage of logistics data by using terminals such as code printer, RFID reader, industrial PAD, bar code scanner and RFID scanner.

Finally, we research the logistics simulation and virtual mapping visualization technology, the logistics process simulation is carried out by using Plant Simulation software. The simulation model of ship block workshop is built, the process logic relationship is defined, and the design data of block intermediate products, the data of mid-schedule nodes, and construction resources is imported. And then, the whole production process in the node is simulated and optimized. It can quickly and accurately determine the efficiency bottleneck of logistics system, and provide support for the scientific decision-making of production managers.

Based on this study, the accurate distribution and tracking of pallets, parts and assembly will be realized, and the production and management efficiency, and ship block construction efficiency will be improved.

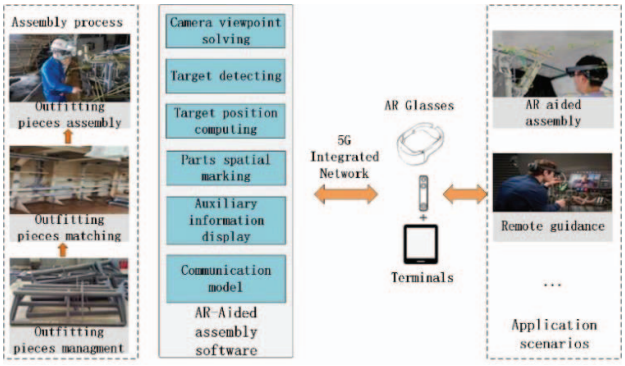

Fig. 6. AR-aided ship block assembly based on 5G integrated network.

C. AR-aided Ship Block Assembly

At present, operators must view paper assembly process documents before assembling of ship blocks[7]. 5G Network and AR is used to assist the material handling and assembly process of block outfitting pieces, which can liberate operators' hands and provide more intuitive operation guidance, so as to improve the efficiency of ship block assembly.

For the auxiliary installation requirements of pipelines, equipment, electrical outfitting pieces, iron outfitting pieces in the ship block cabin unit, by studying the multi terminal integration technology, AR space annotation technology, target detection and target pose estimation technology, an AR-aided block assembly system which has the function of three-dimensional model processing, auxiliary material handling, auxiliary assembly, communication, and multi input interactive is designed. Based on 5G network, AR glasses, PAD, scanning terminal devices are connected to the servers, as shown in fig. 6.

In the process of block outfitting pieces assembling, the operator wears AR glasses to collect image, video, sound and other data in real time, and transmit them to the ship block AR-aided assembly system on the server side in real time through 5G integrated network. The system obtains the perception data of assembling process in real time, analyzes and processes the data, constructs a collaborative AR operation environment, and generates auxiliary information of ship block assembly. At the same time, the system establishes the information communication and integration channel between multiple devices. Using the multi-modal information data model, the system automatically pushes the process information, key data, auxiliary assembly information and assembly operation guidance to suitable terminals through 5G network, so as to realize the enhanced image overlapping of operation steps and the visualization of assembling process. The interactive intelligent display helps operator assemble complex outfitting pieces, realizes ship block assembling while consulting operation instructions, which can improve assembling efficiency.

V. SUMMARY

This paper introduces the development of 5G independent private network equipment for ship block construction environment, and simulates the interconnection and data collection of key equipment in the shipyard through software simulation, simulates the data collection of logistics status

through AGV, real-time data transmission through AR glasses and HD camera data, which verified that the performance of 5G private network equipment can meet the special environment of shipbuilding. At the same time, three types of 5G application scenarios are introduced. Based on 5G integrated network, the networking rate of equipment, the tracking rate of intermediate products and the efficiency of ship block construction will be greatly improved, so as to improve the efficiency of ship construction.

In future works, we will deploy 5G integrated network including 5G independent private network equipment, public 5G network, WiFi and wired network in the shipyard, test the performance of 5G independent private network equipment in key equipment interconnection and predictive maintenance, quality online detection, intermediate product status tracking and AR-aided assembly application scenarios. Meanwhile, a 5G based application rapid development system will be developed to shorten the development cycle of 5G applications in shipyards and improve the efficiency of application deployment.

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