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Study on the application of information technology in inland maritime supervision

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STUDY ON THE APPLICATION OF INFORMATION TECHNOLOGY IN INLAND MARITIME SUPERVISION

By

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

Title of Dissertation: **Study On the Application of Information Technology in Inland Maritime Supervision**

Degree: **MSc**

Abstract: The construction of marine power has great and far-reaching significance for the realization of the great rejuvenation of the Chinese nation. The maritime safety administration is an important force to provide public services, protect the rights and interests of the country and promote the development of regional economy and society. Therefore, building and maintaining the world's most advanced water transport support system with modern information technology can provide security for navigation, convenient environment for ships, and economical, reliable and efficient conditions for the flow of goods. In addition, it can also supply safe, convenient and green service for people.

As China's largest inland river, the population and GDP of the Yangtze River Economic Belt account for more than 40% of the country. In this dissertation all the research background is established on the Yangtze River. The purpose of this research paper is to study means of information technology used in inland maritime supervision and to create a new field monitoring system. A brief look was taken at the existing problems in the field work, in which three methods of communication network were used stage by stage with the development of Information technology, and all the methods were evaluated for performance. It was because of the breakthrough of the communication technology during these years that maritime field supervision could be implemented on site. In addition, by using the network as the foundation, the field data were collected to do real-time monitoring, and the data were analyzed in the later period to put forward a reasonable decision-making model. In this process, all the data,

models and assessment tools were investigated, and the limitations and defects were also presented. What's more, the proposed means of IT is examined and the potential use of IT means in China MSA is also discussed in the last chapter, along with several recommendations on future developments.

KEY WORDS: Inland Maritime Supervision, Field Monitoring System, Maritime Network, Modern Supervision Trend, Data Analysis.

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LIST OF ABBREVIATIONS

AIS	Automatic Identification System
CPE	Customer Premise Equipment
DBS	Direct Broadcasting Satellite Service
GIS	Geographic Information System
GMDSS	Global Maritime Distress and Safety System
GPS	Global Positioning System
HD	High Definition
IOT	Internet of Things
IT	Information Technology
MSA	Maritime Safety Administration
NE	Net Element
RSRP	Reference Signal Receiving Power
TDD	Time Division Duplexing
UAV	Unmanned Aerial Vehicle
VTS	Vessel Traffic System
VHF	Very High Frequency
WLAN	Wireless Local Area Networks
WSN	Wireless Sensor Networks

Chapter 1 Introduction

1.1 Background

In the age of information, with the development of information technology, many traditional human activities are undergoing a great change. China Maritime Safety Administration, the water traffic safety management department, follows the development of the times, and never stops the pace of progress in the information-based road. With the completion of 12.5m deepwater channel project and the beginning of the second phase of the project, the production activities of the Jiangsu section of the Yangtze River are becoming more and more frequent. Meanwhile, the risk of pollution and serious traffic accidents and other emergencies is getting higher and higher. The pressure of water safety supervision continues to increase. Thus it is important and effective to adopt information technology to strengthen water traffic order maintenance, safety regulation and emergency guarantee.

The Yangtze River is China's largest inland tidal river. The economic benefits Jiangsu section of the Yangtze River generated account for more than 65%[1] of the entire Yangtze River Basin, so choosing Jiangsu section of the Yangtze River as the research object is representative. Jiangsu section of Yangtze River lay in China Eastern area, which transports more than 1.5 billion tons of goods in 2015. The main river channel is plain channel. The Yangtze River water system in Jiangsu area is 1.91 square kilometers. The average width of the river is 2 km.

American expert Richard. L. Nolan analyzed the management information system of more than two hundred companies in information system development process and then put forward the famous "Nolan model" (Nolan, 1979), which is illustrated in Figure 1 for further understanding. This Model suggests that we must follow the objective law of development path from tissue manual information systems to computer information systems. Therefore, in formulating plans for the development of

[1] See further information on http://english.mep.gov.cn/SOE/soechina1999/waterc/waterc.htm.

IT, every institution must be clear about this unit's stage of development, constantly improving information construction.

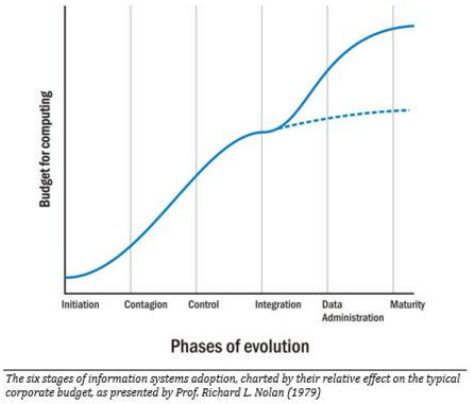


Figure 1 Nolan Model

Although the regulatory modernization construction has made breakthrough progress in the construction of the VTS, VHF, AIS and other information systems, the site regulatory is lack of means of IT Maritime Supervision. The current maritime information technology model is not in line with the current development of the maritime regulation. In order to meet the needs of the inland waterway department in the field supervision, it is necessary to keep up with the development of information technology, and use the advanced information means to serve the field supervision.

1.2 Objectives of Research

This dissertation, based on Jiangsu Maritime Administration, focuses on the problem with the inland zone such as Jiangsu section of the Yangtze River supervision. Given the limited existing field regulatory capacity, the author put forward a new plan on the basis of the existing technology ability, covering the construction of Jiangsu section of the Yangtze River 4G data network and WSN sensor network. The new type of network provides on-site supervision, on-site law enforcement terminal, river rescue workers and positioning, antifouling tracking and temperature meteorological service. All the data will be collected and analyzed, which may do a lot of help for reasonable decision-making model and give full play to the role of information technology in maritime supervision.

1.3 Literature Review

At the present stage, there are still large gaps in inland navigation information management and service in our country as compared with the developed countries. This is mainly due to the low efficiency of intelligent inland shipping and the high cost of ship information collecting and sharing. This bottleneck problem has to some extent restricted the development of inland river shipping in our country. With the rapid development of world trade and shipping market, maritime safety management concept has been further developed and maritime security has become a key consideration to MSA. One of the important ways is the implementation of effective real-time monitoring. From the traditional VHF communications, marine radar, the VTS system (Vessel Traffic Service, VTS), ship self-identification system (Automatic Identification System, AIS), the direction of development of maritime monitoring technology mainly focus on continuous improvement on the timeliness of access to information, accuracy, reliability and completeness.

The application of information technology in inland waterway maritime supervision is mainly focused on the application of office process and administrative examination and approval; each information system is isolated and it is not convenient to be used in inland waterway maritime supervision (e.g. Xu, 2011; Xu & Chen, 2009; Yuan,2011). Some people also introduced a lot of information technology in the application of inland waterway regulation (e.g. Zhang, 2009; Yu, 2016; Wang, 2010), such as Business system, video conference, e-government website, VTS, AIS, which have played a certain role in ensuring the safety of the ship navigation. According to Li (2011), Luo (2014), Wang (2010), and Tian & Yang (2010), the weakness of the inland maritime supervision by IT mainly lies in imperfect information network construction. Information security management and ship-to-shore communication exists a problem which need to provide field mobile data communication ability, improve the maritime information collection, transmission and processing capabilities.

In conclusion, the recent research on Means of Information Technology used in Inland Maritime Supervision is limited to the bird-eye view of the work process and remote monitoring. More attention should be paid to maritime field supervision, laying the

foundation for the field communication network, and studying the relevant system to fill the gap of maritime supervision in inland water.

1.4 Research Structure

This thesis is made up of 6 chapters. The first chapter is introduction. Chapter 2 concerns the current situation of information technology in inland waterway maritime supervision. Chapter 3 is about the Network, the basis of IT field supervision regulation and Chapter 4 includes Information supervision means, Information integration, processing and analysis. Chapter 5 is the conclusion of this thesis.

Chapter 2 summarizes the current situation of the application of information technology in maritime affairs, puts forward the corresponding suggestions and countermeasures. What's more, the author points out that advanced information technology is an urgent need for modern maritime supervision.

Chapter 3, mainly based on the three stages of the development of maritime communications in the field maritime supervision, studies each type of network planning, provides detailed explanation of network planning techniques, and analyzes the network architecture and the construction of the simulation model. What's more, protocols and algorithms are compared and optimized.

In Chapter 4, the author introduces the application of several kinds of site supervision system in maritime application, such as hydrological and meteorological information collection, oil spill recovery detection, CCTV field monitoring and so on. An information system analysis all the collected data, which may have great help for next step of planning and management.

Chapter 2 The Current Situation of Information Technology Used in Inland Waterway Maritime Supervision

2.1 Introduction of China MSA Information Construction

China Maritime Safety Administration information construction began in the late 1990s, which is less than 15 years so far. Although MSA has achieved a lot through this information process. But there exists a big gap between other information-based degree higher industry country and China in the aspects of development, concept, capital investment, operational research.

Information construction is to make full use of information technology, develop and utilize information resources, promote the exchange of information and knowledge sharing, improve the quality of economic growth, promote the transformation of the historical process of social and economic development (Mul, 1999). Maritime supervision system is the comprehensive utilization of various ways of maritime regulation to manage the waters in order to ensure ship navigation safety and prevent water pollution. Modern maritime supervision system has absorbed advantages of traditional supervision system and integrated the modern means of IT supervision, which can not only greatly improve the maritime management efficiency and search and rescue, but also supply convenient service for ship navigation safety. The current maritime supervision system is mainly composed of GPS, AIS, VHF, CCTV, VTS etc. Land-based systems rely on land-based communications. VHF is generally combined with other systems. The four systems of VTS, CCTV, GPS and AIS constitute a set of field management system involving daily dynamic management, traffic control and remote command.

2.2 Existing Major Information Supervision System

2.2.1 CCTV

CCTV (closed-circuit television) system is installed at the dock and patrol boat which uses the camera as a visual sensor for monitoring safety of navigation and operations of port passenger ships, ship of dangerous goods, tourist boats 1 nautical miles away from the shore and monitor the traffic of narrow waters. The next step should further standardize scope of application, the monitoring of moving targets and the islands in the river. The monitoring data should be uploaded in real time to the command center for decision making.

2.2.2 VTS

VTS (Vessel Traffic Service) is an active monitoring system for monitoring ship motion in a certain water area, which mainly focuses on the performance of the public transportation service function. The effective range of communication is 24 nautical miles. VTS monitoring equipment means is an effective way for maritime authority to fulfill the ship navigation environment management and maritime investigation function toward the river. Radar is the maritime system's only sensor to actively detect ship dynamic position. In the next step, MSA should be based on business and needs to promote construction of the radar station in island in the river to realize seamless coverage. At the same time, it is required to carry out research on how to use the existing radar base station for the detection of oil spill at river.

2.2.3 GPS

GPS (Global Positioning System) terminals are installed in the maritime affair law enforcement vehicle terminal and coastal patrol vessels. Each water transport law enforcer has a GPS location module terminal. In the Maritime Command Center, real-time positioning of personnel and law enforcement vehicles and coastal patrol ship can be seen in GIS platform.

2.2.4 AIS

AIS (Automatic identification system) consists of land-based (base station) facility and ship-borne equipment. AIS is a new set of network technology, modern communication

technology, computer technology, electronic information display, digital navigation systems and equipment technology as a whole. MSA uses AIS to enhance vessel traffic management systems and ship reporting functions. AIS's sensor is a passive sensor which accepts ship dynamic sensor, at present base station of the effective detection range of up to 30 nautical miles, and part of the base station can reach 70 knots. Next step should be to increase construction of base stations, cover communication blind spots, improve capacity, and achieve all the messages from maritime AIS ship-borne Terminal in inland rivers.

2.3 Problems in Current System

After years of information construction, the marine department has a wide range of information systems. These systems are implemented with one or more features, and one or more regulatory aspects have been covered. But the lack of overall planning and unified management, lack of ability to share data between different regulatory systems, scattered information resources also become increasingly outstanding. These system data do not form a unified platform, presence information island phenomenon (Wang, C.Q., 2008), which may affect the exchange of information and interactive level of collaboration.

With the use of VTS, AIS, CCTV and other dynamic monitoring means in recent years, China MSA has a significant improvement in the ability to monitor the dynamic target. Compared with the developed countries, China's primary maritime sector still stays in low level in the area of the jurisdiction of the target and the risk of dynamic perception ability. For example, most of the inland ports have not set up a full range of river pollution and real-time hydrological information perception network. CCTV monitoring system does not have the ability to automatically warn the hidden danger. In the existing systems in the ship's trajectory tracking, remote real-time view of the field supervision, traffic analysis is still dependent on manual, which has greatly reduced the efficiency. At the same time, the accuracy of selection vessel target supervision is not high. Some maritime departments determine whether a vessel should be inspected according to the type of the ship. China MSA's dynamic sensing ability is

insufficient, which leads law-abiding ships and illegal ships to receive the same frequency of field inspection.

2.4 Comments and Suggestions

2.4.1 Construction of Full Coverage, Multi-tier Maritime Communication Network

All field IT regulation system needs the support of communication network. In consideration of the weather, seasons, and the natural environment of the Yangtze River, so not all types of mobile communication technology can be applied to the maritime communications work. So how to apply land-based mature broadband wireless mobile communication technology to the Yangtze River maritime communications with the consideration of actual situation of inland water, which is an important task of MSA field supervision. While Wireless LAN is involved in research in recent years, most applications are widely used for setting up an emergency rescue fast communication network system on the river. With the rapid development of information technology, maritime communication technology will also be improved, and we should continue to study the inland river communication technology to provide a better basis for a variety of information management system.

2.4.2 Enrich Technical Means of Maritime Field Supervision

MSA should strengthen the application of IT in the maritime sector informatization construction as soon as possible, by means of radio frequency identification, infrared sensing technology, laser scanner, regional unmanned aerial vehicle, oil spill monitoring buoy, GPS global positioning system and other advanced information detection device, which will gradually achieve comprehensive perception, effective transmission and intelligent applications in the ship and its crew, shipping companies, marine environment, meteorology, hydrology and marine pollution status and management factors. In Patrol Boat, integrated management information platform should be built. Officers may change the habits depend on the fixed office place of the traditional office methods, filed law enforcement and investigate violations can be conducted in anywhere and in anytime. In all law enforcement places should be

equipped with synchronized audio and video recording CCTV equipment, which meet the actual needs of dynamic monitoring and investigation work.

2.4.3 Automatic Data Collection, Analysis and Mining

Ship recognition system based on radio frequency technology can automatically, continuously statistics the ship traffic in a section area. It is important to use data mining technology to carry out shipping statistics work. At the same time, self-service payment work can also be automatically completed through association with the bank card. MSA should set up with the automatic illegal behavior recording and dangerous operation process monitoring system based on the intelligent maritime supervision and assistance decision-making network, which can automatic early warning of accident.

Chapter 3 Network, the Basis of IT Maritime Supervision

3.1 General Instruction

The wide application of modern information communication technology is not only in people's daily life, but also relates to some key development areas of our country, such as modernization maritime supervision. Application of modern communication technology and information technology is to ensure the ship navigation at sea, which requires safety, stability and reliability. This chapter mainly studies the comprehensive utilization of wireless communication and information network technology in communications of the Yangtze River "ship to shore" or " ship to ship" to build a safe and reliable wireless broadband access network, which may solve "last mile" access communication problem between ship and shore. Network is the basis of each IT maritime supervision system, especially the field supervision system in these years. Without the development of IT communication technology, there is no way to talk about the IT means used in inland maritime supervision.

The Yangtze River has a long history with abundant, ice-free water all year round. Owing to its advanced water conditions, it is known as the "Golden waterway" around China. With the development of IT in maritime safety, land-based cable network platform for law enforcement that began to extend to water-based wireless network platform, the need for construction of maritime mobile video monitoring system and mobile platform for law enforcement has further improved the ability of water regulation, cruising and rescue capabilities. In the meantime, data acquisition equipment and the enforcement of terminal diversification also put forward higher requirements for the network security, stability and bandwidth. Jiangsu selection of Yangtze River is using the traditional rental of telecommunication carriers' wireless network to build maritime wireless communications networks Although it has the advantages of low maintenance requirements, large coverage, strong anti-jamming ability and so on , for the maritime private network, it has more insufficient aspects: 1. Low coverage. There exists some cover blind points and unstable regional in some zones away from urban of Yangtze River waters,; 2. Network bandwidth is insufficient,

which cannot meet maritime video monitoring and the business management transmission requirements; 3. Information security has no guarantee, and operators working on public network can be easily attacked by illegal users; 4. Network rental has high costs, for instance, transferring HD video signal, substance high rate of flow is very expensive.

In order to enhance the IT ability of the maritime supervision, there is a need to build a broadband wireless network that can cover Jiangsu section of the Yangtze River. Only by doing so can MSA strengthen the supervision of maritime safety, improve water security capabilities, and further improve comprehensive emergency command level of the water traffic safety.

3.2 Three Stages of Communication Network for Maritime Field Supervision

With the development of IT, maritime communication network has been steadily progressing, which can mainly be divided into the following three stages.

The first stage is from 2010 to 2013, building maritime communication network by renting wireless network of telecom operators. According to the wireless network interface technology of the existing standards of 3G technology mainly refer to WCDMA, CDMA2000, TD-SCDMA three types, which were by China Unicom, China Telecom and China Mobile. Among them, the use of code division multiple access, frequency division duplex mode of CDMA2000 is fully compatible with CDMA (IS-95) system, and for subsequent network extension provides a basic platform. Packet domain provides IP network with CDMA2000 compatible business. As a packet data service node PDSN is a packet data network connected with a wireless network access gateway, which provides users with the establishment and termination of PPP service, also provides a simple IP and mobile IP service. Prior to this, the development and application of GMDSS and Inmarsat, which have greatly changed maritime communications. However, its complex equipment deployment and expensive rental are not suitable for the use of maritime inland waterway supervision. While DBS has the advantages of covering a wide range, no geographical restrictions

are suitable for the Yangtze River field supervision communication. But its technology is not only too complex and costs high, but also has high network latency. For the various reasons above, the maritime safety administration in the first place chooses CDMA2000 for 3G maritime field supervision communication wireless network access according to the China telecom CDMA2000 characteristics and business ability.

The second stage is mainly from the year of 2013. Due to the lack of means of communication in the field, a lot of maritime law enforcements and decision-making chain of command cannot be applied on the water patrol boats. Therefore, the construction of high-speed and stable wireless network has become an urgent need for maritime law enforcement and assistance in the river. Wireless mesh network is IP based broadband wireless access technology (Raffaele, M. Conti, 2005). It combines the advantages of WLAN and multi-hop wireless networks, which support multipoint to multipoint network structure with the characteristics of ad-hoc network, self-repairing, intelligent advantage of self-managed nodes and mobile broadband, no positioning line etc., which is a kind of large capacity, high rate, covering wide range network. Mesh network has become an effective mean of broadband access. Jiangsu MSA in Zhenjiang and Nanjing Jiangxinzhou has carried on the Mesh network deployment as research, which has achieved good effect. Mesh-based wireless network is a high-quality solution to all aspects of network performance to solve the structure of maritime multi-service applications demand, which can meet the needs of the maritime regulation use. It has many superiors to other types of wireless communications advantages. Inadequacies of the system lie in a straight line 5.8G wireless signal transmission, for the transmission distance is short, vulnerable to interference. Since it has relatively good health and reliability, the network is intended to be used to construct wireless sensor networks (WSN), which can monitor the Marine traffic, meteorology, water temperature and trajectory of oil spill, etc.

The third stage is from the beginning of 2016 to deploy 4G LTE private maritime network. At the end of 2015, the state administration of radio fulfilled the new demand of the industry informatization, extending the private network frequency application range of 1785 ~ 1805 MHZ band, such as the planning of 1447 ~ 1467 MHZ (1.4 G)

spectrum for public security, government affairs private network construction, etc. Currently the technology and products of main terminal applications, such as digital trunking terminal, CPE, communication module, and so on, are already very mature. Therefore, the Yangtze River ship shore wireless broadband network construction has policy support, technical support and industry support, so that the large-scale construction has become possible. TD-LTE technology is our country's independent research and development of the next generation wireless mobile communication technology, which can better ensure the national overall strategic security. Compared to the mesh network, its main advantages are as follows: TD - LTE uses time division duplex using time-division duplex (TDD) mode, which can effectively save the bandwidth resource, easy to apply for independent bands (such as 1.4g, 1.8g); TD-LTE can fully meet the network of the uplink data volume downlink small amount of demand; TD-LTE uses flat network scheme and reduce NE levels, which can effectively reduce the data transmission delay. Through comprehensive comparison and analysis, combined with characteristics of the Yangtze River, MSA suggested that Yangtze wireless broadband network construction is the future direction for the construction of main mining with TD - LTE network construction.

3.3 Network Technology Comparison

At present the main broadband wireless technology mainly has the LTE technology, CDMA2000, WCDMA, TDSCDMA, WLAN and so on. From the technical comparison in Table 1, it’s obvious that to meet the coverage of along the Yangtze River users, wireless broadband technologies need to support high mobility. Apparently, WLAN technology cannot meet the demand. Also in order to meet the needs of high-definition video services, broadband wireless technology also needs to provide high speed rate, therefore TD-SCDMA, CDMA2000 cannot meet the demand. Mature industry chain can effectively reduce the cost of network construction, so Wimax is extremely immature industry chain that does not meet the demand. In addition, the frequency band of current network available is mainly at 1.4GHz and 1.8GHz, whose use has granted to TDD standard. Therefore, the FDD WCDMA and

LTE FDD cannot meet the requirements of the frequency. In conclusion, only the TD-LTE can meet all the conditions, so the project mining uses TD-LTE as intangible broadband network technology. At the same time, the Mesh WSN network should be deployed to meet the backup and sensor data collection work.

Table 1 – Wireless Network Technical Comparison

<table>
<tr><th colspan="2">Network Type</th><th>Download rate (Mbps)</th><th>Upstream Rate (Mbps)</th><th>Mobility</th><th>Security</th><th>Air interface</th><th>Bands</th></tr>
<tr><td colspan="2">TDSCDMA HSPA</td><td>2.8</td><td>2.2</td><td rowspan="3">Hi-speed</td><td rowspan="3">Authentication and encryption mechanism</td><td rowspan="3">CDMA</td><td rowspan="3">Authorized frequency band</td></tr>
<tr><td colspan="2">WCDMA HSPA</td><td>14.4</td><td>5.76</td></tr>
<tr><td colspan="2">CDMA2000 EVDO</td><td>3.1</td><td>1.8</td></tr>
<tr><td rowspan="3">WLAN WSN</td><td>802.11b</td><td colspan="2">11 (Shared)</td><td rowspan="3">Static</td><td rowspan="3">Common encryption</td><td rowspan="3">OFDM</td><td rowspan="3">Public band</td></tr>
<tr><td>802.11a/g</td><td colspan="2">54 (Shared)</td></tr>
<tr><td>802.11n</td><td colspan="2">150 (Shared)</td></tr>
<tr><td colspan="2">LTE FDD</td><td>150</td><td>40</td><td rowspan="2">Hi-speed</td><td rowspan="2">Strict authentication and encryption mechanism</td><td rowspan="2">OFDMA /SC-FDMA</td><td rowspan="2">Authorized frequency band</td></tr>
<tr><td colspan="2">TD-LTE</td><td>100</td><td>50</td></tr>
<tr><td colspan="2">Wimax（802.16e）</td><td colspan="2">70</td><td>Nomadic movement</td><td>Authentication and encryption mechanism</td><td>OFDM</td><td>Partially authorized frequency band</td></tr>
</table>

3.4 Network Requirements of Regulatory System

3.4.1 Emergency Communication Demand

Nanjing following 12.5 meters deep-water channel is the main framework of the construction of the Yangtze River as the integrated transport system, which is also important support and guarantee for Yangtze River Economic Belt. At present there are 116 berths of more than 50,000 tons level along the waterway. With the construction of 12.5 m-deep channel, the number of the berths of more than 50,000 tons level will further increase, and Yangtze River shipping will become even busier. In order to

ensure the normal operation of the 12.5- meter-deep channel of the Yangtze River, government must establish the emergency plan for major traffic accidents, pollution accidents and other emergency preparedness to strengthen the ability of water safety supervision. After the completion of the maritime private wireless network, MSA can quickly and accurately respond to emergencies relying on its powerful wireless data bandwidth capability and fusion of multimedia dispatching function. When emergency happens, emergency response personnel arrive at the event site, through the car/ship individual handheld terminals. HD video and voice communication will be sent to the emergency command center in the first time. Command center uses the wireless network for remote command scheduling according to the field situation.

3.4.2 Field Remote Office Demand

The rhythm of modern society is getting faster and faster. In order to adapt to the fast pace of society, the government's efficiency is also in the corresponding synchronization to speed up. With the strengthening of the site supervision, the need for on-site information verification and on-site forensics is increasingly strong, which has made a strong demand for field remote office. Maritime Wireless Network with existing MSA internal business process platform interoperability, administrative admissibility can be treated at the scene by maritime officials, which can greatly enhance administrative efficiency.

3.4.3 Perception of Field Data Demand

With the development of shipping and exploitation of the underwater natural resources, the potential risk of marine oil spill is increasing. Vast and complex ocean environment makes it hard to monitor oil spill event and evaluate the environment damage of the event. It is necessary to detect the event of marine oil spill and take a quick response. The effective measures would keep the oil contamination from expansion and minimize the effects of the accident. Compared to traditional detecting methods, such as remote sensing and patrol boats, Wireless Sensor Networks (WSN) is characterized as cost-effectiveness, full-time, energy-aware, flexibility and easy

deployment, and thus it has been the hot research interest in water monitoring. And, WSN is capable of reporting the ship situation, water status and pollutant source timely. So, the information collected from the target area would support the timely and effective decision-making in the emergency situation. In a word, the application of WSN in oil spill monitoring will be promising research field.

3.4.4 Remote Video Conference Demand

MSA currently has a video conference system, but because of long-term work of the maritime personnel in the frontline, organizing a video conference in the MSA office is very difficult. After the completion of the maritime wireless network, participants even in command car / boat can also participate in a video conference, which can help lower the cost of on-site meetings and enable more personnel to attend the video meeting. In the meantime, it also meets the needs of remote command.

3.4.5 HD Video Capture Demand

The length of Nanjing Yangtze River Waterway Downstream is up to about 450 km, which contains a wide range of ships. MSA needs to build more HD video cameras from point to point to monitor channel situation. Due to the fact that the channel of the accident prone locations often braided river sand clouds, it is difficult to layout wire cable, which may result problems in the return of high-definition video signal. After the completion of the maritime wireless network, MSA can use maritime wireless private network as the high-definition video signal return path in good private network coverage place, which is conducive to the construction of HD video collection point and fulfill the demand of maritime sector to passing ships scheduling, dredging and management.

3.5 Network Flow Estimate

After the completion of maritime private wireless network, video services will occupy the main private network data traffic. Suppose every maritime law enforcement boat is equipped with a high-definition camera (1080P), every Maritime Branch with 6 search maritime law enforcement boats and 15 man-handheld monitor terminal (720P) considers mobile video backhaul demand within the normal circumstances of each Maritime Branch range of the maximum bandwidth does not over 6*4+15*2 = 54Mbps. Also video conferencing, remote office and emergency communications should be considered, which requires that the current maximum data traffic for every Maritime Branch area should normally be less than 100Mbps. 4G TD-LTE Wireless Network Traffic Capacity is shown in Table 2:

Table 2 - Wireless Network Traffic Capacity

Type	Bandwidth Requirement（kbps）		Single Sector Bearer User Number
	Download	Upload	
VoIP	16	16	500
Video Call	800	800	10
HD CCTV Camera	64	2000	4
Computer Hi-speed Internet Access	1000	256	12

3.6 Technical Characteristics

3.6.1 Wireless Sensor Mesh Network

3.6.1.1 Why we need WSN?

As mentioned above, Jiangsu MSA chose two points of mesh broadband network experiment in the Yangtze River and achieved good results. However, given that the Chinese government vigorously supports TD-LTE technology and Mesh network has its own weak points, the author defines it as a data receiver network and builds it into a wireless sensor network (WSN).

Although we have to build the 4G-LTE network for field, we spend a lot of money researching Mesh Network. Although we have the 4G-LTE network, WSN Mesh network has some advantages over 4G-LTE. Converting the current Mesh Network to

WSN is a supplementary means of LTE 4G network which can save a lot of money and collect different data, In various environmental monitoring means, the wireless sensor network (WSN) is widely used in environmental monitoring and protection, due to its low power consumption, low cost, distributed and self-organization characteristics. Especially in water environment monitoring, the monitoring has advantages of high efficiency, low system cost, high flexibility, etc. Therefore, deploying WSN effectively in some important port areas, route areas and islands in the Yangtze River can realize real-time monitoring to the maritime environment. It can help find oil spill pollution sources in a timely manner and promptly take effective measures to prevent pollution and reduce economic losses caused by the accidents. The promotion application and industrialization prospect are very optimistic.

3.6.1.2 What is WSN?

WSN Mesh technology is completely different from the traditional wireless network wireless network technology. In the traditional wireless local-area network (WLAN), each client is connected to the access point (AP) via a wireless link to access the network. If users want to communicate with each other, we must first visit a fixed AP. This network structure is known as the single hop network. By contrast, in the wireless network, any node of the wireless devices can be a router at the same tim e, and each node in the network can send and receive signals, each node can communicate directly with one or a plurality of peer to peer nodes. The biggest advantage of this structure is: if the recent AP encounters excessive traffic congestion, then the data can be automatically rerouted to a small traffic flow adjacent to the node for transmission. As shown in Figure 2, the data packets can also be based on the situation of the network, continuing to route to the nearest next node for transmission until the final destination. This way of access is multi hop access.

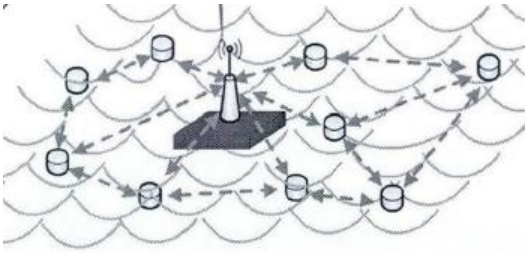


Figure 2 Working Model of WSN network

Generally speaking, the emergence of WSN for the future study of maritime surveillance technologies and development provides a new technical means. WSN is composed of a ubiquitous, tiny sensor nodes capable of communication and calculation, constituting the autonomy in the form of multiple hops communication network system. The system can do real-time monitoring, sensing and acquisition network distribution area of all kinds of monitoring object information. It can deal with the information, and then provide the information to the users. In a word, WSN can be defined as Sensing + CPU + Radio = Thousands of potential applications (Liu, L., Zhang, Y. Z., & University, S. M., 2014), which is illustrated in Figure 3.

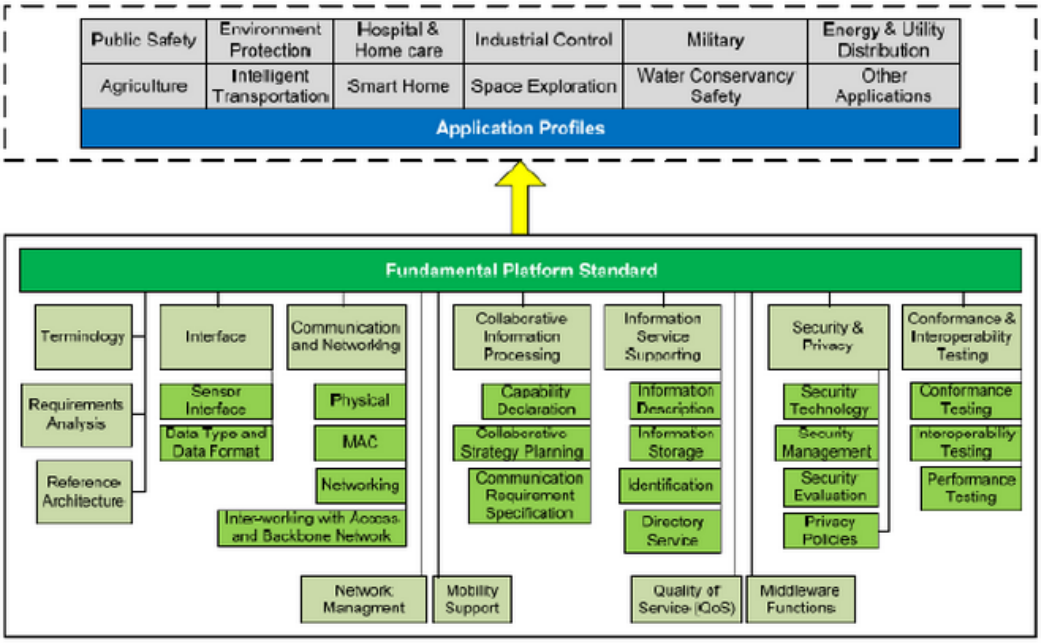


Figure 3 WSN Platform and Applications

3.6.1.3 Features of WSN

According to the characteristics of maritime surveillance, in which the adaptability and feasibility of wireless sensor network are analyzed, the maritime surveillance sensor network (MSSN) has the following characteristics:

(1) A wide range of monitoring object and quantity. To complete the monitoring of the vast expanse of water, monitoring objects include ports, fairway, anchorage, dock, goods yard, and ships;

(2) Monitoring object data source is diverse. To carry out a comprehensive monitoring of the vast water area, the monitoring object will include the basic information of the ship, the position of the ship, the ship and its current velocity, water temperature, environmental humidity and so on;

(3) Monitoring data levels of diversity, including metadata and attribute data, performance in updating frequency, accuracy of calculation, function distance and so on;

(4) Monitoring the pertinence of target object. In the case of large traffic flow, the accident should be monitored in the waters of the corresponding objects, such as oil spill detection waters, key observation waters and so on;

(5) Invulnerability. In wireless sensor networks, there is no strict control center, all nodes are equal. Node can always join or leave the network due to destruction, the failure of any node does not influence the operation of the whole network, thus it has very strong invulnerability. This feature is of great significance in ensuring the reliability of maritime surveillance information in complex background;

(6) Fault Tolerance. In order to perform monitoring tasks on a regional level, a large number of nodes tend to be devoted to the region, the distribution of the sensor nodes can be very intensive, and the use of high connectivity between nodes can ensure the fault tolerance of the system;

With the development of network technology and wireless communication technology, WSN as an intelligent maritime surveillance provides a new method and means. The application of WSN technology in scientific research in the field of maritime surveillance has received a great deal of attention in the developed countries. On September 20, 2005, the White House released eight Maritime Safety Research support plans which clearly pointed out that priority should be given to the development of maritime technical based on WSN. Kavelaars on the feasibility and adaptability of sensor networks for maritime surveillance conducted a preliminary study (Kavelaars, 2005). Carapezza proposed the intelligent maritime security monitoring system based on wireless sensor network (WSN), and he carried on the preliminary study on the wireless buoy sensor network system, the feasibility of the system architecture and composition (Carapezza, 2005). Mathew discussed the

underwater sensor to communicate with each other and maritime surveillance sensor network data transmission problem (Mathew, 2007). Paik discussed issues such as full scale ship monitoring system based on wireless sensor network (Paik, 2007). The related research of maritime surveillance WSN attracted the attention of domestic and foreign researchers. Related research results and analysis of the adaptability of wireless sensor networks and the maritime surveillance systems have proved features and application scenarios. Maritime monitoring wireless sensor networks has a strong similarity and adaptability, which is of great theoretical value and application prospect.

3.6.2 4G TD-LTE Private Maritime Network

3.6.2.1 Why we need 4G TD-LTE Private Maritime Network?

Given the development trend of wireless communication network system and the bias of China's domestic policy, the TD-LTE possesses high bandwidth, high rate, high spectrum efficiency, and obtained the massive global deployment. TD-LTE 4G is the international standard with independent intellectual property rights, which can ensure the safety of China maritime private network. TD-LTE uses advanced air interface access and MIMO technology, which has higher downlink peak rate. TD-LTE can be flexibly allocated in the uplink and downlink time slots, which is more suitable for carrying IOT data services and better supports maritime CCTV and remote video conference. Currently, TD-LTE has formed a complete industrial chain globally. In the part of system, terminal, chip and the test equipment, it has many mainstream factory investments in research and development. In response to emergencies, 4G TD-LTE private maritime network can carry out fast, flexible deployment, enhance mobility, complement each other wired and wireless, and comprehensively improve the urban prevention and emergency response capabilities.

Compared with what was said above about WSN, TD-LTE networks can perform intervention with higher speed on the basis of good mobility. In the experiments, we

found that TD-LTE has optimal network performance at low speed (0 ~ 15 km/h) and good performance at the speed of 15-120 km/h. While in the coverage, the limit of WSN can reach nearly 2 km, which can meet most of the Yangtze River, but a pure omission and the boundary of a signal is not stable. Spectrum efficiency and throughput fully meets the design limit when TD-LTE network covers radius within 5 km. Meanwhile, there will be a slight attenuation within 30 km and its maximum coverage radius is 100km.

3.6.2.2 What is 4G TD-LTE?

TD-LTE as a new generation of broadband wireless communication network, has been included in the national major science and technology projects. China government departments, research and development departments, manufacturers and operators are strongly supported by this system. TD-LTE system with the 20M bandwidth can achieve downlink 100Mbps, uplink peak rates of 50Mbps system. TD-LTE spectrum allocation is very flexible, support 1.4 MHz / 3 MHz / 5 MHz / 10 MHz / 20 MHz bandwidth. TD-LTE adopted the new wireless access method: downlink OFDMA, uplink SC - FDMA, the antenna terminal adopts MIMO (multiple input multiple output) and Beamforming technology. These new technologies can improve the transmission power and Beamforming, and improve the channel fading caused by interference, which can greatly improve system capacity and high spectrum efficiency, thus can get higher data rate and better transmission quality or greater coverage system. For the aspect of network, the TD-LTE wireless broadband network construction in the 1.4G band has been carried out in Beijing City, Tianjin City, Nanjing City. As a new generation of broadband wireless network, TD-LTE technology has been widely used.

3.6.2.3 Features of 4G TD-LTE

According to the characteristics of maritime field supervision, in which the adaptability and feasibility of huge flow of data are analyzed, 4G TD-LTE has the following characteristics:

(1) The air interface of TD-LTE system adopts TDD duplex mode, and the downlink uses orthogonal frequency division multiple access (OFDM) transmission technology, which uses a single carrier DFT-s-OFDM technology scheme. The spectrum efficiency is higher and the antenna performance is better.

(2) MIMO (multiple input multiple output) sends and receives double end uses multiple antennas, respectively, while transmitting and receiving, through space-time processing technology, which makes full use of space resources without the need to increase the spectrum resources and transmit power. The capacity and reliability of the communication system has been greatly improved, and the spectrum utilization has been significantly promoted.

(3) Link adaptation technology refers to the system according to the current access to the channel information, adaptive adjust transmission parameters, in order to overcome or adapt to the impact brought by the change of the channel. This mainly includes two aspects of content: one is the channel information acquisition, accurate and effective access to the environmental parameters of the channel and the channel indication parameters can be more effectively and accurately reflect the channel condition; the other is the adjustment of the transmission parameters, containing modulation, coding, redundant information, emission power and time frequency resource etc..

(4) Interference coordination is the basic idea of inter cell according to certain rules and methods, coordinated resource scheduling and allocation in order to reduce the inter cell interference. Interference coordination can be divided into static interference

coordination, semi static interference coordination and dynamic interference coordination. Interference coordination can work on frequency domain, airspace and power, which is designed avoid and reduce the inter cell co channel interference.

3.7 Network Architecture and Planning

3.7.1 WSN

The object of maritime surveillance can be divided into static objects and moving objects, which form a stationary node and a mobile node in the wireless sensor network. In order for the network to reach a stable state, all of the static nodes have a good distribution. Wireless sensor network (WSN) is usually made up by sensor nodes (Sensor Node) and one or more water base station, shore based management terminal part. Its typical structure is shown in Figure 4.

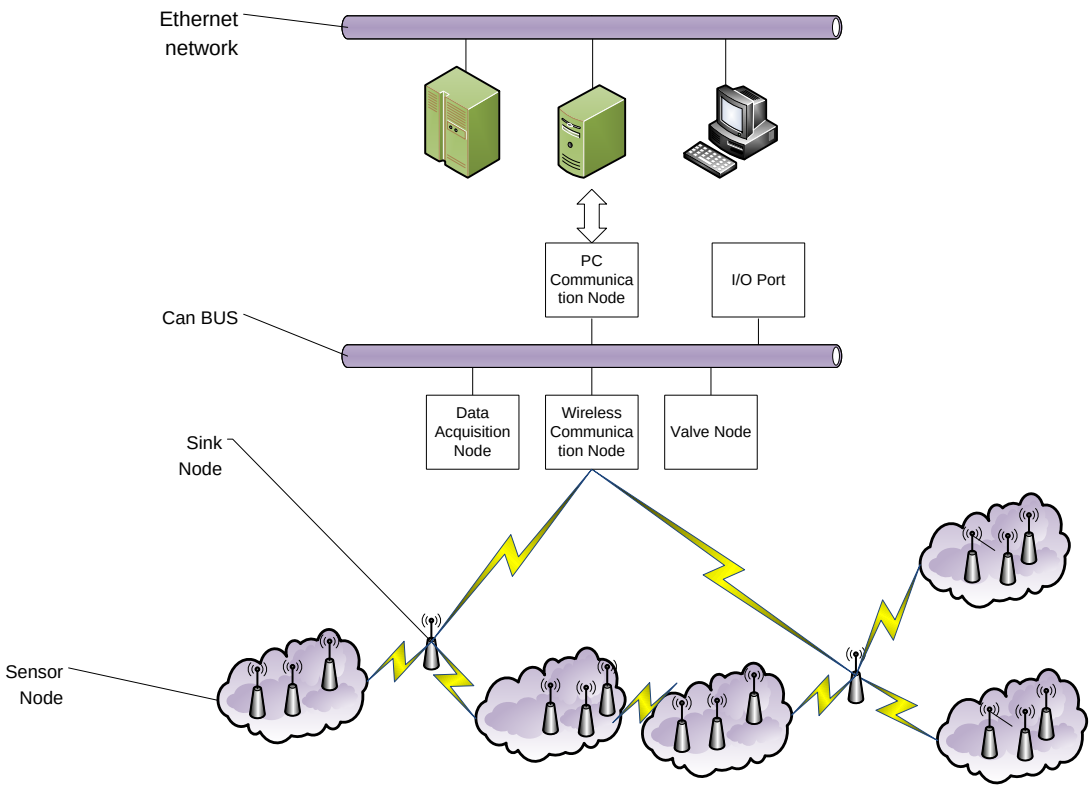


Figure 4 Architecture of the WSN

Sensor nodes: The working mode is shown in Figure 5. It is capable of executing the instructions issued by the task manager node. For monitoring objects of information acquisition, processing and data transmission (contain other relay nodes transmit information), the network protocol can enable the network to have self-organization in order to achieve collaborative information collecting. Then the collected information will be transmitted to the shore-based management terminal. If it is a large-scale deployment usually automatic grouping node cluster formation, however, small and medium-sized deployment will not necessarily generated node clusters, as long as able to transmit the information to the management terminal.

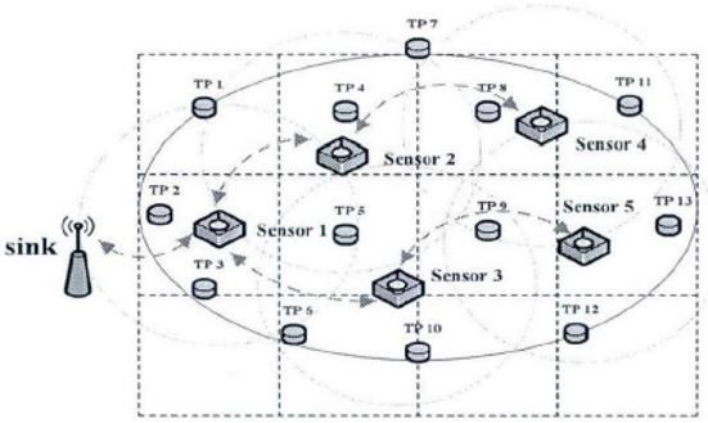


Figure 5 Sensor Node Work Mode of WSN

Water base station: The working mode is shown in Figure 6. It is also known as aggregation node (Sink Node), generally a regional central control node, with underwater acoustic communication and wireless communication capabilities. Underwater acoustic communication send messages to other nodes in the convergence within the region and information of the wireless communication functions can be collected or sent to the satellite receiver and shore-based management terminal that can be received by the published shore terminal management network management, task scheduling and other mandatory operations.

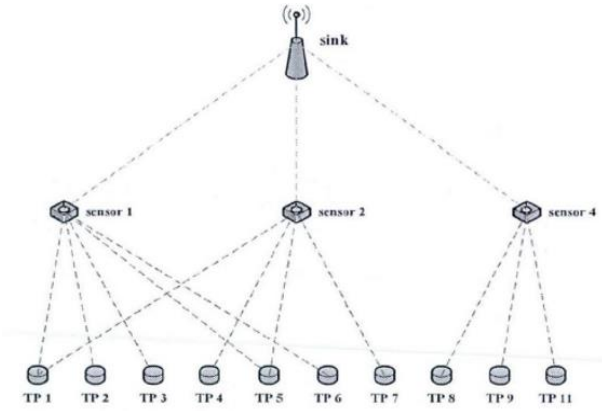


Figure 6 Work Mode of WSN

Shore management terminal: in fact, it is user management of wireless sensor network terminal equipment, such as computers, servers and other capable of comprehensive treatment of the whole network information, and in an intuitive way to present to the user terminal.

3.7.2 TD-LTE Private Maritime Network

The wireless communication system on the Yangtze River needs high reliability, large coverage radius, and so on. System bandwidth has to meet the needs of the ship shore wireless data services, including CCTV video surveillance, Internet services, multimedia services, scheduling business, video conferencing services, positioning business, etc. The system also needs to meet the demand for security and reliability. Security includes channel encryption, mutual authentication, integrity protection, anti-DoS attack, transport security IPSec, encryption hard dense commercial grade, and single gatekeeper. Reliability includes equipment reliability, link transmission reliability, the reliability of power supply, transmission reliability.

Through the analysis of the demand of maritime private 4G wireless communication system in the Yangtze River, the TD-LTE fixed wireless communication system must include switches, fixed station, ship station, handheld terminals, PAD, CPE terminals.

Fixed station with LTE technology is the basis for complex electromagnetic environment, technological innovation and distance covered terrain conditions, which meets the transport needs of various broadband services. TD-LTE fixed station generally has the following characteristics: little space occupation, high integration, low power consumption and flexible installation. What's more, it is of great safety and reliability.

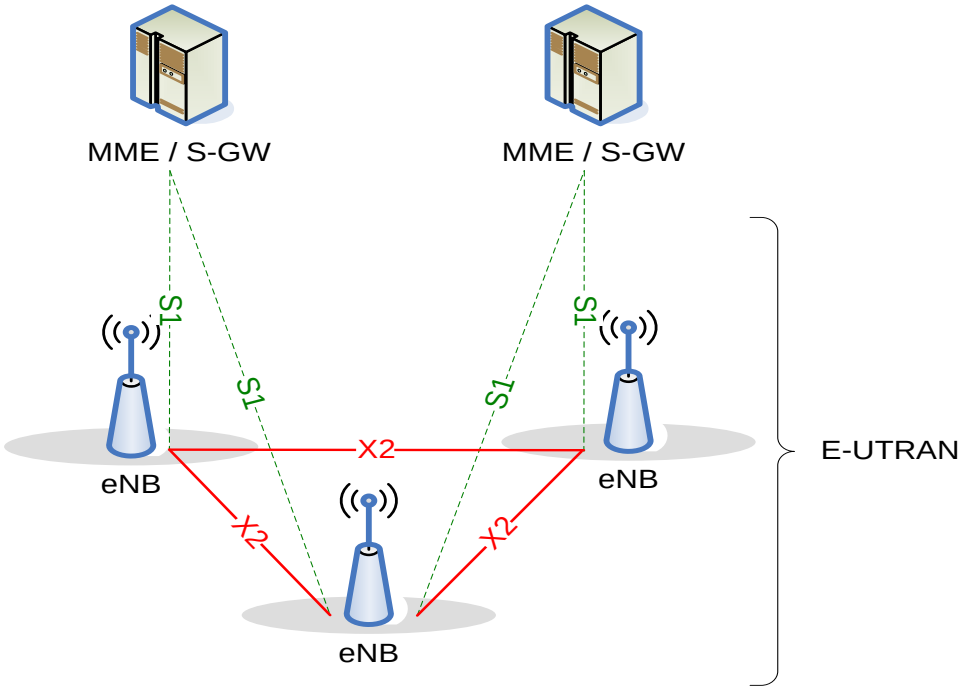


Figure 7 Architecture of 4G TD-LTE

LTE uses a different method from 2G, 3G air interface technology, namely the air interface technology based on OFDM technology and the traditional 3G network architecture. LTE establishes flat network architecture, in which access network e-utran no longer contains RNC, but contains only node ENB that provides E-UTRA households face PDCP/RLC/MAC/ physical layer protocol function and control surface of the RRC protocol function. The system structure of the E-UTRAN is shown in figure 7 above.

3.7.3 Tri-networks Integration

The MSA network framework plan of maritime supervision IT system now is based on tri-networks, namely, WSN network, 4G LTE maritime private network and Ethernet organic. Tri-network takes the advantages of three types of network to build a set of intelligent network. The IT maritime supervision system can choose the optimal way of accessing, which can solve the problem of accessing to the field of information systems. Its structure is as follows in figure 8:

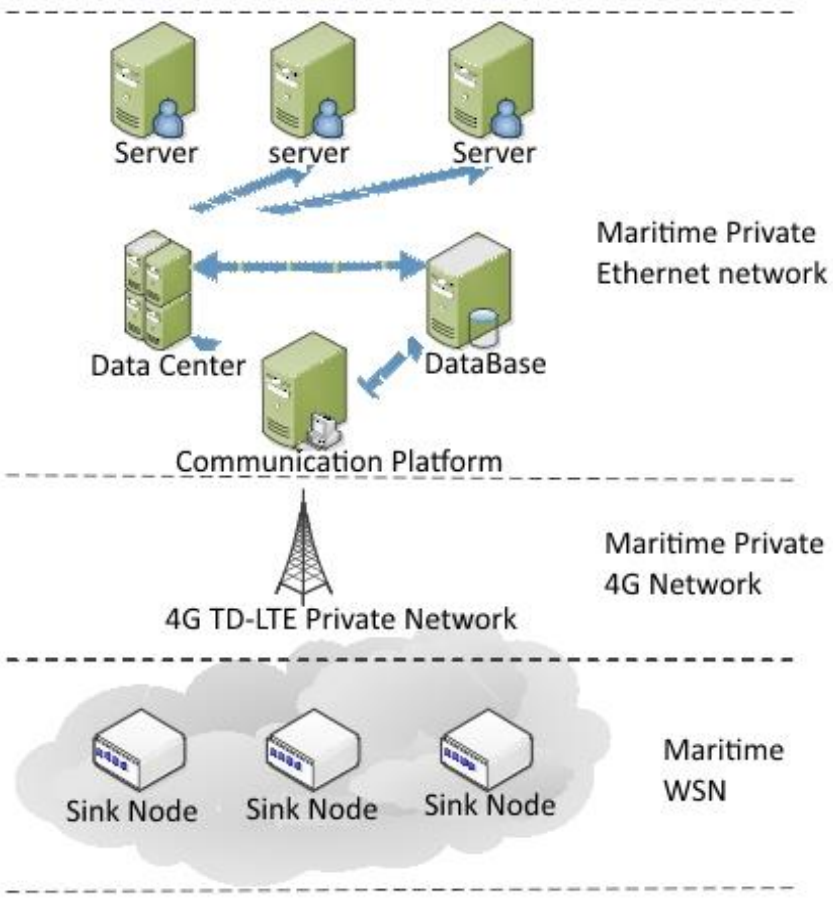


Figure 8 Architecture of Tri-networks Integration

3.8 Network Plan and Verification

3.8.1 WSN

The entire WSN is composed of Core Layer, Relay Layer and Access Layer, as shown in Figure 9. The three layers are as follows.

(1) Core Layer: 1. The high capacity of the WSN base station should be built in the top of maritime safety administration building; 2. The cable core network switches, access to the maritime bureau access related server; 3. Considering the downstream capacity of fixed base station, increase high bandwidth relay bridging equipment; 4. Switch the front set up nets brake device, data in and out of the switch should be filtered before routing (strategy).

(2) Relay layer (the fixed base station): 1.the fixed WSN base station spacing of 5-10 km; 2. Fixed base station between the 5.8G frequency network; 3. Fixed base station using 5.8G frequency band covering the surface of the river to move the ship borne equipment.

(3) Access layer: 1. On the patrol boat mounted mobile WSN base station equipment; 2. Mobile base station through 5.8G module return to shore fixed base station; 3 mobile base station by the 2.4G module covering 200 meters wide area around the cabin and the ship; 4. Four access equipment were installed in the cabin interior, which meet the sensor data collect terminal equipment.

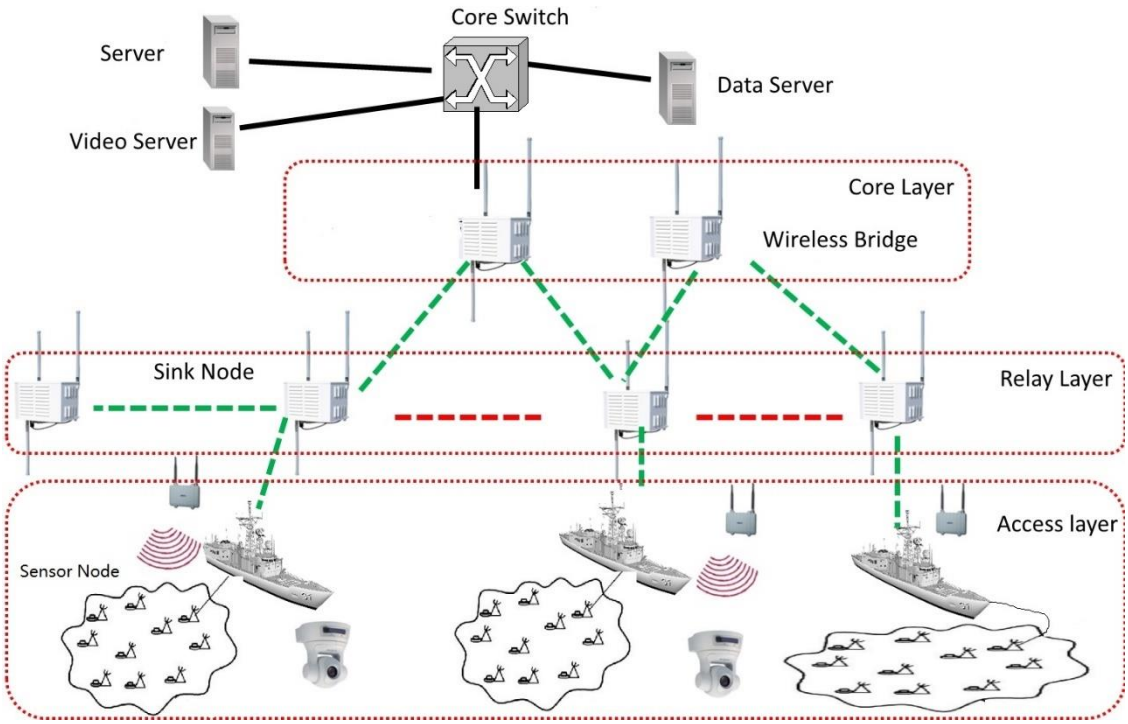


Figure 9 WSN Topology

Taking the existing WSN experimental network as an example, the system is proved to be feasible. In maritime WSN system, the shore base station is wireless network convergent point. WSN mesh network is used for interconnection between the base stations, between the base station and the terminal. The base stations are shown as Figure 10. The base station distribution and link state are shown in Figure 11.

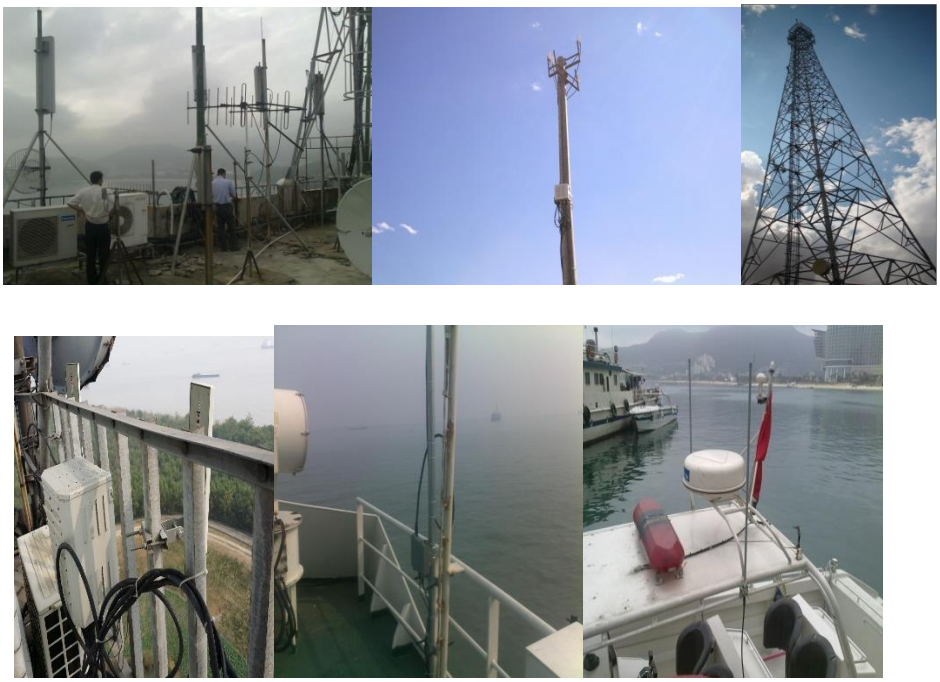


Figure 10 Base Stations for Land and Vessels

Figure 11 Base Station Distribution and Link State

The WSN of Jiangsu Zhenjiang section of the Yangtze River course has been completed, and wireless sensor data in anytime, anywhere can be accessed to the WSN. And the real-time signal can upload command center monitoring platform operation.

(1) The whole channel network signal coverage quality is good. The sea patrol boats in the area access WSN network, the other side of the server for Ping package, the overall packet loss rate of less than 1%, the average delay in the 10ms.

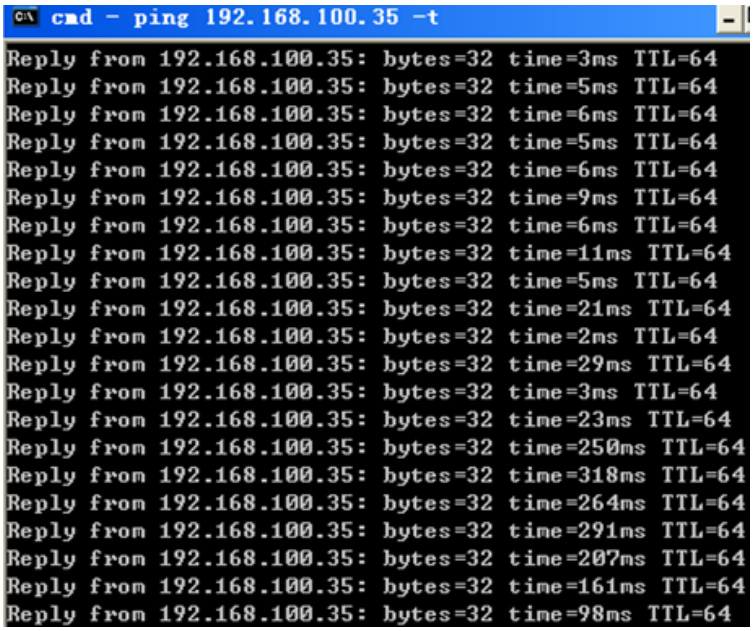


Figure 12 Time Delay of WSN

(2) The stable backbone links. Wireless multi hop network performance is good, as shown in Figure 13, even under 10 hops, the network also can only lose 40% return throughput, 32byte packet delay only 15ms, 1400byte packet delay is 25ms. In this case, WSN network works well all the time.

Network Throughput Capacity (Mbps)	Number of Hops									
	1	2	3	4	5	6	7	8	9	10
Noise-Free	23.80	23.80	23.70	23.50	23.40	23.40	23.30	23.20	23.10	22.90
Ambient Noise	21.30	20.15	19.15	18.70	17.80	16.55	15.20	14.25	13.00	12.15

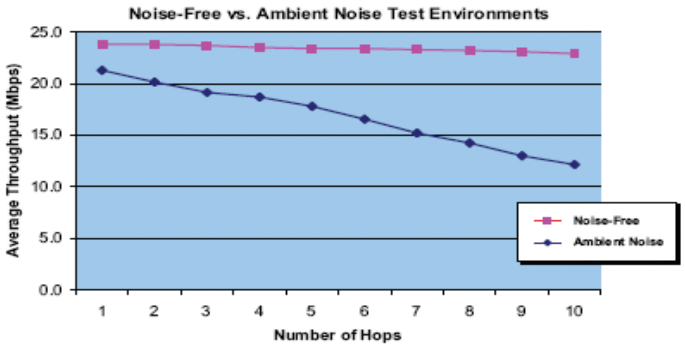


Figure 13 Multiple hops network performance

3.8.2 4G TD-LTE Private Maritime Network

Maritime Private Ethernet Network now is star type structure network. Each maritime branch is connected by a special 100 mbps private line to Jiangsu MSA platform, and the bandwidth is relatively limited. The data flow of relevant law enforcement branch and the branch vessel monitoring center accounted for most network bandwidth. In order to reduce the pressure on the current internal private network bandwidth, MSA can build six core networks. Each core network node is responsible for gathering two branch data within the scope of their jurisdiction base station. The terminal return information can be distributed to the nearest branches, reducing the cost of existing network bandwidth resources. The specific 4G TD-LTE maritime private network architecture is shown below:

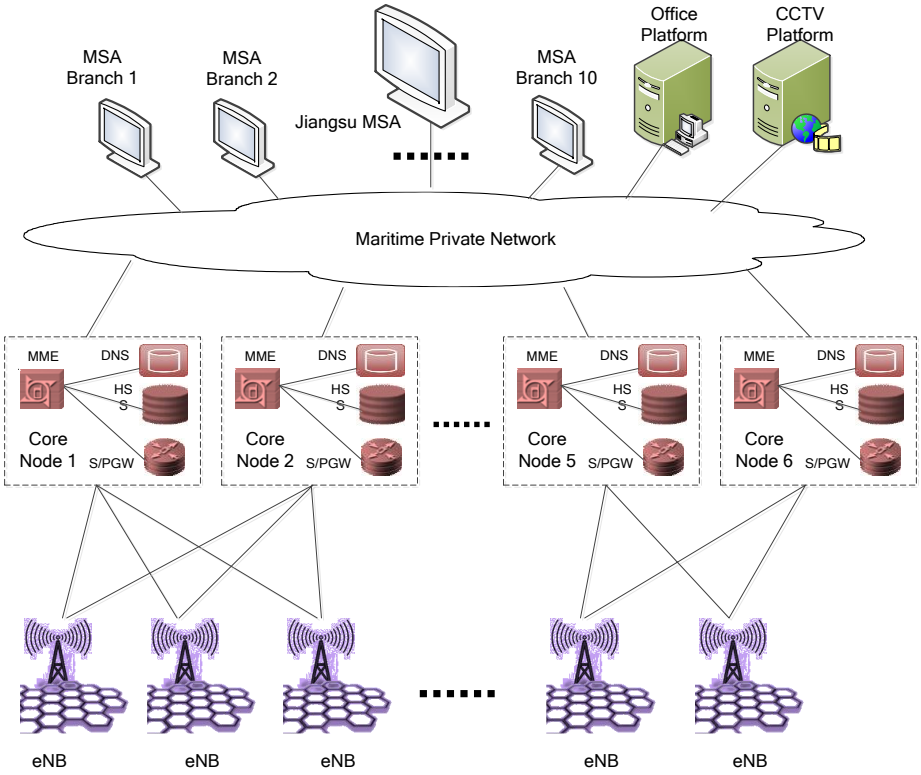


Figure 14 Multiple hops network performance

The 4G TD-LTE maritime wireless network coverage area is from the Nanjing section of the Yangtze River to the Nantong Sea, about 450KM long, as shown below in Figure 15:

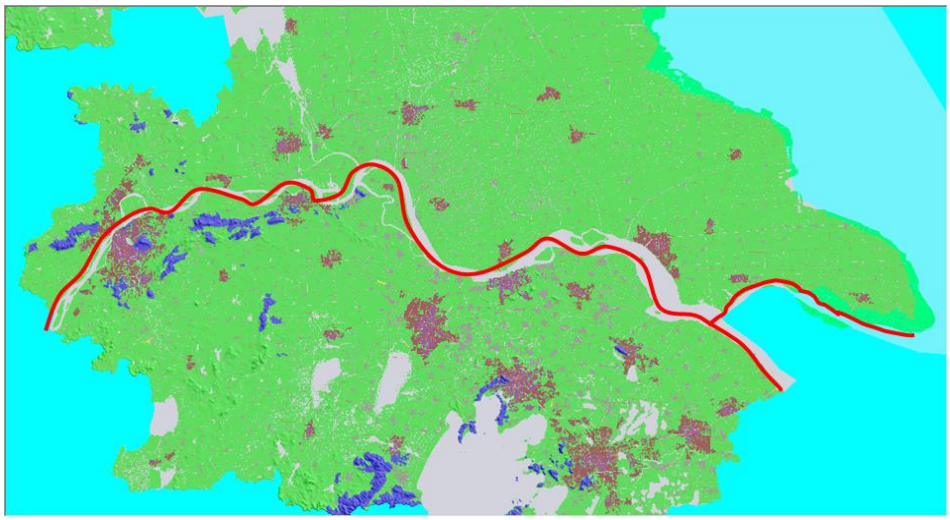
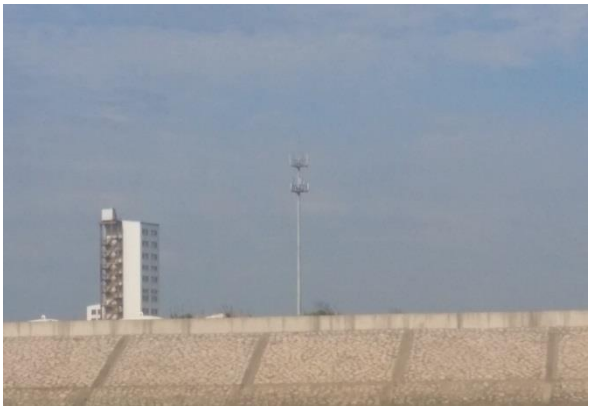


Figure 15 The Coverage of 4G TD-LTE Maritime Wireless Network

Construction of 4G maritime private networks needs to solve the wireless network coverage and capacity problems, which to ensure the river ships and personnel needs of the business. On the aspect of installation of equipment, MSA needs to complete a lot of facilities (including room, tower, power supply, etc.) and mining the potential of the existing communication facilities as much as possible, which to avoid the repeated investment and reduce construction costs, as shown in Figure 15.

(a) Using the original radar station to assume the base station

(b) Qualified Sites Need to Transform



(c) Sharing Sites with Operators

Figure 16 Several Types of 4G Base Station Selection

The wireless network mainly provides services for MSA of maritime law enforcement personnel. At the same time it also functions as the integrated display subsystem collecting front-end subsystem of the return path. At the beginning, all kinds of wireless network terminal are in accordance with the number of 100. In order to ensure wireless broadband private network backhaul for high-definition video support, it has to have adequate sound coverage, coverage of the target current project as follows: cell edge rate: downstream / upstream greater than 2Mbps; regional coverage probability> 95 %.

The 4G maritime private network engineering carrier frequencies are designed according to 1.4GHz, 20MHz bandwidth network. Due to the high demand for uplink data, uplink and downlink sub frame the use ratio of 3:1, special sub-frame ratio 10:2:2; wireless equipment adopts BBU + RRU architecture. The RRU should be best installed on the tower in order to reduce the construction difficulty and feeder losses. The height of hanging is in accordance with 40m meter. Site simulation arrangement is shown in figure 17 below. The base station equipment is 4T4R, the transmission power is 4*10w. Terminal equipment is 1T2R, the transmission power of 0.5W.

Figure 17 Site Simulation Arrangement

Engineering test results:

(1) The speed of mobile terminal is at /s 60km. The actual distance and bandwidth of the test results are shown in table 3.

Table 3 CCTV and Voice Performance Under 4G TD-LTE

Distance (km)	Rate (Mbit /s)	CCTV Performance	Voice Performance
10	34	Fluency	Fluency
48	17.8	Fluency	Fluency
70	8.5	Fluency	Fluency
75	4.5	Fluency	Fluency
82	0.41	Fluency	Fluency
91.6	--	--	Available
>91.6	--	--	--

(2) RSRP coverage

Table 3 CCTV and Voice Performance Under 4G TD-LTE

RSRP Signal Level	Coverage Percent (%)
Best Signal Level (dBm) >=-75	11.6
Best Signal Level (dBm) >=-80	24.4
Best Signal Level (dBm) >=-85	39.7
Best Signal Level (dBm) >=-90	79.5
Best Signal Level (dBm) >=-95	86.8
Best Signal Level (dBm) >=-100	92.9
Best Signal Level (dBm) >=-105	99.0
Best Signal Level (dBm) >=-110	99.2

Figure 18 RSRP Coverage Simulation

(3) Downlink Throughput

Table 4 Downlink Throughput Under 4G TD-LTE

Downlink Throughput	Coverage Percent (%)
Peak RLC Channel Throughput (DL) (kbps) >=20,000	30.2
Peak RLC Channel Throughput (DL) (kbps) >=16,000	39.1
Peak RLC Channel Throughput (DL) (kbps) >=12,000	45.8
Peak RLC Channel Throughput (DL) (kbps) >=8,000	52.5
Peak RLC Channel Throughput (DL) (kbps) >=4,000	90.7
Peak RLC Channel Throughput (DL) (kbps) >=2,000	99.4

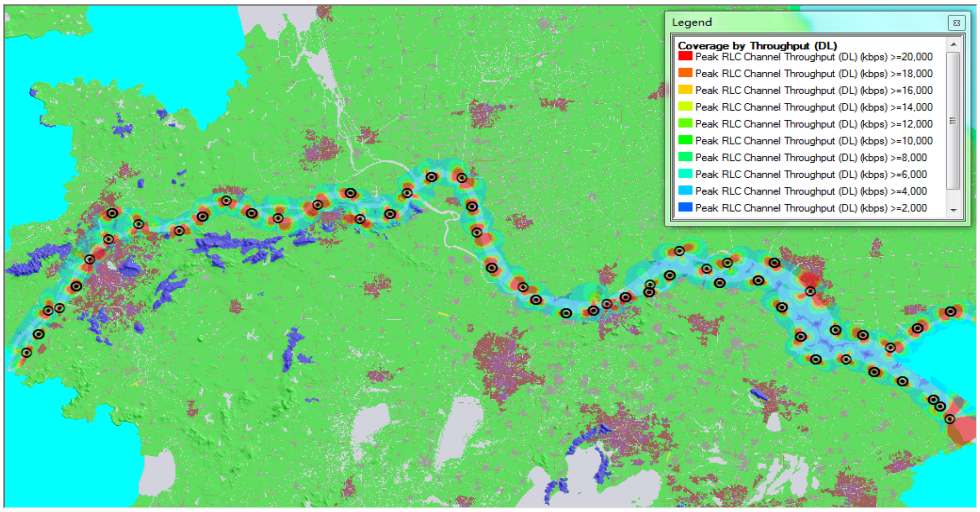


Figure 19 Downlink Throughput Simulation

(4) Uplink Throughput

Table 4 Uplink Throughput Under 4G TD-LTE

Uplink Throughput	Coverage Percent(%)
Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=20,000	28
Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=16,000	31.3
Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=12,000	36.3
Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=8,000	44.3
Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=4,000	80.3
Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=2,000	97.2

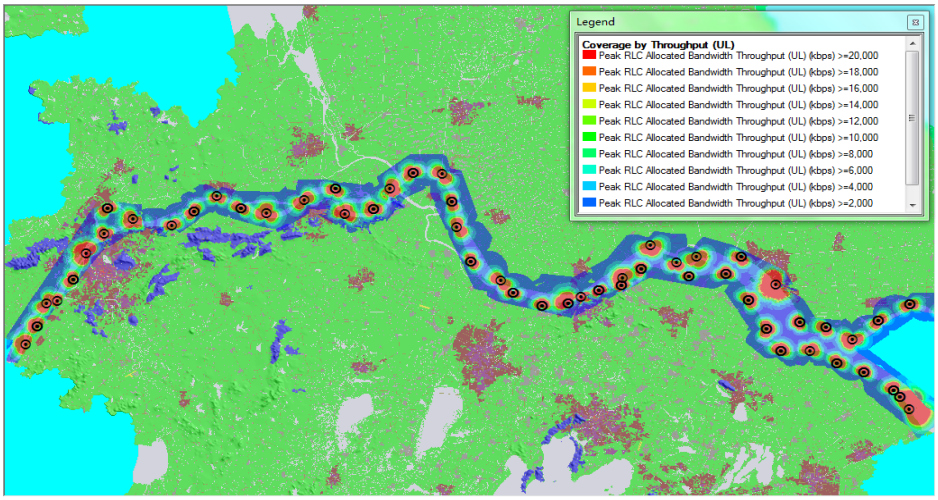


Figure 20 Uplink Throughput Simulation

(5) Field Test: The field test was carried out in the estuary of the Yangtze River. The base station is 100 meters high and at an average of 20 nautical miles offshore. The average value of the signal was obtained from the 50 times of the sea patrol boat in the channel. The Receiving rate was 96.83%, the end-to-end delay of 0.00798 seconds.

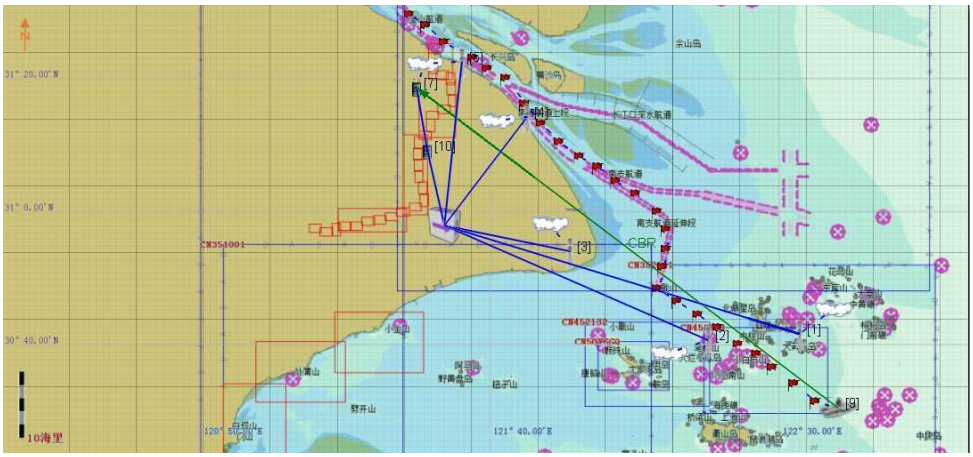


Figure 21 4G Field Test

According to the test results, with full consideration of various factors, TD-LTE can undertake the long distance high bandwidth of the Yangtze River. When the terminal is beyond fixed TD-LTE system coverage area, relay and motor network can be used to solve the problem of long distance transmission. TD-LTE broadband digital trunking system is fully functional, which meets the requirements of maritime field supervision.

3.9 Concluding Remarks

The author finds that MSA has been finding the solutions to the problem of accessing to information system in the field from the three stages of the development of maritime communication. MSA has to face the outmoded communication technology on the Yangtze River and its drawbacks. In this chapter, the author applies WSN and TD-LTE 4G technology these two kinds of new wireless technologies to the field communication on the Yangtze River and carries on the wireless network planning and simulation. It concluded that the signal has been able to achieve complete coverage of the Yangtze River region. These two kinds of communications are easy to establish and their communication bandwidth can fully meet the communications needs of the maritime field supervision on the Yangtze River. What's more, this solution solves the difficulties of field accessing problem of supervision system and office system, which makes the maritime intelligent detection system can be achieved.

Chapter 4 Maritime Real-time Intelligent Detection System

4.1 Introductory Remarks

The development of maritime IT supervision is based on the development of the network. According to the 3 stages of the development of maritime network, the maritime IT field supervision methods are constantly enriched, the ability is being continuously improved. In the first stage, network of maritime surveillance system mainly adopts centralized control and centralized management mode, the rental costs high, information source is single. What's more it runs in a public network, which is neither stable nor safe. It's usually used in an emergency the field supervision for demonstration. In the second and third stages, MSA constructed modern private network, which is mainly used to solve the field "last mile" access problems and achieved good results. This chapter mainly studies modern IT maritime supervision systems established in WSN and 4G TD-LTE maritime network.

The current monitoring system can only achieve the monitoring of ship and buoy, but it more than willing but lacking the power to form full range of three-dimensional monitoring for the wharf, waterway, hydrology, anchorage, oil spill and so on. And maritime surveillance system of channel resources before is limited, China MSA's limited real-time tracking and management are only for the extreme maritime supervision purpose. Therefore, it has become an important research topic in the field of maritime safety research to build a distributed multi-dimensional real-time maritime information intelligent monitoring platform. The structure design of real time monitoring system is shown in Figure 22.

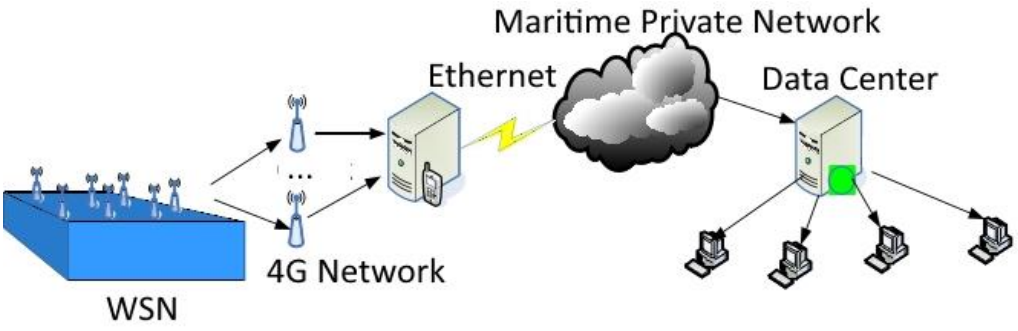


Figure 22 Structure of Real-time Monitoring System

Maritime real-time intelligent detection system is based on geographic information system platform, through the vessel traffic service system, ship automatic identification system, global positioning system, CCTV system, meteorological information system, water information system technology such as system to obtain the field supervision data. In data processing stage, the maritime supervision information and preset database were compared in order to achieve the water transportation service and supervision, inland water monitoring and ship tracking, search and rescue coordination of maritime field supervision system.

4.2 Design Characters based on Wireless Maritime Private Network

4.2.1 Acquisition of environmental parameters

Maritime environment parameter acquisition mainly includes the basic information, location, ship flow speed, water temperature, environmental humidity and so on. Wireless network node uses hierarchical design model, each cluster area is equipped with a high-performance sensor for receiving data nodes, data is periodically transmitted from the sensor nodes to the cluster head up the integration of information, which can be tailored to the redundant data avoid information overload and cause obstruction. Each cluster head for information fusion, the final information is sent to the terminal node or base station.

4.2.2 Maritime Safety Monitoring

The network nodes in the security monitoring application are fixed arranged in the monitoring environment, which is used for continuously monitoring one or more sensors to detect the occurrence of abnormal events. The biggest difference between security monitoring and environmental data acquisition is that there is almost no data for security monitoring. This point has a very important influence on the optimization design of the network structure. Each node must frequently check its sensor status and send a report data if there is a security exception. The real-time and reliable communication of alarm message is the most important requirement of the system.

Once a node in the network fails, the abnormal event report must be sent, and the network configuration must be able to determine the status of the node.

4.2.3 Localization and Tracking

The wireless network technology can be used to track and locate the position of the target at any moment by the sensor nodes installed on the target. The nodes in the target tracking network do not collect sensing data, but they can be used to complete the positioning by monitoring the radio frequency signals, and any node can be used as a label for the presence or not of the corresponding target. The system users can easily determine the location of the target in the current or any moment by establishing the database. The communication of the stationary nodes in the network remains relatively stable, and the mobile nodes will be added to the network at the same time. In addition, as the tracking node leaves and enters the monitoring area, the tracking target will be changed, and the new goal of real-time monitoring to enter the network is one of the basic functions of the network.

4.2.4 Distributed Information Processing

Different from the traditional centralized information processing method which is based on the central server based database system, the new type network adopts a completely distributed information processing method. From the point view of the database information system, the wireless network is a distributed database information system, and each node only keeps a small part of the whole system. Due to the centralized information fusion for each node information transmitted directly to the central processing node to achieve fusion, disordered transmission of each node will lead to the wireless network congestion, which can reduce the transmission reliability and the lifetime of wireless sensor networks. Distributed information fusion method is divided into clusters and select the cluster head node. In the process of information fusion, cluster fusion is done at first, and then the information fusion result is transferred to the central processing node to realize the final information fusion.

4.3 System Composition

The design principle of this system is the "Virtual Cruise", which is fictional patrol boats cruising at Yangtze River for surveillance of the area. The system based on the modern maritime wireless private network that makes networking technology applied to water traffic regulation. It establishes the ability of early warning of abnormal state through the acquisition maritime state parameter information from WSN, transport regulation, supervision and evaluation expert system security status of objects, thus it provides decision-making reference for MSA in inland water safety management.

The system is composed of information collection and transmission subsystem, information processing and display subsystem, communication and command subsystem and static database subsystem. The frame of the system is shown in Figure23. The system integrates the latest regulatory technology and prior management. This chapter will focus on the introduction of the latest information technology regulatory means.

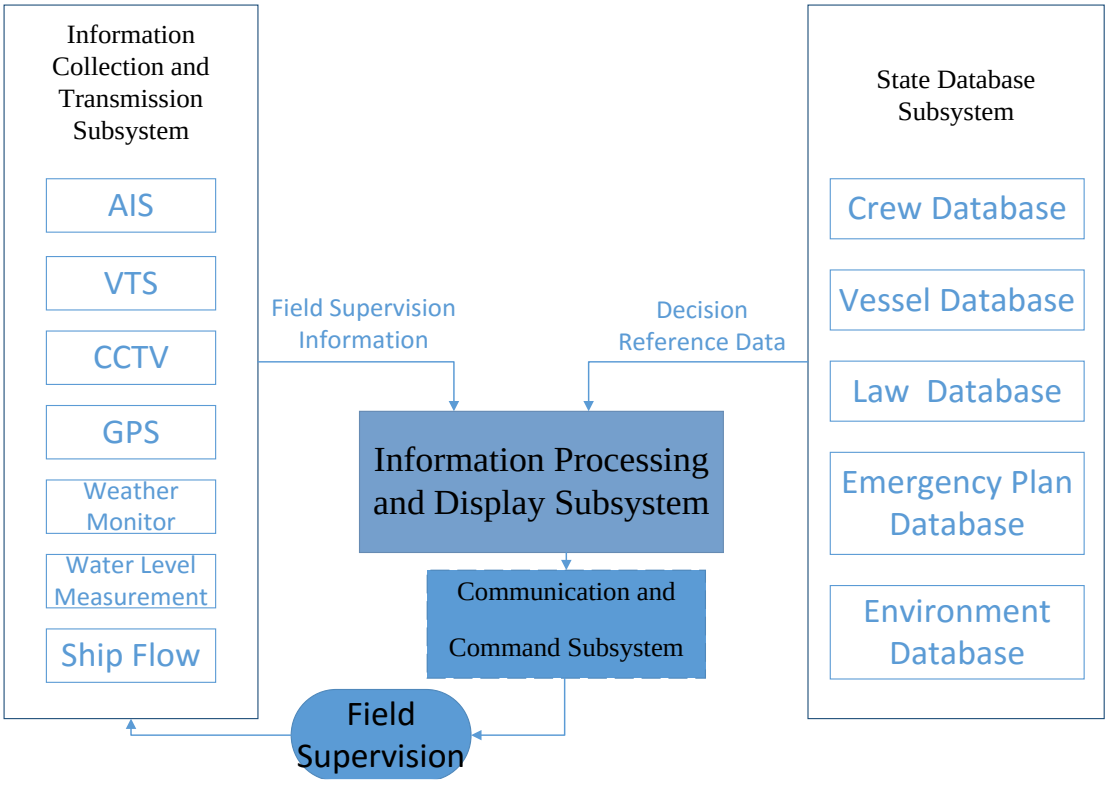


Figure 23 Frame of Maritime Real-time Intelligent Detection System

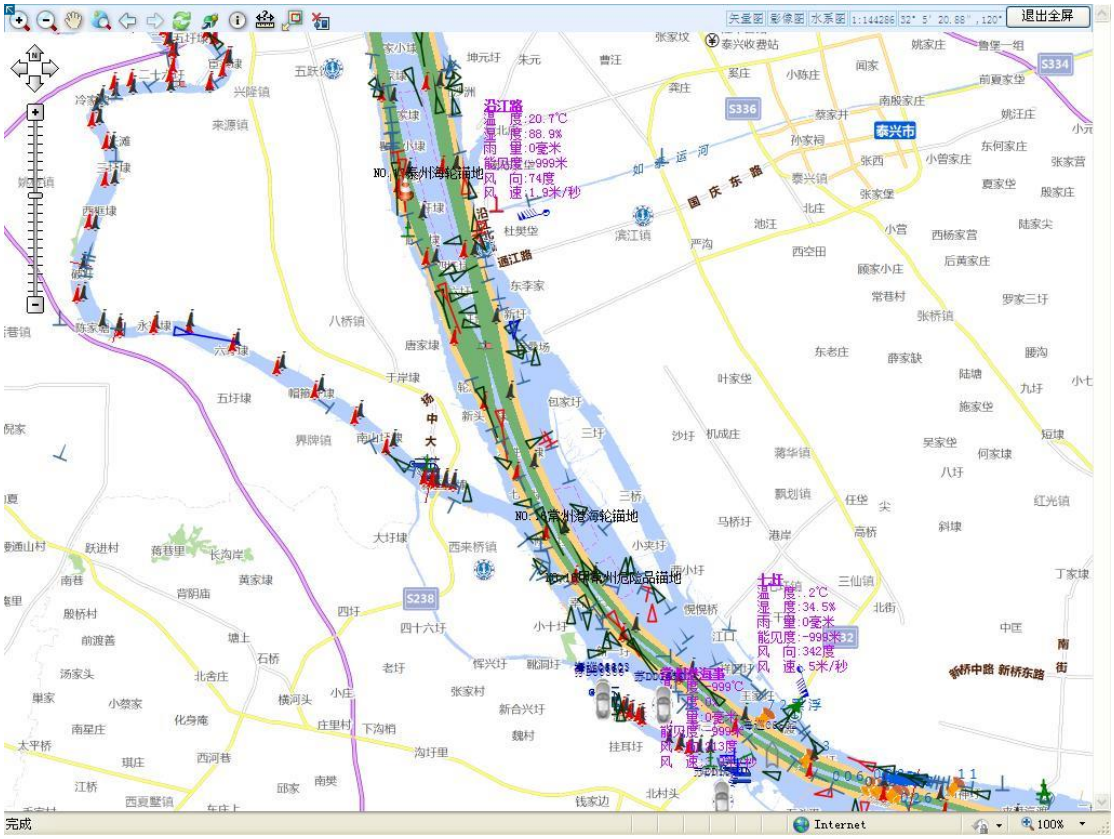


Figure 24 System interface of Maritime Real-time Intelligent Detection System

4.3.1 Information Collection and Transmission Subsystem

This subsystem is mainly used for all kinds of field information acquisition in maritime supervision (such as the navigation of ships, the water level of meteorological information) and transmits the information to the information processing and display subsystems. System consists of AIS, VTS, GPS, CCTV, weather information systems, sharing of water information system, etc., which can gather the name of vessel, ship, ship's position, speed, heading and meteorological water level information automatically. It is located at the bottom of the system architecture, which is the foundation of the whole system. Here is a brief introduction of several new information collection systems based on presented wireless maritime network.

(1) Weather Sensor System

At present, the technology for foreign meteorological data collection, transmission, processing has been quite mature. Weather monitoring sensor nodes are established on the trunk line of Yangtze River, with each node consisting of 18 floating nodes on the ocean surface, two shore relay nodes and a water-base station node. The station consists of a set of automatic monitoring system for intelligent data collection and a variety of meteorological sensors, all nodes communicate through the WSN network. The water surface temperature, light intensity and RSSI nodes value are sent back to the base station, which to achieve real-time monitoring of the Yangtze River waterway meteorological conditions. The monitoring contents include: visibility, wind direction, wind speed, precipitation intensity, humidity properties, temperature and other types of weather index.

(2) Water Level Measuring and Monitoring System

The Yangtze River water level has a direct impact on water traffic safety, and the ship's draft and waterplane height will decide whether the ship can safely sail through the channel and under the bridge in the area. Therefore, how to obtain real-time water level information accurately and quickly is a problem which is concerned by maritime management department, water channel department and ship itself. There are numerous equipment and tools for automatically measuring the water level and depth are very, and they are divided into two types: fixed and mobile. Fixed sounder typically is mounted on barges and buoys timing measurement point depth with high accuracy, but it lacks mobility and coherence. Mobile echo sounding instrument is directly loaded on the ship, with the ship's continuous trajectory measurement of the water depth, and now can real-time upload the water depth data through the WSN. Currently the system can not only measure water depth, abut also can generate real-time underwater topography data, detect underwater wrecks, sediment and hinder airlines, which provides real-time water level and channel data for the maritime administration.

(3) Ship Flow Monitoring System

Ship traffic statistics are traditionally based on artificial visual estimates, which is not only a waste of human resources, but also lacks accuracy and visual data. Ship identification system based on radio frequency technology can automatically and

continuously provide statistics of the ship flow in a certain section. Ship flow monitoring system senses ships through electronic fence of WSN sensor network, which can automatically identify the statistic of the ship flow. The technology has the advantages of covering long distances, good penetrability, low requirements for environment and higher accuracy.

(4) Wireless CCTV System

Along the signal coverage was incomplete, poor signal strength level, which has become a serious constraint bottlenecks in improving modern maritime law enforcement. For a long time, the comprehensive bottleneck problem with network coverage in the Yangtze River has directly affected the live line terminal of law enforcement and all kinds of monitoring equipment at the scene and maritime network docking. In this condition, it is difficult for IT field supervision to be fully effective. On the basis of already established CCTV system in the fixed place (such as skyscraper, pontoon dock, bridge deck) along the Yangtze river, maritime 4G private network can be adopted in the remote but important shipping point. CCTV system can be installed in the moving boat (sea patrol boat, beacon vessel) and the, officers can be equipped with individual law enforcement recorder. By using 4G wireless transmission technology, the river real-time video signals can be sent to monitor center display terminal directly. This innovative initiative can not only reduce the consumption of conventional maritime cruise resources caused by the manpower and material, but also improve the efficiency of daily maritime supervision. In addition, it can further test the accuracy of early warning information and verify the collected meteorology, hydrology, geological disasters, and the ship traffic etc.

(5) The Law Enforcement Process Real-time Recording System

Law enforcement real-time recording system based on 4G maritime private network, which is composed by law enforcement officers information system, law enforcement vehicles / portal boat information system information system and the law enforcement place information system. Grassroots law enforcement stations are equipped with law enforcement recorder, collection workstations, servers and electronic evidence management software and maritime electronic evidence management system. Remote

integrated management information platform was mounted on the patrol boats through 4G maritime private network to communicate with MSA data center, which change the habits of staying in a fixed office and make law enforcement and illegal scene investigation anywhere and anytime. Synchronous recording equipment is installed in all law enforcement places to meet the actual needs of the maritime daily dynamic monitoring and investigation.

4.3.2 Static Database Subsystem

The function of the subsystem is to provide decision-making reference to the standard data information for the system of data processing and warning function settings, also provides a basis desired environmental information range for system identification and the object of supervision. This subsystem mainly refers to the basic information database and knowledge support database in Jiangsu MSA information center, which includes the crew information database, the ship information database, the emergency response plan database, the expert database, the library and the navigation environment database and so on.

4.3.3 Information Processing and Display Subsystem

The subsystem calculates and processes the collected field supervision information through the software program. Compared with the standard data, the results are displayed on the user terminal screen. Data processing subsystem has established database, which receives the information stored in the database to prepare for data processing. While monitoring the working state of each sensor node in the data acquisition subsystem, this system will send corresponding control instructions according to different work tasks. The subsystem is operation and display terminal of the real-time intelligent maritime detection system. GIS data was imported to achieve the supervision of geographic areas of electronic and visualization. This system provides a software interface for operation. Information processing subsystem also has the following functions: data acquisition subsystem and the communication between

data processing subsystem, including the control commands from the center of sensor module, sending back the fault alarm sensor module information, etc. The database and the mathematical model are established, and the parameters of the sensor are brought into the mathematical model.

4.3.4 Communication Command Subsystem

The subsystem mainly includes VHF and sea patrol boat. Maritime management institutions provide information service through VHF, and provide filed supervision through WSN and 4G maritime private network.

4.4 Regulatory Function

4.4.1 Virtual Area Cruise Surveillance

Through the simulation of cruise technology, which can monitor global cruise on the area of the whole Yangtze River. Through the collection and comparison of internal information system, access to the area of the ship traffic and navigation environment information, found that the ship's existing problems. Through the collection and comparison system to verify vessel traffic and navigation environment information, which to find the problems existing in ships.

4.4.2 Remote Video Supervision of Various Forms

Benefitting from the construction of the Maritime 4G private network, CCTV can be established at any location, which can truly realize all-weather traffic monitoring 24 hours. Any authorized personnel can control and access the video images of other nodes from any node in the system, and can play them back. Command center and the Through the port, ship, car, personal handheld video CCTV monitoring system Maritime Department can realize remote video supervision of the whole area

including the main channel, anchorage, berthing, and operation of the ship situation, and so on. Figure 24 shows the CCTV video signal on ship.

Figure 24 CCTV On One Ship

4.4.3 Mobile Office On the Water

Through 4G phone officers can directly query the static and dynamic information from the law enforcement management platform, site disposal and upload to do static and dynamic information disposal results, take on-site pictures illegal activities and do evidence collection, on-site registration, on-site printing of the illegal information to inform the single, on-site circulation of internal approval procedures, and so on.

4.4.4 Key Ship Dynamic Tracking

The system has the functions of automatic identification, marking and inquiry for the key monitoring ships, such as dangerous goods ships, passenger ferries, super large ships, etc., which is convenient for the dynamic tracking management of marine management personnel.

4.4.5 Ship Traffic Order Organization and Maintenance

This intelligent system can be intelligent evaluation of the data on a specific area of the ship's navigation, parking and operating conditions for security early warning. As

shown in Figure 26, it can perform intelligent evaluation of the data on a specific area of the ship's navigation, parking and operating conditions for early security warning. When the ship does not comply with ship routing system or the distance between ships, between ships and special area is too close, MSA can remotely correct or provide warnings and navigational services via VHF and other communications equipment.

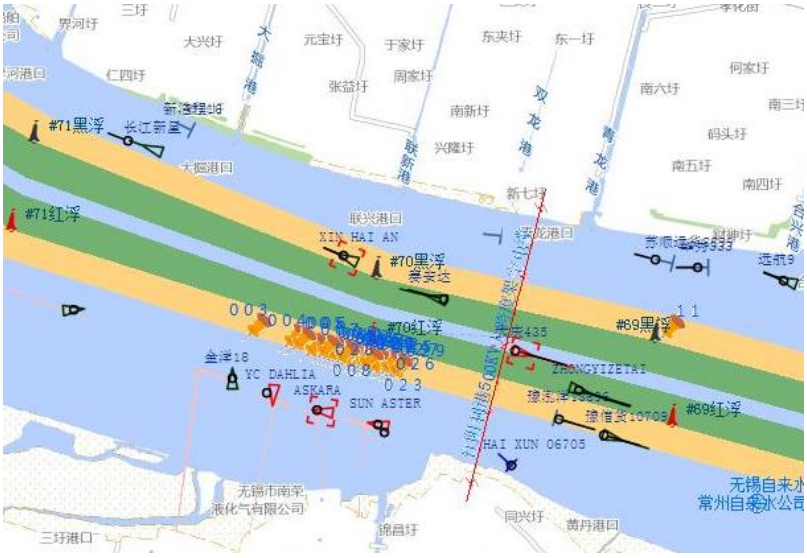


Figure 26 Ship Traffic Order Monitor

4.4.6 Ships Illegally Obtain Evidence

Regarding the monitoring of the inland river ships, the output information of a single piece of equipment has limitations. Just relying on a single type of sensor device cannot fully reflect the comprehensive traffic state information of the whole river. Because of its own limitations and the influence of information collection environment, the information collected maybe wrong, redundant, false and leakage, which will greatly affect the safety of navigation monitoring. Using a variety of information acquisition devices can monitor the navigation of ship from multi facets and get more complete, accurate and reliable information. For example, on the base of the traditional AIS, GPS, VTS methods, using CCTV real-time tracking ships, infrared remote sensing method to obtain target image and using 4G network real-time

transmission to send it the command center can be more intuitive to reflect ship navigation state. In this way, the system can collect evidence of the illegal behavior of the ship, record and file the illegal evidence, process results and payment information, etc., and thus the efficiency of maritime supervision and law enforcement standardization can be improved.

4.4.7 Release Traffic Information

Real-time Intelligent Detection System Maritime using the critical value technology. While the hydrological and meteorological information obtained from the WSN compares with the system preset value to judge whether the situation is right. The AIS SMS broadcast, VHF communication channels can help issue navigational warnings, safety warning, and meteorological and hydrological safety information. The information collecting and publishing platform can provide emergency action on hydrology and meteorology. It can also schedule regional Marine traffic order and coordinate the emergency action of the ship.

4.4.8 Emergency Command Decision

Patrol boats access to maritime real-time intelligent detection system through 4G maritime private network dynamic, which can make the search comprehensive. The system can work 24 hours a day. Search and rescue officers who receive a report on the accident danger can intuitively understand the situation at the scene, make pre-judgment and decision under the complex rescue environment and reasonably deploy the emergency search and rescue near the scene. Experts can guide through the field 4G CCTV video. The superior command center can give guidance under the real-time video, which achieve the rescue work Science issued instructions. Hand-held 4G mobile video communication terminal can help realize the search and rescue field command by audio and video information real-time transmission. At the same time, the system can enable the command center, field and sub command center to see the same field video information flow.

4.5 Implementation Status and Effects

The implementation of the system can effectively reduce the labor intensity of the personnel in maritime supervision and management. It can also achieve the power to supervise in the condition of 24-hour all-weather of key sectors, which improve the timeliness and accuracy of the command decision. In the system running, illegal behavior keeps falling steadily. For example, during the first 60 days after it was officially launched, electronic patrol police found 3650 ship illegal acts, 3526 of which were corrected. In the first 30 days, the number of ship illegal acts was 2200 while the number dropped by 34.1% to 1450 in the last 30 days. The electronic cruise alarm volume gradually reduced, which shows the reduction of ship illegal behaviors. Furthermore, the specification and synchronization of navigation order also contributed to the reduction of the cost in human resources. This system creates a new situation in the safety management.

The effectiveness of the system since the pilot prov**e**d that the implementation of maritime real-time intelligent detection system can improve the safety of inland waterway safety supervision and maintain safe operation play a positive role. On a pilot basis, it has great promotional value.

Chapter 5 Conclusion

In recent years, developing countries continue to invest in maritime business, and thus maritime network information system has made great progress. With the continuous efforts of the maritime officers, China's maritime management information system of the network platform has become one of the world's few influential management information and processing platforms, which plays an important role in the local economy and maritime supervision.

In the beginning of the application of information technology in maritime safety, our information technology supervision means has limitations. The limitations are mainly manifested in VTS, CCTV, GPS systems, which cannot achieve full coverage of the important port, dock, water and ship. What’s more, each information system was not extended to the field law enforcement unit. The author analyzed the present situation of the information supervision means in inland water and pointed out that the biggest obstacle is the problem of the field communication.

In the last few years with the rapid development of information technology, especially the abundance of means of communication has made it possible for information to be transferred from the front to the data center. The author analyzed the existing means of communication and studied the most suitable wireless communication technology for maritime, namely the WSN and 4G maritime private network technology, then pointed out their application in the inland river maritime communications planning and deployment. After simulation and field testing, the designed network can solve the problem of the extension of the existing maritime system.

In this paper, a new maritime supervision information system based on new network architecture is studied. With the wireless transmission technology WSN and 4G network, maritime real-time intelligent detection system can have a variety of functions such as information transmission, analysis and release. With the continuous development of wireless transmission technology, the defects of the traditional wireless transmission technology like the slow transmission speed of the data, low coverage,

and poor universality have been overcome. This inland water supervision system plays a key role in protecting the people's safety along the Yangtze River and promoting the rapid development of the local economy along the river.

Through the application of informatization in inland river maritime supervision in these years, the following results have been achieved:

(1) Significant enhancement of Law enforcement and supervision

By means of science and information technology, not only the provisions of law enforcement procedures and law enforcement standards have been improved, but also law enforcement process design has been optimized. All law enforcement actions can be recorded, played back and traced back, and supervision and discipline inspection departments can have access to law enforcement personnel's records through the intelligent transformation of sea patrol boats and law enforcement vehicles. As a result, internal supervision is more convenient and objective, the randomness of law enforcement is effectively restrained, and the law enforcement is greatly improved. All kinds of comprehensive utilization of resources and explore the great potential of modern facilities and operations supervision system.

(2) Marked improvement of effective regulatory capacity

Early to know the weather changes, the water level change to clear, the ship can be early warning of violations. Maritime real-time intelligent detection system is used for monitoring the dynamic of ships of the entire area. Law enforcement personnel can begin investigation and evidence collection of ships' overloading and other illegal activities at the first time and effectively investigate and deal with violations with the help of law enforcement recorder and the device. The application of maritime supervision platform has realized not only the extension of supervision of ships and crew to ships' loading but also the extension of jurisdiction of the navigation environment, order and ships after berthing and anchoring to the whole process of dynamic monitoring of ships' berthing, unberthing and entering into and out of anchorage.

(3) Great enrichment of public service

On the one hand, standards, norms and procedures have been established by science and information technology under the construction of informatization of whole law enforcement process. On the other hand, the design of informatization has made law enforcement results known to the public, which reflects the fairness and transparence of law enforcement. Meanwhile, application of the software for law enforcement site which helps law enforcement personnel deal with acts in violation of regulations effectively has reduced both time cost of administrative counterpart and workload of law enforcement personnel. Operation of the maritime supervision platform has been an important role in the promotion of convenience of shipping, effcience of shipping logistics and development of local economy.

(4) Strong reinforcement of risk-preventing capabilities

Real-time record of the whole law enforcement process not only requires law enforcement personnel to correct attitude and discipline activities of law enforcement, but also asks for standardization of law enforcement. What's more, their law-enforcement immunity has been enhanced so that a rigid self-restraint mechanism is formed. Recording the process of administrative counterpart's application for administrative licensing, inspection and penalty effectively curbs the administrative interference to maritime law enforcement actions which protects law enforcement personnel and maritime administration and reinforces the risk-preventing capabilities of law enforcement.

(5) Considerable advancement of Emergency handling management

Depending on informatization of maritime law enforcement, Command Center can quickly command sea patrol boats to go to the accident scene and acquire accident situation at the first time in the use of CCTV and ship borne records and transmission

system. Patrol boats can achieve all-weather, full-time, full-range search with the help of dynamic management system, GIS system etc. by logging in the integrated management information platform. At the same time, search and rescue personnel can fully grasp the information of the ship in distress, timely implement search and rescue instructions, and quickly carry out emergency relief. Advanced ways to bring the law enforcement costs down, the labor intensity is reduced, while strengthening the effectiveness of maritime safety supervision. Through more than two years of practice, Maritime Safety Administration has achieved significant periodical results in law enforcement informatization.

Reference

Barbosa, P., White, N. M., & Harris, N. R. (2008). Wireless Sensor Network for Localized Maritime Monitoring. *International Conference on Advanced Information NETWORKING and Applications* – Workshops (pp.681-686). IEEE.

Bekkadal, F., & Yang, K. (2010, August). Novel maritime communications technologies. In *2010 10th Mediterranean Microwave Symposium* (pp. 338-341). IEEE.

Bloisi, D., Iocchi, L., Fiorini, M., & Graziano, G. (2011). Automatic maritime surveillance with visual target detection. In *Proc. of the International Defense and Homeland Security Simulation Workshop (DHSS)* (pp. 141-145).

Carthel, C., Coraluppi, S., & Grignan, P. P. (2007, July). Multisensor tracking and fusion for maritime surveillance. In *FUSION* (pp. 1-6).

Carapezza, E. M. (2007). Intelligent maritime security system with sensor networks for coastal environmental and homeland security applications. *Proc Spie*, *6736*, 67360F-67360F-15.

Cho, K., Kang, C. G., & Yun, C. (2012, October). Transmission rate control of ASO-TDMA in multi-hop maritime communication network. In *2012 International Conference on ICT Convergence (ICTC)* (pp. 85-86). IEEE.

Cho, K., Yun, C., Lim, Y. K., & Kang, C. G. (2013). A MAC protocol for integrated service in the multi-hop ad-hoc maritime communication network.*The Journal of Korean Institute of Communications and Information Sciences*, *38*(7), 603-611.

Gad, A., & Farooq, M. (2002, July). Data fusion architecture for maritime surveillance. In *Information Fusion, 2002. Proceedings of the Fifth International Conference on* (Vol. 1, pp. 448-455). IEEE.

Ge, Y., Kong, P. Y., Tham, C. K., & Pathmasuntharam, J. S. (2007, December). Connectivity and route analysis for a maritime communication network. In *Information, Communications & Signal Processing, 2007 6th International Conference on* (pp. 1-5). IEEE.

Ilcev, S. D. (2011). 13. Maritime Communication, Navigation and Surveillance (CNS). *International Recent Issues about ECDIS, e-Navigation and Safety at Sea: Marine Navigation and Safety of Sea Transportation*, 101.

Jun, L. U. (2012). Maritime Supervision Model in Three Gorges Dam Area Based on Multi-functional Buoys. *Journal of Transport Information and Safety*, *6*.

Jung, Y., Chin, S., & Kim, K. (2004). Informatization index for the construction industry. *Journal of computing in civil engineering*, *18*(3), 267-276.

Kavelaars, W., & Maris, M. (2005). Wireless sensor networks in a maritime environment. *Proceedings of SPIE - The International Society for Optical Engineering, 23*(10), 1513 - 1525.

Kong, P. Y., Wang, H., Ge, Y., Ang, C. W., Wen, S., Pathmasuntharam, J. S., ... & Dien, H. V. (2008, March). A performance comparison of routing protocols for maritime wireless mesh networks. In *2008 IEEE Wireless Communications and Networking Conference* (pp. 2170-2175). IEEE.

Li-bo, Y. A. N. G., & Wang, W. A. N. G. (2003). Project design of closed circuit television (CCTV) system for the maritime affairs [J]. *Port & Waterway Engineering*, *10*, 002.

Li Hui. (2011). Some thoughts on the integration of maritime management and information. *China water transport, 11*.

Liu, L., Zhang, Y. Z., & University, S. M. (2014). 3d maritime search and rescue based on the node positioning of WSN. *Science & Technology Vision, 21*.

Luo Weixin. (2014). Discussion on Problems and Countermeasures of Xijiang River Maritime Information Supervision. *Pearl River Water Transport,23*, 82-83.

Maglogiannis, I., Hadjiefthymiades, S., Panagiotarakis, N., & Hartigan, P. (2005). Next generation maritime communication systems. *International Journal of Mobile Communications*, *3*(3), 231-248.

Mul, J. D. (1999). The informatization of the worldview. Information, *Communication & Society*, 2(1), 69-94.

Nartey, E. Information Sharing of Vessel Traffic Service (VTS) and Maritime Surveillance. *Regional Maritime University Journal*, *4*, 48-60.

Nonna Richard. (1979). Managing The Crisis In Data Processing. *Harvard Business Review* 57 (2): 115–126.

Paik, B. G., Cho, S. R., Park, B. J., Lee, D., Yun, J. H., & Bae, B. D. (2007). *Employment of Wireless Sensor Networks for Full-Scale Ship Application*. *Embedded and Ubiquitous Computing*. Springer Berlin Heidelberg.

Pei-zhen, L. A. N., & Jin, T. A. O. (2010). The Intelligent linkage System for Inspecting of Marine Closed Circuit Television. *Navigation of China*, *4*, 007.

Ponsford, A. M., Sevgi, L., & Chan, H. C. (2001). An integrated maritime surveillance system based on high-frequency surface-wave radars. 2. Operational status and system performance. *IEEE Antennas and Propagation Magazine*, *43*(5), 52-63.

Raffaele, M. Conti. (2005). Mesh networks: commodity multi-hop Ad-hoc networks. *IEEE Communications Magazine, 31*(11), 123-131.

Rice, J., Wilson, G., Barlett, M., Smith, J., Chen, T., & Fletcher, C., et al. (2010). Maritime surveillance in the Intracoastal Waterway using networked underwater acoustic sensors integrated with a regional command center. *Waterside Security Conference* (pp.1-6).

Sondaal, H. H. M. (1980). Current Situation in the Field of Maritime Communication Satellites: INMARSAT, The. *J. Space L.*, *8*-9.

Tian Chi & Yang Zhongbao. (2010). Some reflections on the development of maritime information in the Soviet Union. *China water transport*,*10*(8), 34.

Wang, C. Q. (2008). The analysis of china's e-government "information island" phenomenon. *Journal of Library & Information Sciences in Agriculture*.

Wang Hui. (2010). Research on the leading development strategy of China's maritime information. *China Water Transport*, *10*(8), 108-109.

White House. (2005) The National Strategy for Maritime Security. Retrieved July 17, 2016 from the World Wide Web: https://www.whitehouse.gov/issues/homeland-security

Xu Jingjing. (2011). Thinking on the management system and operation mechanism of maritime information. *Journal of the Management Cadre Institute of the Ministry of Communications 3*, 12-14.

Xu Tingting, & Chen Yongjian. (2009). Research on the development and trend of marine information in Zhejiang. *Waterway Engineering 8*, 16-18.

Yang, T., Liang, H., Cheng, N., & Deng, R. (2015). Efficient scheduling for video transmissions in maritime wireless communication networks. *IEEE Transactions on Vehicular Technology, 64*(9), 4215-4229.

Yu Xiaofan. (2016). Development and direction of maritime information. Pearl River Water Transport (9), 13.

Yuan Zhongxiang. (2011). Reflections on the development of maritime information. *China MSA, 1*, 43-44.

Zhang Chunjiang. (2009). On the network planning and construction under the background of "digital maritime". *Institute of navigation Chinese navigation along the HNA Group Specialized Committee standard proceedings*.

Zhang, Y., Zhou, M., Xiao, S., & Fujise, M. (2006). An Effective QoS Scheme in WiMAX Mesh Networking for Maritime ITS. *International Conference on ITS Telecommunications Proceedings* (pp.612-616).

Zhou, M. T., Harada, H., Kong, P. Y., & Pathmasuntharama, J. S. (2010). Interference Range Analysis and Scheduling among Three-Hop Neighborhood in Maritime WiMAX Mesh Networks. *IEEE Wireless Communications & Networking Conference* (Vol.29, pp.1-6). IEEE.

Zhou, M. T., Harada, H., Kong, P. Y., Ang, C. W., Ge, Y., & Pathmasuntharam, J. S. (2009). Multi-channel transmission with efficient delivery of routing information in maritime WiMAX mesh networks. *International Conference on Wireless Communications and Mobile Computing: Connecting the World Wirelessly*. ACM.