RESEARCH ON TECHNIQUES OF HIERARCHICAL - HETEROGENEOUS NETWORKING AND OPTIMIZATION OF RESOURCE SCHEDULING IN THE SEA AREA

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Abstract: The realization of a unified and efficient marine communication network is not only about how to develop a communication system, but also how to manage them, that is, how to set up an efficient marine communication network. Marine hierarchical-heterogeneous network is a multi-level integrated marine communication network, with shore-based, ship-based, star-based, space-based, underwater sound/light base station access, transmission and information aggregation capability. The access control, heterogeneous networking and resource optimization scheduling technology is facing enormous challenges, according to different priorities and types of services. Considering the complexity of the heterogeneous network as a cross-network with multi-user and multi-service, it is necessary to apply the delay tolerance network technology, cooperative technology, TD-LTE and software definition network technology into the network architecture design. The vision is exploiting DTN technology based ship-borne Internet, and the space-sea cooperative DTN data transmission scheduling mechanism; exploring the underwater acoustic/optical communication network switching scheduling mechanism; and then software definition heterogeneous network implementation is proposed, especially its optimal target network selection scheme. The project is meant as a petri

dish to provide valuable theoretical guidance and technical support of planning and performance evaluation for future marine hierarchical-heterogeneous network.

Keywords: Hierarchical-Heterogeneous Network; Resource Scheduling; Marine Communication; Delay Tolerant Network

1. Introduction

At present, marine communication system mainly includes maritime wireless communication, marine satellite communication and shore-based mobile communication system, which together constitute a basic realization of the marine full coverage of the communication network. The system can guarantee the daily communication of coastal, offshore and ocean-going ships-coasts, ships and ships; in the fields of ocean transportation, oil and gas exploration and exploitation, marine environmental monitoring, marine fishery, mariculture and marine science and other fields, accurate, timely and secure communication infrastructure. In general, marine communication technology is still at a lower level of application stage, which only basically meets the maritime activities of the conventional communication needs. Although there are some ships on the river which based on the public network GPRS/CDMA/3G construction of the maritime communications system, but it can’t achieve a wide range of remote network coverage. At the same time, because the conventional communication system of marine communication network is not compatible with each other, the communication bandwidth is different. There is a blind spot in the coverage area, lack of flexible configuration, efficient and unified management mechanism. Conventional marine communication network is becoming increasingly difficult to meet growing ocean activities demand, as constraints of marine development and exploration to the development of a major bottleneck. In particular, the International Maritime Organization has also proposed the development of electronic navigation E-Navigation strategy [1] to meet the future of marine business expansion, user needs, marine environmental protection and other development needs. Therefore, we must fully investigate the development of marine communications, understand the world's advanced marine communication technology, explore the development of suitable marine communication network architecture, and ultimately build a high-speed, high reliability,

full coverage, easy management, flexibility, low cost of the new ocean communication network [2].

At the same time, marine communication network resource management mechanism is another challenge that can't be ignored in marine communication. The realization of a unified and efficient marine communication network is not only about how to develop a communication system, but also how to manage them, that is, how to set up an efficient marine communication network. The research on the optimal allocation of resources of marine wideband communication system is still at the initial stage, and the related references are few. In [3], the Nautical Ad-hoc Network (NAC) is proposed for three scenes of harbor, seaside and ocean. Singapore-related scholars combined with Japan NICT research institutions with the start of the WiMAX-based Mesh network distributed adaptive slot allocation [4] and routing research work. However, research has focused on routing protocols, connectivity, and maritime channel modeling. Lin et al. analyzed the performance of maritime DTN network based on WiMAX technology, simulated the navigation data of Singapore Strait, and compared the performance of different routing protocol algorithms. The results show that the DTN routing protocol has a better probability of packet transmission in the maritime environment [5]. The paper [6] proposed a transmission performance analysis based on the theoretical model of the ship's encounter probability. The paper [7] is based on the existing AIS system, mobile data, predict ship-ship encounter model. However, ship-ship communications are within the scope of their respective communications. In our previous research process, Delay-Tolerant Networking (DTN) [8], WiMAX technology, and green communication technology were applied to the implementation of sea wideband networks. The storage-carrying-forwarding method was used to support intermittent connectivity, large and high bit error rate of maritime communication environment, and around the sea wideband data transmission in the optimal allocation of resources and scheduling issues to start a certain research work [9-11]. In addition to the above discussion of the marine communication network management methods, there are other literature, such as the literature [12-13] researchers also put forward their own management methods, the practical application should be based on different needs to adopt appropriate integration the internet. At present, the fifth generation terrestrial mobile communication technology (5G) is under trial operation, and 5G will be an important part of the future

information infrastructure. It can be used to solve the expansion of marine communication coverage and improve system capacity and other problems. Therefore, although there is already a variety of unique integrated network, but the development of more efficient integrated marine communication network, the study of the corresponding efficient marine communication network resource management mechanism is still one of the future research focuses.

2. System model

The hierarchical-heterogeneous network is a multi-level integrated marine communication heterogeneous network. Through the comprehensive utilization of shore base stations, satellites, island reefs, sea floating platforms, unmanned ships, stratospheric airships and other relay nodes, at the same time, depending on the maritime communication priority (distress, emergency, safety, regular), different types of services (different types of traffic, voice, data communication, multimedia services, etc.), different communication initiators (ship, shore) and network access (shore-based close-up access, offshore distance access, offshore mobile platform access) access control, heterogeneous networking and resource optimization scheduling technology is facing great challenges. This project takes full account of the complexity of the multi-level heterogeneous network in the sea as a cross-network and multi-user and multi-service giant system. The application of delay tolerant network DTN technology, collaboration technology, TD-LTE and software definition network (Software Defined Network, SDN) technology, to explore the multi-level heterogeneous network and resource optimization scheduling key technology research. The hierarchical-heterogeneous network has the capability of wide area coverage, real-time acquisition, safely control, accessed and on-demand service. Its flexible multi-access scheme and resource scheduling scheme can be used for marine hydrological meteorology and resources Exploration, disaster reduction, ship data transmission and other applications to provide network-based information services, especially on the maritime burst application mode of resources to support the flexible scheduling research to optimize the system business access control and network service performance. The smooth implementation of this project will become a human understanding of the ocean, the use of ocean information stations, and will also open up the future of information technology in the field of one of the important research.

Vessels network which is an intelligent transportation system on the sea, belongs to a new generation of maritime network. It is one of the most important supplement and extension of land vehicle networking, i.e. VANET [14]. In this paper, we build up this Space/Air/Sea integrated network, which is a multi-layer heterogeneous network, has shore-based, space-based and air-based access ability. This heterogeneous network could provide network access, data transportation and information gathering functions at the same time. The system model is shown in Fig. 1.

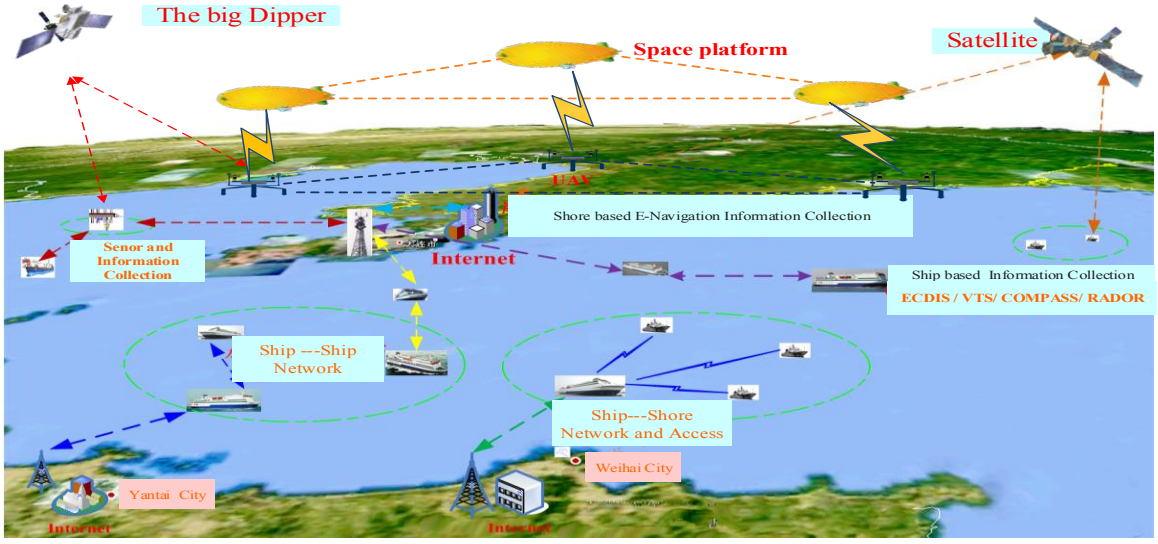

Fig.1 System model

3. Key Scientific Issues of Space/Air/Sea Integrated Network

The specificity of this study lies in the analysis of future demand and application pattern of intelligent ship communication. According to the coexistence of broadband data and narrowband data, the cost of shore base station construction is high, the distance of sea communication is far, the connectivity of the network node is sparse, And the high bit error rate, and constructs the multi-level heterogeneous network with the infrastructure such as communication satellite, air platform, ground base station, underwater sound/optical communication and so on. Considering the hierarchical-heterogeneous networks according to the specific structure can be divided into multiple levels, so in a wide range of multi-dimensional data transmission network heterogeneous characteristics. According to the different ship communication needs, maritime communication priority and application mode,

the interactive data scheduling and resource allocation mechanism are studied, and the resource utilization efficiency of each information platform is effectively improved.

- **Research on Data Transmission Scheduling Mechanism of Ship-borne Internet Based on DTN Technology**

Considering the ship mobility and network topology time-varying, especially due to the particularity of the maritime communication environment, so that the layout of the base station will have a discontinuous problem in time, but the existing classical scheduling mathematical algorithms are mostly based on continuous time characteristics, Which gave the ship-borne Internet DTN data transmission scheduling issues posed a serious challenge. Therefore, the design of a variety of ship-borne interconnection, seamless, and efficient ship-borne interconnect delay tolerance of network data transmission scheduling problems to be solved key scientific issues.

In order to solve the discontinuity problem of DTN network in time domain, we consider the time-capacity mapping method to convert based on time-capacity domain scheduling problem.

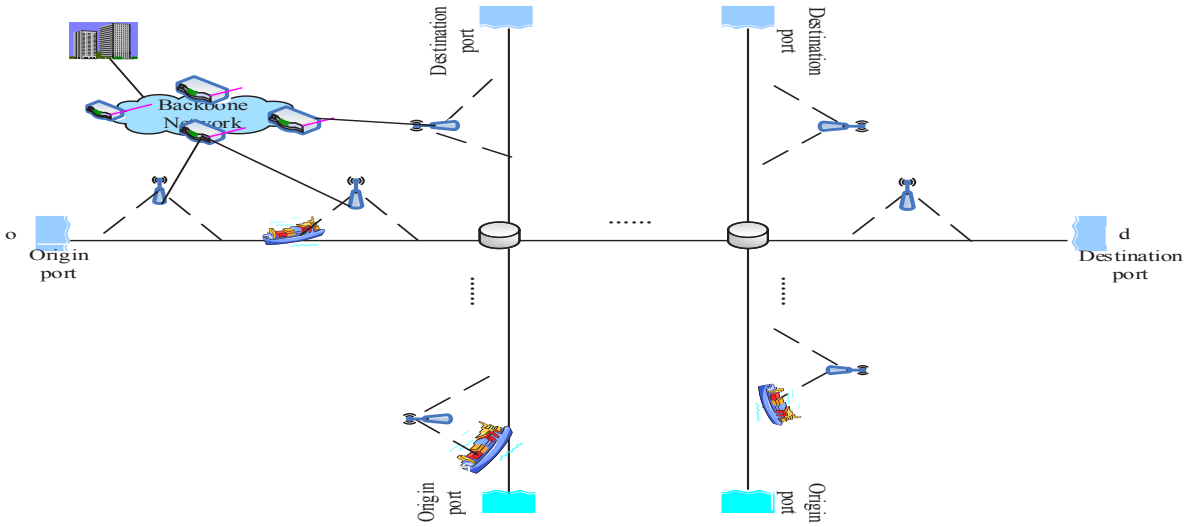

Fig.2 The Model of Ship-borne Internet Based on DTN Technology

Define $T_h^i(T_h^o)$ for the time at which the ship enters (leaves) the h shore base, respectively. $[T_h^o, T_{h+1}^i]$ is the time at which the ship is outside the coverage of two adjacent base stations, the ship can't transmit information via the base station in this time slot, and $A_{h,k}$

is the capacity of the k frame within the h shore coverage. The time-capacity mapping function is $f(t):[T_I,T_o]\rightarrow[0,1,\mathrm{L}\ \sum_{h=1}^{H}\sum_{k=1}^{K}A_{h,k}]$

$$f(t)=\begin{cases}\sum_{m=1}^{(t-T_{h_t}^i)/T_F}A_{h_t,m}+\sum_{l=1}^{h_t-1}\sum_{m=1}^{K_l}A_{l,m}, \text{if } h_t\geq 1 \text{ and } T_{h_t}^i\leq t\leq T_{h_t}^o \\ \sum_{l=1}^{h_t}\sum_{m=1}^{K_l}A_{l,m}, \qquad \text{otherwise}\end{cases}$$

$h_t=\arg\max_h\{T_h^i\leq t\}$, if $T_{h_t}^i\leq t\leq T_{h_t}^o$, otherwise $h_t=0$.

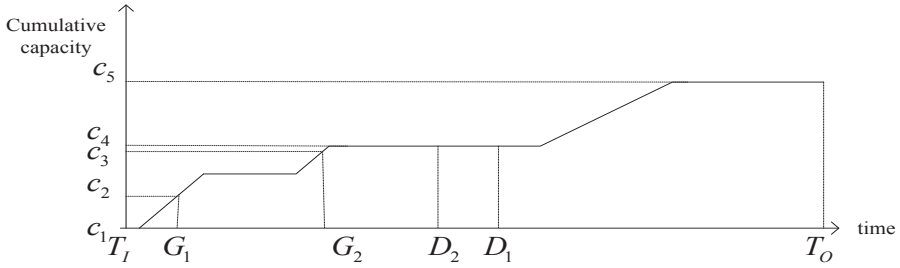

Fig.3 Time-Capacity Mapping

- **Research on Dispatching Mechanism of Underwater Acoustic / Optical Communication Network Switching**

Underwater acoustic/optical communication networks have different transmission characteristics and conditions of use. In this paper, the user in the underwater communication network is used to study the allocation mechanism of the acoustic/optical communication network resources to realize the optimization of the underwater data transmission. The subject first performs underwater acoustic/optical communication network modeling. In consideration of the total amount of transmission data of the underwater network user, the total amount of the received data of the underwater data transmission base station and the overall performance of the underwater data transmission to study how to use optical communication resources. This study can reduce the drawbacks of using high-latency and low-rate when the large amount of data is transmitted using the underwater acoustic transmission, so as to realize the optimal switching scheduling of the underwater data transmission mechanism.

- **Hierarchical - Heterogeneous Software Definition Network Realization and Optimal Target Network Selection Mechanism**

Techniques of hierarchical-heterogeneous networks can cope with the complex environment and tasks of future maritime communications environments. Considering that the network consists of ground access stations, airborne unmanned aerial vehicles, airships,

shore-based, underwater communications equipment and other access and control equipment, the network topology is changing, and a variety of information exchange frequently, direct and effective control. This project constructs the multi-level heterogeneous network of aggregated SDN based on fog calculation, which can play the advantages of unified management of network information and local information quickly [15]. It is very suitable for emergency treatment of marine environment, especially sea emergencies. And make full use of the software to define the advantages of SDN control plane and data plane separation, and effectively solve the network switching decision, and finally build a seamless, transparent, efficient, unified multi-level heterogeneous network selection mechanism. The SDN model is shown in Fig. 4.

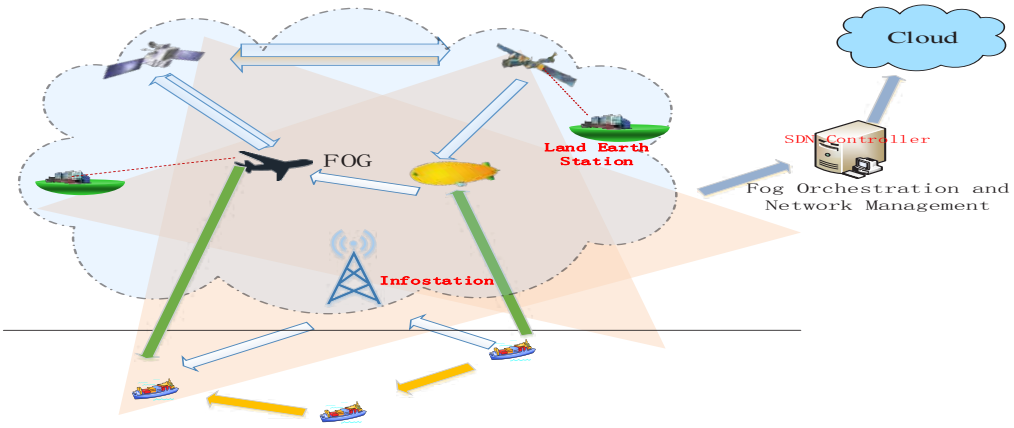

Fig.4 SDN-based Space/Air/Sea Integrated Network Architecture Leveraging Fog Computing.

4. Conclusion

In this paper, we propose a novel heterogeneous network. Marine hierarchical-heterogeneous network is a multi-level integrated marine communication network, with shore-based, ship-based, star-based, space-based, underwater sound/light base station access, transmission and information aggregation capability. SDN-based Space/Air/ Sea integrated network architecture leveraging fog computing. Targeting the dedicated communication on the sea, we design the unique network structure, as well as the component accordingly. And the working procedures are listed to show how this network works and it concerns. The project is meant as a petri dish to provide valuable theoretical guidance and technical support of planning and performance evaluation for future marine hierarchical-heterogeneous network.

In future work, we will take into account the maritime communications network security issues, while strengthening the scientific research in this area. Considering the above issues, combined with some of the problems of the new architecture of maritime communications, IMO legislative work will also be the focus of our work.

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