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The Challenges and Key Technologies of Wireless Transmission and Mobile Networking in Near Maritime Environment

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Abstract. The world economic development is facing important requirements of ocean fishery, marine oil and gas exploration, and ocean environment monitoring in ocean areas. Designing a cost-efficient, reliable, flexible, efficient, and service-rich communication system that can fully cover sea region including both offshore and high ocean areas is highly concerning research issue in electronic communication field. This paper first reviews the maritime communication research and identifies significant trends in the theory and key technologies for wireless transmission and mobile communications networking in order to establish maritime communications infrastructure. And then, the maritime radio propagation characteristics, spectrum usage mechanisms, and wireless transmission technologies suitable for marine communications are revealed to increase the transmission distance and performance. Finally, the big challenge of establishment of an integrated networking system covering ocean and terrestrial areas with characteristics of dynamic establishment, cooperative extension, and flexible access is discussed.

1.Introduction

With the development of ocean fishery and transportation, mobile users on ships need to be facilitated with effective communications and services at any sea area. Currently the communication technologies can be used for ships include single sideband (SSB) shortwave radio, VHF (Very High Frequency) radio, FM radio, cellular phone and satellite phone. Among them, the SSB shortwave transmission can be used for long-range communications because its signal is reflected by the ionosphere. However, blind zones exist in the SSB shortwave radio when the receiver is located away from the bounced distance. In addition, it often suffers from serious interference problems because of overcrowding on the wave bands and atmospheric disturbances. The transmission distance of VHF radio is about 20 nautical miles and the VHF radio transceiver is mainly used for ship-to-ship and ship-to- shore voice communications. The FM radio is mainly used for short-distance ship-to-ship voice communications with about 8-nautical-mile effective transmission distance. Another option is cellular phone, such as CDMA mobile phone with a global positioning system (GPS), whose advantages are low equipment cost and cheap calling charge. The drawback of cellular mobile network is that the coverage of cellular base station signal is limited usually in the tens of nautical miles offshore. The last option is satellite mobile communication by the Inmarsat (International Maritime Satellite) system, which is suitable for ships far away from shores. However, the mobile users (e.g. fishermen) are not always able to afford it due to the price of satellite terminal equipment, high cost of maintenance and replacement, and high communication fee. It seems that the high cost

and low data-rate of legacy maritime communication technologies and systems deployed in sea pose major limitation to establish reliable and affordable maritime communications.

The sea has specific electromagnetic characteristics and geographical features, and therefore, the wireless propagation environment is different with the land. The sea has the characteristics of large ocean area and less fixed support points for building communication infrastructures, etc. The traditional terrestrial communication theory must be expanded to complex marine communication environment. In order to provide reliable communication infrastructure for maritime information service, we should study the characteristics of radio wave propagation at sea and study how adapt marine wireless transmission theory and technologies for the marine communication environment.

Researchers have started to design maritime Ad Hoc and wireless mesh networks to provide network connectivity for maritime fishermen and enable them to communicate with correspondent users connected to terrestrial communication networks in near the sea [1-3]. However, the characteristics of sea wave propagation and the adaptability, efficiency and robustness of ad hoc and wireless mesh wireless transmission, and the protocol adaptation and service coordination of heterogeneous network integration remain some open problems.

The remainder of the paper is organized as follows. In Section II, we review the research on marine communications and its development trend. In Section III, we discuss the key technologies and technical challenges in the design of integrated communication network system and mechanism. We conclude in Section IV.

2.The literature review

2.1. The current technical methods of marine communications

Currently, the marine wireless communication in China sea provided by the Global Maritime Distress and Safety System (GMDSS) is mainly included single sideband shortwave radio, very high frequency (VHF) radio, and satellite communication [4-5]. These means of communication have their advantages and disadvantages. Single sideband shortwave radio uses high frequency (HF, 4MHz~22MHz) and reflects the shortwave through the atmosphere and ionosphere to achieve the long distance and low cost communications; while the disadvantages are that the shortwave transmission exists blind area, susceptible to interference, easily affected by the weather, and no data transmission function. VHF radio (around 156MHz) is mainly used in the near distance ship to shore and ship to ship voice communications, and only supports low bit rate data transmission. Maritime satellite communication systems (such as INMARSAT maritime satellite system [6]) are suitable for the ocean vessel, however the cost of terminal equipment, maintenance and update, and the communication tariff is so high that the fishermen cannot equip adequate satellite communication and navigation equipment due to the insufficient funds. Moreover, the offshore communication can rely on the cellular mobile communication system, which has low cost and cheap tariff. The shortage is the signal coverage distance of the cellular base station is limited, usually within tens of nautical miles [7]. The current maritime communication technology, therefore, can support few service species and low data transmission rate.

2.2. The latest developments

A significant sign of the development of maritime communication technology is the use of mobile ad hoc network (MANET) in ship to ship communication. MANET is a temporary multi hop wireless network, which does not depend on the preset basic communication facilities. Using the MANET in maritime communication is still in the exploratory stage.

British researchers Pullin et al demonstrated the possibility of using the 160MHz VHF-MANET to realize the ship to ship communication [8]. The Chinese scholar Wu Huafeng put forward the frame of the next generation of maritime data communication network, which makes use of the short wave (high frequency, HF) MANET to realize long distance communication between ships (tens of miles above) [9]. These studies give the realization of exploratory method of communication between ships,

but the VHF-MANET and the existing VHF wireless phones can cause interference, while HF-MANET can only be used for long distance communication between ships. They, therefore, are not suitable. Moreover, the wireless Mesh network is mainly used to build low mobility and high rate terrestrial wireless backbone network, which is convenient for users to access the internet [10],[13]. At present, wireless Mesh network protocol standard has IEEE 802.11s [14] and WiMAX system in mesh mode. WiMAX works in the frequency range above 2GHz, radio waves attenuates with distance. This causes the transmission distance to be limited. Singapore researchers use the WiMAX wireless Mesh network for the communication experiments between offshore ships in TRITON project [15]. Chinese researcher and his research team carried out researches on the theoretical and technical problems involved in the wireless network under marine environments [1-3,14,16,17,29,30]. Combined three heterogeneous wireless communication networks (MANET, cellular network, and satellite communication network), the technology scheme of marine mobile communication system is proposed (Figure 1.). Mesh network is extended to the marine environment for supporting the wireless communication between ships. Each ship has a wireless access point (AP), and the entire fleet constitutes the multi hop wireless Mesh network. Special wireless transmission technology is used between Mesh APs, which can also be used as WIFI AP facilitated the access of the user terminal on board. For supporting the communication between ship and shore, the ship borne cellular gateway and satellite gateway are employed as the interface for the MANET, cellular communication network, and satellite communication network in the minority ships. The ship communication terminals first access the MANET, and then connect the cellular network or satellite communication network through the ship borne gateway. Satellite communication network has large coverage area; MANET has flexible and economic networking; cellular communication network has the convenience in onshore and offshore area. The network architecture and mobility management technology has applied for the national invention patent [3, 16, 17, 28, 29], and part of the key technologies has carried out maritime experimental verification.

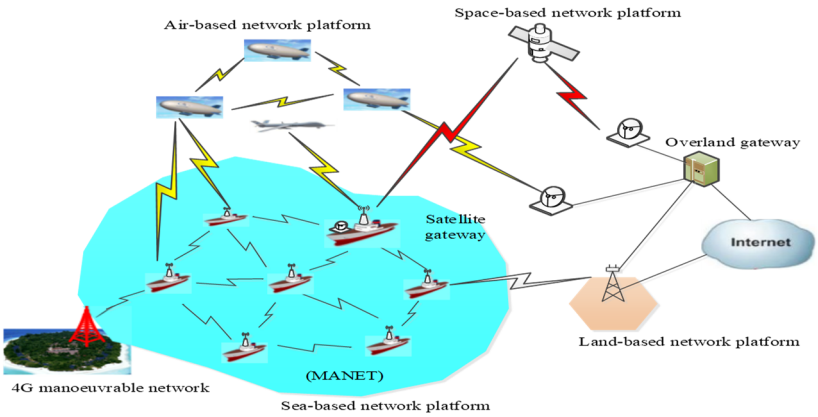

Figure 1. An integrated Land with Sea Maritime Communication Networking Framework.

2.3. Unsolved problems

To construct the maritime MANET, the wireless transmission scheme between ships should be first considered. The practical needs of industrial applications require that the marine communication can achieve single hop transmission distance more than 10km. However, the current MANET standards, such as IEEE 802.11s and WiMAX system, still cannot meet the requirement. Therefore we need to reveal the sea wave propagation characteristics, select available frequency band, explore suitable baseband and radio frequency (RF) technology for dynamically construct the maritime MANET in order to satisfy the communication between ships in the fleet. In addition, in order to satisfy the quality of data, voice, and video of the inter-ship multi hop communication, the effective MAC layer channel access mechanism and congestion control mechanism [18] need to be proposed for reducing

the data traffic delay and packet loss rate, improving the network capacity, and ensuring the stability of the network. Furthermore, the MANET nodes, consisted by offshore ships, will lead to network separation and intermittently connection. Therefore, the suitable topology control [19] ~ [22] and routing technology [23] [24][28] need to be designed to ensure the robustness of the network connection.

3. The key technologies and technical chanllenges in the design of integrated communication network system and mechanism

3.1. Key technologies

To build maritime MANET, the following key scientific problems need to be solved.

1）The sea wave propagation characteristics and adaptability of wireless transmission

It is well known that the sea wave transmission has unique characteristics which are different with that of terrestrial transmission. The frequency, parameters of transmitter and receiver (such as transmission power, antenna height, gain, directivity, the motion of the ship, etc), geographic characteristics, environmental factors and climate parameters used by maritime radio transmission equipment, will affect the sea wave propagation characteristics. Currently, the fading propagation characteristics caused by the irradiation, reflection, and diffuse reflection under different sea conditions are revealed insufficiently. Researchers only study the fading characteristics in low maritime satellite frequency band [25] [26]. Therefore, the general sea multipath channel model based VHF/UHF band, which can guide the design of offshore radio transmission technology, needs to be explored urgently. Meanwhile, due to the shortage of spectrum resources, using what kind of band to provide broadband communication between ships also remains to be investigated. In addition, in order to ensure the long distance transmission (over 10km), the innovative wireless digital transmission enhancement technique (including new modulation, channel encoder/decoder, adaptive power control and transmission transform rate adaptation, etc.) needs to be studied, based on the revelation of the sea wave propagation characteristics.

2）Multi hop transmission efficiency and network robustness of maritime MANET

To ensure the connection robustness and transmission performance of the MANET, the theory and technology of the terrestrial communication in ad hoc network (such as wireless Mesh network) need to be developed based on the characteristics of signal transmission and application of sea environment. Based on the traditional CSMA/CA (with the carrier sense multiple access with collision avoidance) MAC layer, when data transmits, each hop need to fight for the wireless channel, which increases delay, causes buffer packet loss, and greatly reduces the performance of multi hop transmission [27] [28]. Therefore, the MAC layer protocol which can improve the multi hop transmission efficiency of MANET needs to be designed.

For the robustness of the dynamic networking of marine network platform, the topology control algorithm and routing algorithm must be programed in accordance with the actual movement situation of marine ships. Topology control can ensure the requirements of network connection, mainly through dynamically changing the transmission power of nodes. The main goal of traditional topology control algorithm is to guarantee the probabilistic connectivity of the whole network (i.e., all nodes connect with a certain probability). For the maritime MANET, some specific nodes need to be treated differently. Special movement regulations in maritime navigation and operation require to enhance topology control and routing algorithm to better ensure the network stability and reliability. Besides, ship movement will cause network separation and intermittently connection, which must be solved by taking corresponding measures.

In maritime integrated mobile communication system, the quality of service (QoS) parameter of MANET is far different from that of land wireless network. It can easily cause the network data congestion. Hence, the characteristics of the network system of congestion control mechanism need to be considered. It addition to the congestion of multi hop transmission of MANET between ship and ship, the communication between ship and shore must pass through the MANET and the ship borne

gateway. At this time, the ship borne cellular gateway and satellite gateway may also become a communication bottleneck and cause congestion [28-29]. Meanwhile, the nodes of gateway often need to support the multiple end-to-end data transmissions, which accordingly increases the probability of congestion. Moreover, using satellite mobile communication network, long delay and asymmetric of satellite links also increase the difficulty of congestion control [29].

3）Protocol adaptation and service coordination of heterogeneous network integration

Maritime integrated mobile communication network involves a number of different access technologies of wireless communication networks, hence a variety of problems of protocol adaptation and service coordination of heterogeneous network demand to be solved. Firstly, it need to propose the interconnection method of heterogeneous wireless network. In the basis of maintaining the integrity of the existing wireless network structure, how to achieve the interconnection and interoperation of different heterogeneous networks through the gateway should be explored. Because of the existence of overlapping coverage and a variety of available links between the network platforms, the mobile terminal needs appropriate gateway discovery and selection mechanism to achieve the best access. Second, there is a need to investigate the mobility management under maritime integrated network environment to ensure the service accessibility and continuity when user moves. The mobility management of variety of heterogeneous wireless networks is more complicated than that of two interconnected heterogeneous networks on land (such as 3G cellular mobile network and WLAN), including the mobility of mobile terminals and ship borne gateway.

3.2. Technical challenges

To design maritime integrated mobile communication system, we encounter three kinds of technical challenges.

The first challenge we meet is how to adapt the wireless transmission enhancement technology to the sea wave propagation characteristics. For instance, how to make use of electromagnetic field and electromagnetic wave theory and experiment to explore the sea wave propagation characteristics, and establish the offshore large scale wave loss channel model and multipath small scale fading channel model, how to select the core band in the sea wave propagation and establish the marine and terrestrial radio frequency resource sharing and utilization mechanism. Based on the research results in the special nature of the marine wireless transmission, new type of modulation and demodulation, channel coding, adaptive power control, adaptive rate transformation, and relay technology can be found.

How to build theory and mechanism of the maritime MANET dynamically aiming at reducing the delay and packet loss rate, improving the network capacity, and ensuring the network stability, improving the performance mechanism of the multi hop MANET MAC, and improving the transmission performance of different services (data, voice, video) when using multi hop MANET is the second challenge. For example, how to program a topology control algorithm and routing protocol of maritime MANET based on the actual situation of marine ship movement parameters (size, speed, moving model of the fleet) and the typical moving model of ships to ensure the stability and reliability of network based on this typical model. Second, how to design a congestion control algorithm suitable for multi hop MANET and heterogeneous integrated network, find the congestion control mechanism of the multi hop MANET with bottleneck gateway nodes, and to propose the congestion control mechanism in the situation of long delay satellite transmission in heterogeneous integrated network. Finally, how to design the management framework based on the adaptive QoS control policy and put forward the cross layer QoS model and efficient service control algorithm for maritime MANET issues one's challenge to dynamic policy adaptive QoS management mechanism.

The last challenge is how to integrate the mobility management of cross network platforms of several heterogeneous wireless network systems and QoS guarantee mechanism of integrated network. Take an interconnection mechanism of multiple network platforms into consideration, we have to do researches on how to realize the method of solving the interconnection of heterogeneous wireless networks, including design the implementation mechanism of gateway to ensure the interconnection

and interoperability of multiple heterogeneous networks and put forward the discovery and selection mechanism of multi gateways to achieve the best access of mobile terminal. Think over the mobility management mechanism of cross network platforms we must set up the mobility management mechanism of multiple heterogeneous wireless networks, solve the dual mobility of the mobile terminal and ship borne gateway, and design the management mechanism in both concurrence conditions of centralized control network (cellular mobile communication network, satellite mobile communication network) and distributed control network (MANET). In addition, we also need to investigate to design the cooperative mechanism and QoS guarantee mechanism of cross network end-to-end service, including the end-to-end QoS architecture, QoS mechanism, consultation of QoS key nodes, and QoS control strategy.

4. Conclusions

The development status of domestic and international maritime wireless mobile communication technology is reviewed in this paper. The key technologies and technical challenges of revealing characteristics of sea wave transmission, realizing the marine and terrestrial wireless radio frequency resource by using cognitive radio technology, constructing the marine and terrestrial heterogeneous integrated network, and achieving the network interconnection and performance guarantee of multiple heterogeneous wireless network, are discussed.

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