Research on maritime leapfrog emergency communication coverage technology based on satellite relay

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Abstract: According to the Long Term Evolution (LTE) communication technology with a high data transmission rate, a maritime leapfrog emergency communication coverage technology basing on satellite relay is proposed. It solves the problem that has accessible to access the public communication network quickly. This research introduces the components and corresponding functions of the communication system, which provides timely and effective emergency communication support for maritime emergency. The emergency communication system uses unmanned surface vehicle (USV) as a mobile platform, integrating the satellite communication system with a terrestrial mobile communication system. It can achieve the coverage of 4G emergency networks in the rescue area, Internet calls, data and video transmission etc. Using bionic "frog leaping" to improve the flexibility of deployment of marine emergency communication system, it can provide more efficient data transmission services for maritime rescue operations.

1. Introduction

With the continuously upgrading of communication technology and mobile terminals, 4G LTE technology has made rapid progress in a few years, and the number of users is increasing rapidly. It brings great convenience to people's daily life and communication, and is also about to usher in the era of 5G. However, in some special areas, such as the sea area, which limited by the layout and maintenance cost of the eNodeB, and the range of mobile communication signals is very small. Once these areas have a sea traffic danger, maritime search and rescue will be faced with many difficulties. Although communication satellites can provide reliable communications for the whole world, it is limited to the communication between the specific terminals and the cost is high, which can’t guarantee the flexibly use of ordinary mobile terminals in marine emergency communication[1].

In this paper, the satellite communication system and the emergency coverage of LTE network system form a satellite-terrestrial integration. The coverage of 4G emergency network is implemented in the rescue area, which ensures emergency communications at sea. The frog leaping is based on the bionic action of frogs, which vividly depict the flexibly arrangement of the maritime emergency communication. so, the emergency command center can arrange the emergency communication network at the specified position.

2. LTE and emergency communication

2.1 The summary of LTE

LTE is an abbreviation for the long term evolution of 3G technology, which called 3.9G or quasi 4G wireless communication technology. LTE uses orthogonal frequency division multiplexing (OFDM) and multiple input multiple output (MIMO) technology, which makes the network having high
broadband (the peak rate of downlink 326 Mbit/s and uplink 86 Mbit/s is provided at 20 MHz spectrum bandwidth). And it has the features of low-latency (the unidirectional transmission delay in the user plane is less than 5 ms), Flattening, IP, intelligence and so on. LTE has become a mainstay of the new generation of communication technology.

2.2 The summary of emergency communication
Emergency communication is used in the situation of natural or man-made sudden emergencies, such as floods, earthquakes or wars, terrorist attacks, etc. In case of the possible paralysis or congestion of the existing public communication facilities, a special communication mechanism is established by the organization for various communications resources and equipment for emergency situations. The purpose of emergency communication is to inform the relevant government departments as soon as possible in case of emergency. It is convenient for the relevant departments to assess losses and organize assistance. At the same time, it also provides communication support for coordination among various personnel involved in the rescue. For emergencies in the marine environment (such as crude oil leakage, ship accidents, etc.), because of the special geographical environment, and the communication blind area usually exists, the emergency commanders and the on-site emergency personnel cannot communicate effectively, which make the emergency rescue work affected to a certain extent. Therefore, corresponding emergency communication plan is made for different emergency situations to provide strong guarantee for emergency rescue work. The unmanned surface vehicle (USV) is a very flexible carrier to deal with emergencies at sea, which similar to the emergency communication vehicle on the road. This paper takes the USV as the carrier, and the LTE communication technology is used to support the marine emergency communication network. Therefore, reliable communication can be realized under abominable conditions.

2.3 The summary of satellite-terrestrial integration
The blind area of communication can be covered the network by satellite communication system (Such as mountains, seas, and so on). LTE has the advantages of high speed wireless transmission, optimized network structure, flexible spectrum utilization and so on. Combining satellite communication system with the onshore eNodeB, it can construct a communication network which integrates the advantages of these two networks.

In recent years, ETSI (European Telecommunication Standards Institute) has been published GMR-1 GMR-2 Satellite air interface standard which based on GSM (GEO Mobile Radio Interface), and satellite air interface standards that based on UMTS (Universal Mobile Telecommunications System). The establishment of satellite 4G air interface standards is also in progress. A system that integrated mobile communication system with broadband satellite communication system has been proposed. Respectively, Francesco Bastia and Chen Changmeng expound the possibility of using LTE air interface for inter satellite data transmission, and the analysis shows that the LTE air interface can be applied to satellite channels after proper adjustment. To combine the satellite mobile communication system with the ground mobile communication system, it makes use of the complementary advantages of these two systems to achieve seamless coverage to the whole world. Applying it to marine emergency communication system is conducive to the expansion of maritime activities. Based on the integration of satellite and ground network, the application of LTE communication technology and unmanned ship to maritime emergency communication system is realized in this paper.

3. Design of maritime emergency communication system
The maritime emergency communication system is based on the satellite-terrestrial integration network that is composed of Beidou satellite, synchronous orbit communication satellite (Tiantong No.1, 2) and emergency coverage LTE network system. So the maritime emergency communication system is connected to the LTE public communication network, which can realize the function that the emergency command center lays the location and layout of the unmanned base station network, and monitors the state of network.
3.1 Functions and composition of the system
This maritime emergency communication system is comprised of the onshore of LTE public communication network, Synchronous orbit communication satellite and unmanned cluster. Marine emergency communication system architecture is shown in figure 1.

![System architecture diagram of the maritime emergency communication system](image)

Figure 1: System architecture diagram of the maritime emergency communication system

The onshore eNodeB is connected to the EPC (Evolved Packet Core) through the transmission route, and thus connected to the network server. At the same time, satellite links are introduced through BBU (Building Base band Unit) devices and IPRAN edge routers. After these operations, Beidou satellite and synchronous orbit communication satellite (Tian Tong No.1, 2) establish wireless connection. The USV cluster includes a parent-node USV and a USV sub-cluster, which are placed on eNodeB. Unlike the sub-cluster, the parent-node USV is also equipped with satellite communication relay. Thereby implementing network based on a USV eNodeB system.

Beidou satellite and synchronous orbit communication satellite (Tiantong No.1, 2) are important supplements and emergency communication means for the USV eNodeB system. There have the following functions:

1. Monitoring the location
   The USV cluster uses the eNodeB of the ship to receive the satellite navigation signal through the antenna cycle to calculate the location, and according to the frequency of the application and the format of the specified message. The real-time location information will be sent to the Beidou access device through relay station. After the processed information access to command center, the real-time location of the USV will be displayed on the monitoring screen.

2. Transfer station of the communication signal
   The eNodeB is installed on the USV cluster, and the communication network is covered by the LTE communication technology to the designated emergency sea area. Synchronous orbit communication satellite (Tiantong No.1, 2satellite), as a transit station on shore and sea communication signals, implements the interconnection of marine emergency network with LTE public communication network on shore, and provides a guarantee for high-speed network for marine search and rescue operation.

3. Command center sends commands to USV
   According to the command search and rescue mission, command center can send dispatching signal to Beidou system at any time. The Beidou system is forwarded to the parent-node USV in the USV cluster. The parent-node USV receives the control message and regulates the parked position of the USV cluster by the controller.

3.2 The design of emergency coverage LTE network system
Emergency coverage LTE network system is mainly composed of the USV cluster, including USV cluster including a parent-node USV and a USV sub-cluster.
3.2.1 The parent-node USV. As the core part of the emergency coverage LTE network system, this USV is equipped with satellite communication relay, eNodeB, coordination-control module and power-supply module. Particularly, the coordination control-module includes the network deployment unit and the virtual dynamic positioning anchor control unit, and the power-supply module consists of solar panels, batteries and fuel power generation systems. As shown in figure 2. Satellite communication relay is the intermediary between communication satellite and onboard eNodeB, so that the onboard eNodeB is connect to the onshore eNodeB. And the onboard eNodeB is connected to the EPC.

![Figure 2: The core architecture of the parent-node USV](image1)

![Figure 3: The core architecture of the USV sub-cluster](image2)

3.2.2 The USV sub-cluster. Every USV of sub-cluster is equipped with eNodeB, coordination-control module and power-supply module, and the power-supply module is the same as the parent-node USV, as shown in figure 3.

3.2.3 The network deployment unit. This unit is responsible for controlling the coverage of the emergency LTE network. The network deployment unit allocates the licensed spectrum of the mobile communications operator to the emergency communications network deployment area, and uses default LTE protocol parameters, as shown in Table 1. It also obtains cell deployment information of eNodeBs in the emergency communications network, and numbers the cells such as a first cell, a second cell and a third cell, respectively. The cell deployment information contains the distribution of the central area and the edge area of the cells, and also includes the data set by the omnidirectional antenna angle, etc. In addition, the transmit power may be adjusted properly according to the overlapping area and an actual signal-to-noise ratio. At the same time, the overlapping information of the network is also fed back to the virtual dynamic positioning anchor control unit.

| Table 1: The protocol parameters of eNodeB |
|------------------------------------------|
| Frequency band | Frequency band A (2010 MHz to 2015 MHz) is used for an offshore TD-LTE macro eNodeB |
| Peak rate | DL: 100 Mbps UL: 50 Mbps |
| Control plane delay | A delay between camping and activation is shorter than 100 ms, and a delay between sleep and activation is shorter than 50 ms |
| User plane delay | Longer than or equal to 5 ms |
| Supported bandwidth | 1.4 MHz, 3 MHz, and 5 MHz |
3.2.4 The virtual dynamic positioning anchor control unit. The virtual dynamic positioning anchor control unit adjusts the position of the USV cluster based on the feedback information from the eNodeB and the feedback information of the network deployment unit. The control-flowchart of the virtual dynamic positioning anchor control unit on the parent-node USV is shown in figure 4 (a), and the control-flowchart of the virtual dynamic positioning anchor control unit on the sub-cluster USV is shown in figure 4 (b).

Figure 4(a): Control-flowchart of a virtual power positioning and anchor control unit on a parent-node USV

Figure 4 (b): Control-flowchart of a virtual power positioning and anchor control unit in a USV sub-clust

4. Deployment process of maritime emergency communication system

When the emergency search and rescue work begins at sea, the whole emergency communication system is self-checked. The results of self-checked include the state of each device (normal / fault), which displayed on the display controller of the emergency command center. Hypothetically, the result of self-checked is normal. Then, the eNodeB on the USV cluster and satellite communication relay are started. The emergency command center arranges the USV cluster to arrive at the specified position according to GPS information of an eNodeB on a USV, then start the solar panels on the USV. In addition, usage of the licensed spectrum of the mobile operator in the coverage area is detected. If it is detected that the licensed spectrum of the mobile communications operator is not used, the licensed spectrum of the mobile communications operator is allocated to the emergency communications network; if it is detected that the licensed spectrum of the mobile communications operator is used, an unused frequency of the TV white space is allocated to the eNodeB on the USV. Next, the network deployment unit sets the LTE protocol parameters to the eNodeB and deploys the network cell, and allocates corresponding power to the coverage area of the emergency communications network according to the overlapping areas and the central areas. Finally, after the deployment of the network is completed, the onboard eNodeB is connected with onshore eNodeB through satellite communication relay and synchronous orbit communication satellite. Deployment process of the system is shown in figure 5.
5. Conclusions
This paper studies the network coverage technology of the maritime leapfrog emergency communication based on satellite relay. This network coverage technology uses the Beidou satellite, the synchronous orbit communication satellite (Tiantong No.1, 2) and the emergency coverage LTE network system to integrate into the onshore of LTE public communication network. It implements the deployment and coverage of emergency LTE network based on the USV, and has the advantages of high flexibility and better QoS (Quality of Service). This network coverage technology of LTE provides a new choice for the application of maritime emergency communication.

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