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Emergency communication system based on broadband wireless theory: A review

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Abstract

With the development of the international political and military situation and the continuous deepening of national reform and opening up, the collision of social interests has become increasingly complex, the frequency of emergencies has increased, the impact and spread have become more and more widespread, and the possibility of large-scale conflicts has also increased. The bigger it is, it highlights the importance of rapid on-site handling and control of emergencies. In order to better maintain the development of China's social and economic construction and improve the efficiency of emergency response in the new era, it is urgent to accelerate the transformation of the emergency response team's combat effectiveness generation mode, and put forward new requirements for emergency communications at the emergency site. The main part of this paper has been implemented in actual equipment, and the key algorithms have been verified by the real environment, which has a positive reference for the formulation of the national emergency communication guarantee system. This paper studies and discusses the key technologies of broadband wireless emergency communication, and for the mobile organization and rapid deployment of emergency communication systems on the scene of emergencies, a set of broadband wireless emergency communication system structure oriented to the scene of emergencies is constructed. Then, we conducted in-depth research on the communication reliability and effectiveness of the new architecture in the complex electromagnetic environment of the emergency site.

Keywords: Emergency Communication, Ad Hoc Network, Noise Cancellation, Interference Suppression, Opportunistic Broadcasting

1. Introduction

Since the 25 years' plan, the country's industrialization, urbanization, and agricultural modernization have accelerated, and economic globalization has continued to deepen. Unbalanced supply and demand, regional imbalances, industrial imbalances, urban-rural imbalances, and income imbalances have been exposed, resulting in sudden changes. Incidents occur frequently. With the increasing impact of emergencies on the society and the public, the government has put forward higher requirements for emergency management work [1]. In March 2018, the new central government integrated and optimized emergency forces and resources. The Emergency Management Department (EMD) has been established to promote the formation of an emergency management system with Chinese characteristics featuring unified command, both specialization and regularity, responsiveness, upper and lower linkage, and combination of peacetime and wartime [2].

Emergency communication is mainly used in the communication guarantee for emergencies such as natural disasters, accidents, public health events, and social security incidents [3-5]. It is an important support method for emergency management and is one of the important infrastructures for emergency protection. Emergency communication is an information-centric transmission and processing process, involving monitoring, early warning and alarm before emergencies, emergency communication guarantees at the scene, and communication transition and recovery after the incident [6].

Driven by national policies and market demand, broadband digital communication systems capable of independent networking have become a research hotspot in all walks of life. During the "25-Year Plan" period, the Ministry of Science and Technology organized research and systems related to broadband wireless multimedia systems. Planning and design; since the "25-Year Plan", the Ministry of Science and Technology has set up a key special project "Public Security Risk Prevention and Control and Emergency Technology and Equipment"; the Ministry of Industry and Information Technology and the Ministry of Public Security have guided the establishment of a public protection and disaster relief broadband wireless communication technology forum to promote broadband cluster communication Related product research and industrialization development [7]; China Academy of Information and Communications Technology and related enterprises and institutions launched a broadband cluster industry alliance to promote cooperation and exchanges among all parties in the industry chain in terms of business planning, technology and standard research, product development, and market application promotion [8].

In November 2016, at the twelfth plenary meeting of the fifth research group SG5 of the ITU-R Wireless Bureau of the International Telecommunication Union, the B-TrunC standard was written into the M. In the 2014-3 standard revision, it became the cluster air interface standard recommended by ITU-R [9]. B-TrunC is a broadband trunking system based on LTE technology. Its system structure is shown in "Fig. 1,". Among them, Uu and Uu-T are wireless interfaces based on space transmission, and S1-T and D interfaces are data interfaces based on IP transmission [10].

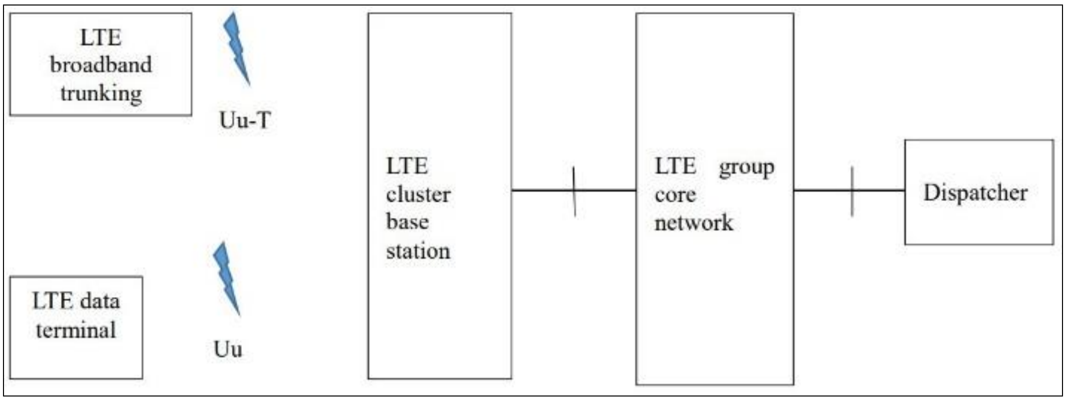

Fig 1: Schematic Diagram of Broadband Trunking System Structure

According to the broadband trunking system structure shown in Figure 1, the connection between the trunking base station and the trunking core network and the connection between the trunking core network and the dispatching station all need to rely on basic network facilities. However, at the scene of emergencies such as large-scale rescue and disaster relief and anti-terrorism and stability maintenance, the basic network facilities are unavailable or unreliable, and the communication guarantee capability of the pure cluster system in similar scenarios is obviously insufficient. It is necessary to combine multiple communication technologies to establish a complete emergency communication security system.

2. Emergency Communication Framework

At this stage, emergency communications on wired networks mainly focus on how to improve the disaster tolerance of wired networks in emergencies and ensure smooth communication in emergencies [11-12]. Wired communication mainly relies on optical fiber and cable for transmission, and its anti-destructive ability is not strong. After an emergency occurs, wireless communication means will play an important role when the wired communication link is damaged and interrupted [13]. According to different working principles, wireless communication can be divided into technical means such as satellite communication, shortwave communication, cellular mobile communication, and wireless ad hoc communication [14-15].

2.1 Satellite Communications

Satellite communication is a communication method that transmits wireless signals through artificial earth satellite transponders. It is less affected and restricted by ground conditions. It has the characteristics of flexible networking, mobile deployment, and convenient opening and suitable for complex ground environments and large-scale long-distance communications [16-17].

In the mid-1960s, the international communications satellite Morning-bird was put into use, opening up commercial satellite communications and international satellite communications services between the European and American continents, marking the entry of satellite communications into a practical stage [18]. In the 1980s, the Very Small Aperture Terminal (VSAT) satellite communication system came out. The VSAT system has the characteristics of strong flexibility, high reliability, low cost, and convenient use, marking the breakthrough development of satellite communication [19]. In August 2016, my country successfully launched the Tiantong One 01 satellite, starting the construction of a satellite mobile communication system with independent intellectual property rights in my country [20]. At present, satellite communication technology will continue to evolve and develop in the directions of miniaturization, broadbandization, and constellation networking.

At present, there are more than 700 communication satellites in orbit around the world, forming multiple satellite communication systems including the maritime satellite communication system, the Iridium satellite system, the Globalstar system, the IPSTAR broadband satellite communication system, and the Beidou navigation satellite communication system [21].

In the emergency communication scenario, satellite communication is suitable for long-distance communication services at the scene of emergencies, such as the wireless interconnection between the mobile platform of the emergency scene and the rear command center and the various dispersed mobile platforms at the emergency scene of major incidents, etc. Multimedia services such as voice, data, image, and video. The satellite communication network topology of the emergency scene is shown in "Fig. 2,".

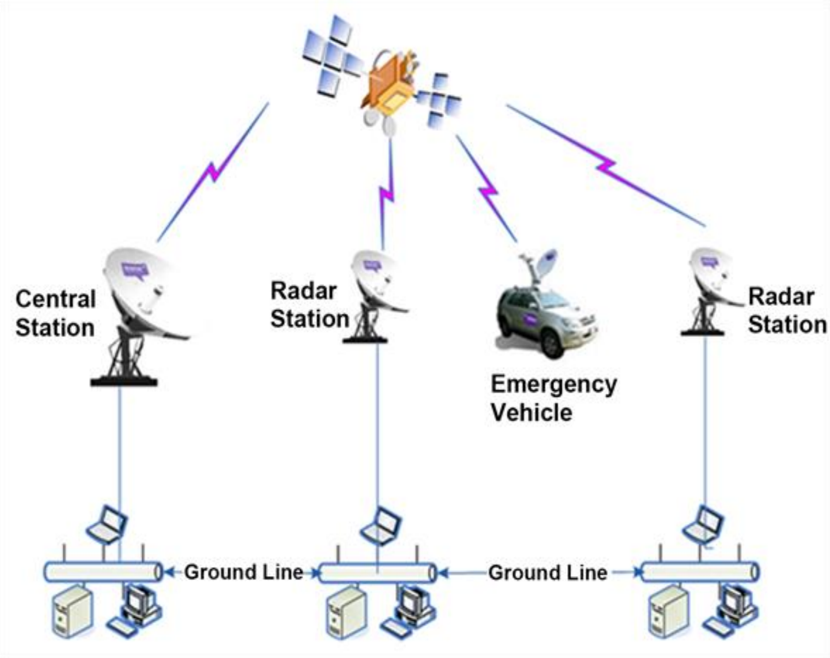

Fig 2: Schematic diagram of satellite communication topology [21]

Satellite communication services are divided into three types: fixed satellite services, mobile satellite services, and broadcast satellite services. The fixed satellite services mainly refer to the application mode of fixed deployment of satellite terminals, and the mobile satellite services mainly refer to the "moving" of satellite terminals on board vehicles. The application model of "Zhong tong" [22]. The broadcasting satellite business mainly relies on satellites to release disaster information to the public at the scene of emergencies.

At present, the spectrum resources of satellite communication on the C-band and Ku-band are becoming more and more congested, the image and video transmission quality is not high, and the voice delay caused by the space transmission delay is also very obvious. Multimedia command and dispatch at the scene of emergencies There are certain limitations in the system, coupled with the high cost of satellite communication, which restricts the application and expansion of satellite communication methods to a certain extent.

2.2 Shortwave Communication

Shortwave communication is a long-distance communication method that uses sky waves or ground waves to propagate wireless signals, and is completely independent of network hubs and active relay systems. It has the characteristics of long transmission distance, flexible networking, and strong anti-destructive ability, and its communication distance is up to for hundreds of kilometers or even thousands of kilometers, the transmission topology of shortwave communication is shown in "Fig. 2,".

The 20 years from the 1940s to the 1960s were the heyday of the development of shortwave wireless communication. Many countries in the world have established shortwave communication networks covering the region or the world.

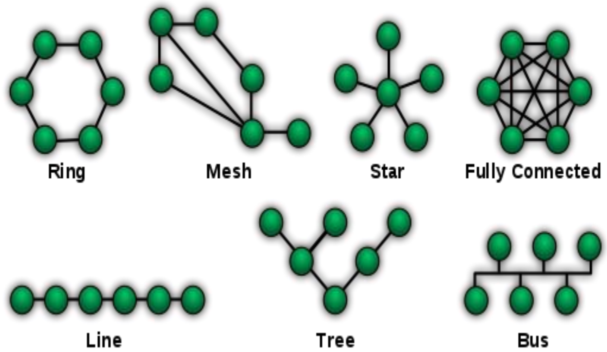

Fig 2: Shortwave Communication Topology

The United States has established the lowest level since the 1970s. The limited emergency communication network includes the ground wave communication network [23]. China has also built a short-wave communication network and established 9 national-level short-wave radio monitoring stations in the country to keep abreast of the short-wave frequency occupancy within the monitoring range in order to select the appropriate frequency to keep the national short-wave communication network in a good state of connectivity [24]. As for the technical research of shortwave communication, the current research mainly focuses on improving the transmission performance through multi-antenna diversity and the detection, prediction and selection of shortwave frequencies [25].

2.3 Cellular Mobile Communication

Cellular mobile communication builds a wireless coverage area centered on the base station. User terminals can access the base station wirelessly within the area covered by the base station, and then carry out end-to-end mobile communication services under the coordination of the base station and the background core network system. Since the first-generation cellular mobile communication system (1G) was put into commercial use in the early 1980s, cellular mobile communication has evolved to the fifth-generation mobile communication system (5G). The inter-generational evolution of the cellular mobile communication system [26] is shown in "Fig. 4,".

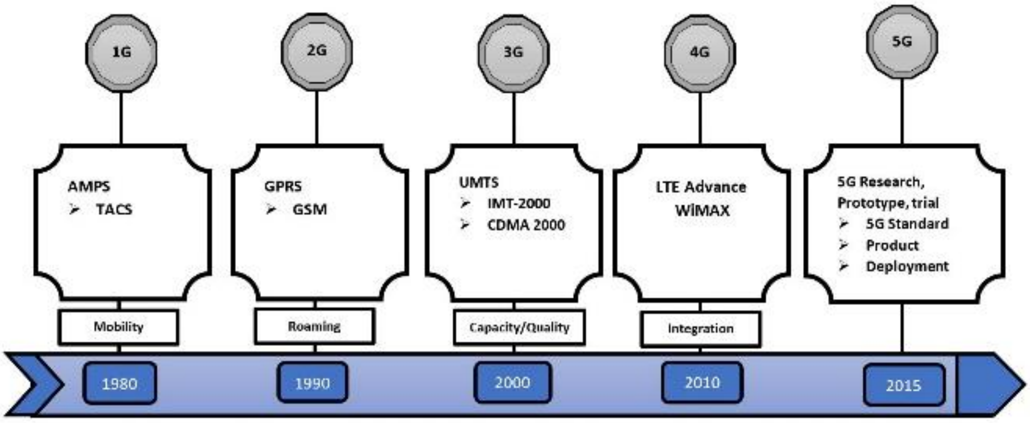

Fig 3: Intergenerational Evolution of Cellular Mobile Communication

The 1G network uses analog modulation technology to provide end-to-end voice communication services. The "Big Brother" phone is a typical representative of the 1G communication era. In the early 1990s, the second-generation mobile communication system (2G) was put into commercial use. The main feature of the 2G network was the use of digital communication technology to provide voice and low-speed data transmission services. Mobile phones and wireless short messages were typical services in the 2G communication era [27]. After entering the 21st century, with the mature application of CDMA (Code Division Multiple Access) technology, high-speed data transmission in mobile communication networks became possible, triggering the evolution to the third-generation mobile communication system (3G).

The 3G network can support the interaction of multimedia information such as voice, pictures, and video, and smart phones have emerged in the era of 3G communications [28]. In order to achieve high-speed mobile data interaction, the fourth-generation mobile communication system (4G) introduced multi-carrier and multi-antenna transmission technology, supporting a network rate of up to 100Mbps, which is almost 10 times that of 3G networks.

High-definition voice communication is only one of the basic functions of the 4G network, and real-time multimedia data services have become the main business bearer of the 4G communication system [29]. As of July 2017, statistics from the Ministry of Industry and Information Technology show that 4G users in my country have exceeded 900 million, and mobile applications such as streaming media on-demand, real-time video interaction, and online games have become popular among the people [30].

2.4 Wireless Ad Hoc Communication

Wireless ad hoc communication means that the nodes participating in the communication complete network establishment and communication transmission through mutual self-negotiation. Wireless self-organizing communication originated from the US National Defence Group Wireless Network (Packet Radio Network, PRN) project. PRN realized the first multi-node networking communication without infrastructure network facilities [31]. With the tremendous improvement in the cost-effectiveness of processors and memory, and the rapid development of technologies such as distributed computing, integrated circuits and signal processing, wireless self-organizing communications have gradually expanded to the civilian field. IEEE802.11 proposed the term "Ad Hoc" in 1991 to identify this networking mode corresponding to a network with communication infrastructure [32]. At the same time, wireless ad hoc communication is widely used in cognitive wireless ad hoc networks that perceive and utilize the space available spectrum and in-vehicle ad hoc networks for the connection of road traffic objects [33]. The physical structure and logical structure of wireless ad hoc communication are shown in "Fig. 5,".

Fig 4: Schematic diagram of the topology of wireless self-organizing communication [34]

When wireless ad hoc communication is applied to emergency communication, each node device can quickly and automatically network without relying on the pre-built network infrastructure. It has strong survivability and flexibility, and is very suitable for rapid establishment of communication guarantees on the scene of emergencies. However, in the wireless ad hoc communication network, the nodes participating in the communication are in an equal position logically and physically, and the communication between nodes is greatly affected by the fading of the transmission environment, leading to the stability of the ad hoc network Insufficient sex, to a certain extent, hinders the large-scale application of wireless ad hoc communication. In addition, in emergency communication, the wireless ad hoc network does not provide enough support for broadcast transmission, and the communication efficiency of trunking services is not high. Related technical problems need to be further studied and resolved [35].

3. The Development Trend of Broadband Wireless Transmission Theory

With the transformation and development of wireless transmission technology, wireless communication is evolving in the direction of high bandwidth and high speed. In order to meet the needs of ultra-high-speed transmission, researchers have continued to study and explore the theory of multi-carrier and multi-antenna [26].

3.1 Multi-carrier Transmission Theory

Due to the influence of transmission distance, terrain, buildings, etc. during space transmission, the wireless signal receiving end actually receives a composite signal that has been reflected, diffracted, and scattered through different transmission paths. Because different transmission paths reach the receiving antenna with different distances and signal phases, the amplitude of the synthesized signal will change sharply, causing frequency selective fading, leading to severe distortion of the received signal. According to literature [36], when the signal bandwidth is greater than the coherent bandwidth of the channel, the transmission signal is prone to frequency selective fading. For broadband transmission systems, directly increasing the transmission rate and expanding the transmission bandwidth in the narrowband transmission system will bring higher complexity to the receiver's recovery of the original signal. Therefore, the use of multi-carrier modulation technology to convert the wideband signal into multiple narrowband signals concurrently transmission, because the bandwidth of each narrowband signal is smaller than the channel-related bandwidth, the transmission of each narrowband signal can be regarded as flat fading, and the receiver can restore the original transmission signal by identifying the channel characteristics [37].

Specifically, multi-carrier modulation divides the data into several data streams and modulates them to different sub-carriers for parallel transmission to increase the transmission rate. It is usually referred to as Multi-Carrier Modulation (MCM) [38]. The principal block diagram of the MCM transmission system is shown in "Fig. 6,". where $g(n)$ and $r(n)$ are the transmit and receive shaping filters f_k, respectively; they are sub-carriers.

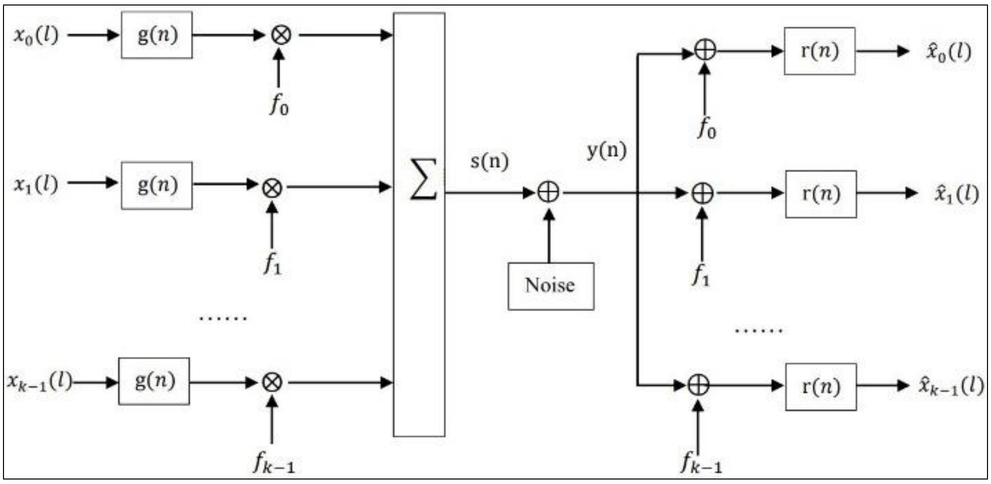

Fig 5: The Principal Block Diagram of MCM Transmission System [39]

If g_n is a rectangular filter and the subcarriers are implemented in an orthogonal manner, such a MCM transmission mode is called OFDM (Orthogonal Frequency Division Multiplexing), so the time-domain transmission signal can be expressed as [14]

$$s(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j\frac{2\pi kn}{N}}, 0 \leq n \leq N-1 \qquad (1)$$

Equation (1) can be regarded as IDFT (Inverse Discrete Fourier Transform), so that the transmission and reception of multi-carrier signals can be based on FT (Fast Fourier Transform), which implements [40]. OFDM reduces the complexity of MCM transmission system engineering implementation, and improves spectrum utilization through orthogonal sub-carrier aliasing. It is widely used in broadband wireless transmission. The fourth-generation mobile communication systems including LTE and WiMAX all use OFDM mode.

In order to maintain the orthogonality of the sub-carriers in the received signal, OFDM needs to insert a cyclic prefix (CP) in the transmitted signal to combat multipath fading in the transmission process. The structure diagram of the cyclic prefix is shown in "Fig. 7, " [41].

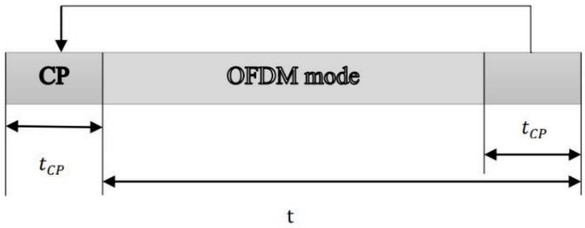

Fig 6: Schematic diagram of the structure of OFDM cyclic prefix

The mathematical expression of the cyclic prefix is shown in equation (2) [42]

$$s(n,l-l') = \begin{cases} s(n,l-l'+N), & l-l'<0 \\ s(n,l-l'), & 0 \le l-l' < N \end{cases} \quad (2)$$

In the formula, r represents the length of the cyclic prefix. In engineering practice, the length of the cyclic prefix needs to be greater than the length of the wireless channel multipath delay to prevent the multipath component of the previous symbol from being superimposed on the next symbol to affect the reception performance. MCM is an important transmission technology for the next generation of mobile communication systems (5G). At present, the academic community is focusing on the design and engineering of multi-carrier filter banks, as well as the anti-interference problem of broadband signals and other key technologies [43].

4. Multi-antenna Transmission Theory

In the process of wireless signal transmission, if there is sufficient spacing between antennas, the correlation of spatial signals can be eliminated, so that multiple transmission channels can be constructed through multiple antenna transmission to increase channel capacity and increase transmission rate [44]. Multiple antennas are equipped at both ends of the communication, and the signals are transmitted by different antennas and through different spatial paths, which are called Multiple Input Multiple Output (MIMO). The traditional MIMO system is shown in *"Fig. 8, "* [45].

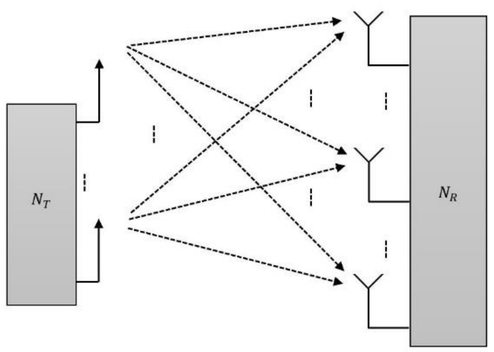

Fig 7: Schematic diagram of traditional MIMO system [46]

Among them, N_T and N_R respectively represent the number of transmitting and receiving antennas, and $H = (h_{j,i})_{N_R \times N_T}$ represents the channel matrix. When $N_T = N_R = 1$, the system degenerates to an ordinary single-antenna transceiver system, usually called SISO (Single Input Single Output).

The literature [44] deduced that the channel capacity of the traditional MIMO system can be expressed as

$$C = E\left\{\log_2\left[\det\left(I_r + \frac{\zeta}{N_T} \cdot Q\right)\right]\right\} \quad (3)$$

Here $r = \min(N_T, N_R)$ and ζ represents the signal-to-noise ratio on each receiving antenna. Q is the autocorrelation matrix of the channel. If it is assumed that the signals from the N_T transmitting antennas received by the receiving end are all in the same frequency and in the same direction, and the channel amplitude is constant, the theoretical maximum channel capacity of the traditional MIMO system can be expressed as [47]

$$C = \log_2(1 + N_T \cdot N_R \cdot \zeta) \quad (4)$$

Equation (4) shows that the number of transmitting and receiving antennas is linearly increasing with the channel capacity. Increasing the number of transmitting and receiving antennas is an effective way to increase the channel capacity. In the face of large-scale MIMO antennas with dozens or hundreds of antennas, considering the size of the antenna array, it is more achievable in the high-frequency and small-wavelength bands. The next-generation mobile communication system (5G) will include millimetre-wave large-scale MIMO arrays. As a candidate technology, the academic community is currently conducting research on key technologies such as pilot pollution, channel estimation, and engineering implementation.

5. Broad Transmission in Wireless ULTI-HOP Network

The wireless signal has the characteristics of spatial broadcasting. In a wireless ad hoc network, the source node directly sends data from the air interface, and the one-hop neighbor node broadcasts it to the two-hop neighbor node after receiving it, and transmits it hop-by-hop in a flood-like manner to complete the broadcast of the entire network node. However, if the flooding of wireless signals is not controlled, it may cause a broadcast storm and waste wireless resources. Authors in [48] proposed that the forwarding node forwards the broadcast data with probability P, and uses the number of times the node receives the same broadcast data C as the control variable to forward the broadcast data to reduce data redundancy and air interface caused by broadcast flooding channel conflict. However, ignoring the actual situation of network connectivity and making a decision on whether to forward or not completely based on probability or the number of receptions may cause normal broadcast forwarding to be cancelled by mistake, making some nodes unable to receive broadcast service data. Therefore, the traditional wireless ad hoc network will select the transmission mechanism of the broadcast service in combination with the node topology distribution [49].

5.1 Broadcast Service Transmission with Planar Distribution of Nodes

In a self-organizing network with planar distributed nodes, broadcast service transmission based on routing topology is an effective way to control broadcast storms and ensure broadcast service coverage. According to the different wireless multi-hop routing technology, the broadcast service transmission technology on the wireless ad hoc network can be divided into tree structure transmission, grid structure transmission and the mixed transmission of the two [50].

The hybrid broadcast service transmission technology is similar to the hybrid routing of traditional routing protocols. The nodes in the system are clustered. The tree structure is used for broadcast service transmission in the cluster, and the broadcast service transmission between clusters is based on the grid structure to improve Network throughput within the Shang clan and enhanced data delivery rate between the clan. EHMRP (Efficient Hybrid Multicast Routing Protocol) proposed in is a typical hybrid broadcast service transmission technology.

5.2 Broadcast Service Transmission in V2V Scenario

In recent years, with the gradual maturity of vehicular ad hoc networks, the broadcast service transmission technology for vehicular ad hoc networks has received a lot of attention from researchers. The application scenario is shown in "Fig. 9,".

It can be seen that in the V2V scenario, the wireless coverage capacity of a single node often exceeds the width of the street, so the V2V application of the vehicle-mounted ad hoc network is actually based on the business interaction of the chain network topology, and only one is required in the broadcast transmission direction. The node can perform broadcast service data packet forwarding.

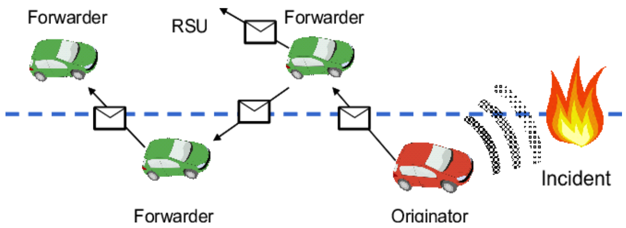

Fig 8: Broadcasting service transmission example in V2V scenario [45]

In "Fig. 9:", originator is the broadcast service source node. The forwarding node of broadcast service data packets only needs to select one node at the edge of the coverage radius from the transmission direction step by step, so only node 2, node 3, and node 4 are needed. Separate forwarding can achieve full coverage of broadcast service data packets to nodes in the network. In view of such topological characteristics, some scholars use opportunistic transmission characteristics to design broadcast service transmission mechanisms in the V2V scenario of vehicle-mounted ad hoc networks. Leterature [51] use opportunistic transmission characteristics to select the "best" forwarding node for broadcast services, forming OB-VAN (Opportunistic Broadcast in VANets). Authors in [52] proposed SOBP (Sender-designated Opportunistic Broadcast Protocol), in which constructs a candidate forwarding set of broadcast services at the sender and improves the priority set of candidates forwarding nodes. The problem of "slow response" and local broadcast storm in the vehicle-mounted self-organizing network is solved. Author in [53] proposed BP-MDF (Broadcast Protocol with the Minimum Delay Forwarding), combined with the candidate forwarding set designated by the sender and the receiver priority auto-negotiation forwarding, a broadcast routing protocol with dynamic prediction was designed. Realize the compromise between real-time and reliability of broadcast service transmission.

Although the special application of one-way transmission and single-hop single-point forwarding in the V2V scenario is quite different from the broadband wireless emergency communication system with flat networking characteristics, inspired by related ideas, this article will discuss the planar distribution of nodes. Opportunistic transmission characteristics of self-organizing communication networks, and explore the design of broadcast service transmission mechanism under opportunistic routing in broadband wireless emergency communication systems.

6. Conclusion

Disasters, accidents, public health incidents, social security incidents and other emergencies occur frequently, in the handling of these emergencies, as the central nervous system for emergency rescue and stability maintenance, emergency communications have undertaken an important mission. In the face of the country's major reform initiative of integrating the emergency response functions and resources of 13 ministries and commissions to form an emergency management department, this article starts with the development of the demand for emergency communications and the evolution trend of wireless mobile communication technology, and provides emergency communications protection at the scene of emergencies. Conduct in-depth research and build a broadband wireless emergency communication system architecture. And on this basis, special researches were carried out on the important and difficult technical issues of the physical layer and the network layer in the new architecture were verified in the field environment. The verification of the research analysis of this paper is mainly based on the self-organizing communication chain of the broadband trunking system in the regional environment. Therefore, the experimental verification of the new architecture proposed in this paper still needs further investment of time and resources for corresponding technical research and product development.

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