Research on Land Battlefield Situation Distribution Network Based on BRN

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Abstract. In order to meet the requirements of battlefield complex electromagnetic environment and situation distribution instantaneity, the Communication network protocol in land battlefield needs to achieve low delay, high scalability and link robustness. This paper analyzes the development and problems of the situation distribution network in the land battlefield. Based on the analysis of the autonomous cooperative communication mechanism, the basic principle of the BRN protocol based on the communication mechanism is introduced, and the research fields based on this technology in the situation distribution network are proposed, so as to further improve the performance of the situation distribution network in the land battlefield.

1. Introduction
Situation awareness information is a kind of important business data on the battlefield, which is the basis of command and control, cooperative/joint operations, and has typical broadcast distribution characteristics. At present, Tactical Internet (TI) is the main system to carry the situation information distribution of land battlefield, and is the infrastructure of digital force construction, which can realize seamless connection and information fusion between combat units. The battlefield electromagnetic environment is very complex, and the nodes participating in the battle are dispersed and highly mobile, which leads to the rapid change of network topology and situation information in the battlefield. Efficient and reliable situation distribution becomes a great challenge for the future land battlefield information network.

This paper analyzes the development and problems of the situation distribution network in the land battlefield. Based on the analysis of the autonomous cooperative communication mechanism, it introduces the principles of Barrage Relay Network (BRN) protocol, and the research fields based on this technology in situation distribution network are proposed, so as to further improve the performance of situation distribution network in land battlefield.

2. Development and Problems of Situation Distribution Network in Land Battlefield
The first generation TI of the U.S. Army has basically deployed in the 1990s. It has improved the ability of each combat unit to perceive the battlefield situation. However, there are still a series of problems, such as the lack of communication in motion, poor anti-jamming ability and limited bandwidth. To deal with these problems, the U.S. Army has proposed Warrior Information Network Tactical (WIN-T) and Integrated Tactical Network (ITN). Broadcast and multicast are usually used to distribute situation information for land battlefield situation distribution. Based on the requirements of tactical communication, ITN cooperated with TrellisWare technology company of the U.S. to develop a multicast TI, BRN. The network does not depend on the change of network topology, and can quickly distribute information, is robust and scalable.[1][2][3]
In the process of combat, the real-time and quality of battlefield situation information directly affect the accuracy of mission decision-making, which is also the key to obtain the initiative of war. In the land battlefield, the formation and distribution mechanism of battlefield situation is usually based on level by level aggregation and information broadcast distribution. In the process of data transmission and forwarding, if the relay node forwards data with a low probability, the coverage of information distribution will be low; if the probability of relay node forwarding is high, a node may receive packets from multiple relay nodes, resulting in a higher collision rate.

Using autonomous cooperative communication technology, we can realize the perfect combination of reliable signal transmission and data relay, transform the transmission conflict caused by traditional broadcast protocol into enhanced cooperative signal, and solve the problems of low broadcast coverage and high collision rate of data packets to a certain extent, so as to meet the low delay, high throughput and high broadcast coverage proposed by the situation distribution network of land battlefield requirement.

3. Autonomous Cooperative Communication

In wireless communication networks, the influence of wireless channel fading will lead to serious signal attenuation. An effective way to reduce the negative impact of fading is to adopt diversity, such as spatial diversity, frequency diversity and time diversity. In the traditional cooperative communication network, a large amount of interactive information is needed to complete the cooperation, and the instability of wireless channel will lead to the dynamic changes of network topology, which will bring more frequent information updates, which will increase the overhead and delay.[3] Cooperative communication usually uses distributed Space-Time Coding (STC) or distributed beamforming technology to obtain diversity gain, but both require a lot of Channel State Information (CSI) prior information to achieve. However, the autonomous cooperative communication in BRN uses modern error correction coding and phase (or phase and amplitude) disturbance to obtain cooperative diversity gain. Unlike distributed beamforming and space-time coding, autonomous cooperative communication does not need to share CSI among cooperative users, nor does it need any user coordination.[5][6][7][8] In autonomous cooperative communication, there are two kinds of pseudo-random jitter. One is symbol level pseudo-random jitter. By adding orthogonal training sequences before each user sends data, the receiver can distinguish which users are involved in the cooperation. The second is packet level pseudo-random jitter. When all relay users use the same training sequence, only one composite channel (amplitude and phase) needs to be estimated.

The cooperative transmission mechanism can achieve the simultaneous interpreting and forwarding of data reliably, avoiding the data forwarding and transmission conflicts of multiple forwarding nodes, providing the best solution for data broadcast and distribution below the data link layer.

4. BRN Protocol

4.1. Principles of BRN

BRN is basically designed for military tactical network broadcast communication requirements. It regards some “guard” nodes in the network, which blocks the data transmission between the interception area and the external area nodes, thus dividing the network into multiple isolated communication areas, and then realizing the effective data transmission from the source node to the destination node. By broadcasting control messages, the source node determines its identity by calculating the hop number between itself and the source node as well as the destination node.

In BRN, multiple independent data transmission areas can be constructed. In different regions, multiple unicast data transmission can be carried out at the same time without interference between each other, so as to maximize the use of network resources. The key technologies used in BRN are time division multiple access (TDMA) and autonomous cooperative communication. [9][10]

4.2. TDMA Technology

The time slot number of TDMA frame format is expressed as M, and coarse synchronization can be realized by low overhead pilot signalling, generally speaking M = 3, assuming that all nodes in the
network use frame format $M = 3$. The time slots are represented as A, B and C, respectively. The broadcast mechanism of BRN can be described as follows:

- If the source node sends data packets in slot A, then the nodes that are 1 hop away from the source node will receive packets in the slot;
- Then, these nodes send the same packets in slot B to relay to the nodes that are 2 hop away from the source node;
- The nodes that are 2 hop away from the source node will continue to relay packets in slot C.
- In slot A of the second TDMA frame sent by the source node, the relay node that are 3 hop away from the source node continues to send out the first packet.

In order to prevent transmission from forming a loop or network flooding, each node relays a given packet only once. This can be achieved by keeping a history of received packets or designing protocol headers. A 2-hop node may receive the same packet from different 1-hop nodes in the same time slot. When autonomous cooperative communication is adopted, these packets will not interfere with each other. [11]

Based on time slot space division multiplexing, data packets can be sent once per $M$ time slots in order. In the case of single point broadcasting, the source node in BRN can broadcast a new packet every three time slots, which can not only effectively avoid data interference, but also ensure the network throughput and reduce data delay.

4.3. Constraints of Autonomous Cooperative Communication in BRN

The autonomous cooperative communication in BRN adopts the following constraints:

- The protocol header contains hop count information. The condition is to ensure that the data packets transmitted by each node are the same, and only the hop number is modified, not the entire protocol header.
- Cooperative communication nodes must relay in the same time slot. Traditionally, the relay is processed at the network layer, and the processing delay is unpredictable. The relay decision in BRN is in the physical layer, so that the cooperative nodes can relay in the same time slot and further reduce the delay.
- Time delay processing capability of receiver. Due to the transmission characteristics of wireless channel, nodes propagating in the same time slot will have different propagation delays, which will lead to cooperative delay extension. Therefore, the receiver has sufficient delay processing ability.

In autonomous cooperative communication, nodes only need to ensure time synchronization of coarse order TDMA and send identical information in the same time slot to avoid conflict. At the same time, this transmission mode can increase the redundancy of information and improve the reliability.

4.4. Controlled Interception Area

The core technology of BRN network communication mechanism is to establish Controlled Barrage Regions (CBR). In BRN, a group of buffer (sentry) nodes are designated around the cooperative nodes to set CBR, and the network space is divided into several unicast streams with data transmission at the same time, so as to improve the efficiency of data transmission.[3] The sentinel node isolates the transmission and does not relay the signal, so the external message will not propagate to the CBR, and the message sent within the CBR will not propagate to the area outside the sentinel node. In this way, multiple unicast transmissions can be established in different parts of the network.

The advantage of using CBR for routing is that since the processing mode of the received message has been determined for all nodes in the established CBR and its boundary, the received message can be directly processed (forwarded or discarded) in the physical layer without judgment, which will effectively improve the communication speed within the CBR. [11]

4.5. Blocking Access Control Protocol

For a single source node, blocking broadcast mechanism can provide low delay and robust mechanism, but for multi-source network, it is necessary to establish appropriate network access control protocol.
For voice access, it can be completed by manual operation, but for data access, manual cannot meet the demand. In Ref. [11], the paper introduces the Barrage Access Control (BAC) protocol and divides TDMA time slots into independent logical channels, those are Request Logic Channel (RLC), Acknowledgement Logic Channel (CLC) and Data Logic Channel (DLC).[11]

RLC and CLC are used to transmit control information to coordinate the use of DLC, so the two channels are considered as the overhead of the protocol.

In CLC, the sentinel node is determined by broadcasting RTS (request to send) and CTS (clear to send) messages. The node does not send or relay messages. If the source node broadcast RTS message, each relay node will update the hop number information in the message. The destination node can determine the shortest hop number path, and then the destination node broadcast CTS message, which contains the shortest transmission path (which is expressed as S). Each relay node will know S in CTS message and update hop number information between itself and destination node. The distance between the source node and the destination node is thus known.

5. BRN Based Battlefield Situation Distribution

Although BRN can solve the problem of data transmission and broadcast distribution in MANET network to a certain extent, in order to meet the needs of land battlefield situation distribution network, we can find that there are still some contents that need to be further explored and studied.

5.1. Slot Scheduling

BRN can propagate data packets effectively in a single point broadcast scenario, but it is not suitable for multi-point simultaneous broadcast scenarios. In order to avoid interference, reduce the delay and improve the throughput, we can choose some source nodes to send packets at the same time, and the relay node can forward the packets in the next slot under the condition of no conflict, so as to improve the possibility of parallel transmission of different packets in the same time slot, so as to reduce the total time to a certain extent the number of slots reduces the delay and improves the network throughput. The related research can refer to the literature.[12]

5.2. Classification Mechanism

In the land battlefield situation distribution network, the simultaneous interpreting of BRN in the edge network can improve the performance. However, the classification mechanism is formed in the whole network. Whether the key nodes can access the network can cooperate with BRN simultaneously, which is worth discussing.

5.3. Network Optimization Considering Interference

There are two main types of interference in BRN network: adjacent CBR interference and CBR internal interference. These two kinds of interference have a certain impact on the optimization of BRN network. Both references and literatures have optimized the size, frame length, number of relay nodes, optimal location of relay nodes and optimal data rate of BRN network with the goal of maximizing the capacity of BRN network.[13][14]

In the land battlefield, with the change of the movement state, the battlefield environment will change. For example, when the obstacles increase and the wireless link connection between nodes is interrupted, how to ensure the reliability and effectiveness of broadcast information transmission needs to be further studied in combination with the above literature.

5.4. Simulation Analysis of Situation Distribution Network in Land Battlefield

There are more theoretical analysis on BRN and CRN, but less research on simulation verification of both. Accurate tactical MANET network simulation needs complex physical layer model support. Only in view of the application scenarios of situation distribution in land battlefield, including network scale, network topology, mobile model, traffic flow and tactical radio, the network model, node model and process model of BRN network are established, and the correctness of the models is verified, which can provide reference for practical application and better understand the working principle of BRN and CBR.[12] [15]
5.5. Network Security

There is no traditional routing concept in BRN, and the traditional black hole attack has no effect, so the establishment process of CBR is the target of black hole attack. It modifies the address and control information of the node, so that normal communication cannot be established (this is a new form of attack), and the data packets will always flow to the black hole and cannot reach the destination node. Therefore, network security is also a necessary research direction. [16]

6. Summary

The broadcast and distribution of battlefield situation awareness information is an important function of tactical information system, and it is also the weak link of current land battlefield tactical information system. The emergence of barrage relay technology opens up a new technical way to improve the reliability and effectiveness of wireless network data broadcast distribution. In the future development of land battlefield situation distribution network, based on more advanced technologies, combined with network planning, it will meet the requirements of high coverage, low delay, high throughput, strong reliability and security, and improve the adaptability of network protocols, so as to seize and maintain the battlefield information superiority.

7. References

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