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An Emergency Communication System based on UAV-assisted Self-organizing Network

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***Abstract*—Emergency Communication System (ECS) becomes more and more important for certain emergency situations such as the affected mountainous areas, temporary battlefield, or filed of fire. Self-organizing network is proverbially adopted by ECS due to its flexible and robust architecture. However, the moving range and mode of mobile node in self-organizing network, especially mobile gateway, constrain the coverage and adaptability of self-organizing network in ECS. In this paper, we design an ECS based on UAV-assisted self-organizing network, which helps nodes on the ground form a self-organizing network automatically. In addition, the system adopts UAV as strong relay nodes to form relay network in the air. We also add some humanized functions in the system to adapt to the needs of different environment, which includes positioning and messages pushing service. The proposed ECS can be easily deployed in the emergency environment and owes high communication efficiency.**

***keywords*—self-organizing network, emergency communication system, UAV, smart phone**

I. INTRODUCTION

A. Research Background

With the rapid development of telecommunication and mobile network, the communication through mobile terminal is particularly important. At present, 4G, WiFi, Bluetooth, etc. may be used for mobile communication with the aid of base stations. But in some emergency or fast moving situations, such as the affected mountain and the temporary battlefield, the traditional mobile communication can't work properly. Consequently, a flexible and quick mobile communication method should be involved to solve this problem. Fortunately, the emergence of the self-organizing network may play such kind of role.

Different from the traditional cellular systems, the self-organizing network is a kind of temporary, autonomous and many jump network system, which is a kind of completely peer-to-peer network and composed of a set of mobile terminals with wireless transceiver and don't need fixed communication facilities [1]. In addition, each terminal node in the network has both the functions of sending and receiving data, which also can forward group information to adjacent nodes. The nodes can join and quit the network freely and move arbitrarily [2]. The self-organizing network compared with the ordinary mobile network and traditional network, has the advantages of no center, self-organizing and dynamic topology. Therefore, this is a good choice to apply self-organizing network into emergency communication system (ECS) in the scenarios of military communication, mobile meeting occasions, emergency service, and disaster recovery.

The self-organizing network also has many problems, whose scope is relatively limited, so it is hard for telecommunication in the absence of base station, which greatly limits the application and development of self-organizing network. As the development of the technology of UAV and the wireless network communication, we utilize UAV with the function of wireless networking capabilities to form the mobile relay network, which can support the self-organizing network on the ground and expand the scope of communication.

At present, the researches of combing self-organizing network and UAV for ECS is still in its infancy. Existing research is on the analysis of its feasibility, which more focus on relatively static network scenarios of UAV layout problem. On the other side, related applications is also imperfect.

In this paper, we design an ECS based on UAV-assisted self-organizing network, which helps nodes on the ground form a self-organizing network automatically. In addition, the system adopts UAV as strong relay nodes to form relay network in the air. We also add some humanized functions in the system to adapt to the needs of different environment, which includes positioning and messages pushing service.

B. Innovation Point and Related Work

With the advantages of communicating without base stations and building network quickly, Self-organizing

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network can be widely used in military field, mobile meeting, disaster scene, and other emergency situations. Self-organized net has the problems of limited communication distance and poor network connectivity because of the movement of nodes in the network, which are greatly limit the application and development of Self-organizing network. To solve the current problems, we use UAV and wireless network communication technology to form two kind of Self-organizing network, which one is relay network in the sky and the other one is mobile Ad hoc network on the ground. This method can improve the connectivity of the network and overcome the problem of scope, and the most important is that this way can achieve widespread communication without base stations.

In present research, there are no relevant authentication techniques to ensure the safety during the communication between nodes in the self-organizing network, so there will be some hidden dangers in self-organizing network communication. Considering this facts, we add the authentication process to ensure the security of the users who use this system during communication.

On the other sides, to ensure the UAV in relax network can provide more well network connectivity, the UAV gather location information of nodes on the ground and then calculate the best location for nodes and adjust the flight path.

II. RELEVANT TECHNOLOGY

A. Self-organizing network

Normal communication of traditional cellular networks must be based on base stations and other external communication facilities, and this kind of limitation causes it can't be used on the spot of disaster relief, military war and other emergency situations. Self-organizing network is a kind of good method to solve this problem. Today, in the network infrastructure is damaged situations such as earthquake and flood, mostly by satellite phone to communicate with the outside world to send related information. Compared with the satellite telephone communication, communicating through Self-organizing network can reduce the difficulty and fee, which can also be used in real-time emergency situations to reducing the rescue time and the harm done by the disaster.

1) The Characteristics of Self-organizing network

Self-organizing network is a kind of temporary, autonomous and many jump network system, which is a kind of completely peer-to-peer network and composed of a set of mobile terminals with wireless transceiver and don't need fixed communication facilities. In addition, each terminal node in the network has both the functions of sending and receiving data, which also can forward group information to adjacent nodes. This kind of structure can make the part of subnets recover quickly when they are damaged, which also has strong robustness [3]. Self-organizing network has the following features:

a) The Dynamic Topology

In Self-organizing network, the nodes can join and quit the network freely and move arbitrarily, which can cause the change of network topology. On the other hand, wireless communication is often affected by noise interference and other factors, which will result in the increase and disappearance of links between nodes in network. These factors all contribute to the dynamic change of network topology, and these changes are unpredictable.

b) Multiple Hops in Self-organizing network

The coverage of each node in Self-organizing network is limited, which means communication must use intermediate nodes to forward information when a nodes want to communicate with another node not in the coverage. The nodes with forwarding information function are not special equipment such as routers, repeaters or switches, but the ordinary mobile terminals. Each mobile terminal in the network acts as the role of the host and the router, and ordinary nodes in Self-organizing network to realize network communication through multiple hops between nodes.

2) Architecture of Self-organizing network

Different from the OSI protocol stack model, Self-organizing network protocol stack has five layers. Combining with the characteristics of Self-organizing network, the five layers are the physical layer, data link layer, network layer, transport layer and application layer as shown in Figure 1. These layers work together to realize network communication.

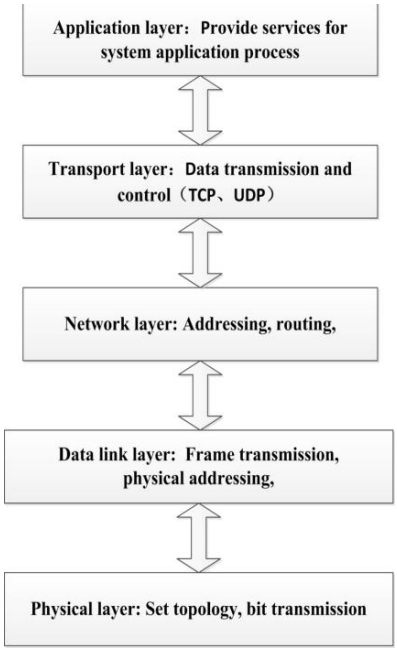

Figure 1 The structure of self-organizing network

The mainly function of the physical layer is to set the network topology, bit transmission, the choice of communication signals, detecting and so on. These functions are the basis of the network communication.

The data link layer is mainly to complete the data frame transmission, physical addressing, error control and flow control, and so on. The data link layer of Self-organizing network can be divided into MAC (Media Access Control) layer and LLC (Logic Link Control) layer. MAC layer mainly

to control and connect the physical media and LLC layer is to provide the logical view to the network layer.

Network layer function is to complete the addressing, routing, and some other functions to achieve the transfer of data between two end systems, which is the most import part of network communication.

The transport layer is responsible for data transmission and control, whose main functions include data segmentation and restructuring, according to port address, connection management, and error and flow control.

Application layer is in the highest of the architecture, which provide services for system application process directly mainly to complete a series of business processes to provide services.

B. UAV

UAV is a kind of aircraft which is controlled by the radio remote control equipment or its program and has the advantages of small volume and low cost. Historically, UAV originally applied in military field and have the functions of surveillance, reconnaissance and supply. With the continuous research and development of UAV technology, it has gradually shifted from military field and extended to widely civilian fields such as electric power, communication and ocean and all facts have proved UAV have incomparable superiority than ordinary planes when performing some dangerous or urgent tasks. Besides, with the popularity of UAV, constantly improvement of communication technology and lower costs, UAV can expand patrol scope and the application scope will be more widely [4].

To solve the problem of the self-organizing network is limited by scope of coverage and network connectivity, we add UAV to self-organizing network to form a relay network in the sky while there would be self-organizing networks on the ground which are composed by many mobile terminals. The mobile terminals can communicate with outside through UAV to exchange of information in some emergency situations, like earthquake and fire, which can improve the connectivity of self-organized and extend scope of coverage. This method will haven wider range of applications.

III. THE REQUIREMENTS ANALYSIS OF THE SYSTEM

A. Summary of Demand

1) Functions Overview

Self-organizing network emergency communication system based on UAV is designed on Android platform. In this system, mobile terminals on the ground can form self-organizing network quickly and don't rely on base stations or other communication facilities to communicate. Meanwhile, UAV can form a relay network in the sky, which can extend communication range and exchange information with other people when the base stations or communication facilities are damaged.

In view of the above requirements outline, the main functions of the system can be obtained as follows：

a) Authentication

In order to ensure the organization the security of network communication, the function of authentication is necessary for the system, which can protect the security of communications and safeguard the privacy of users in the self-organizing network.

b) Function of Forming network

Mobile terminals and UAV form self-organized in the sky and ground, which is the basis of the Self-organizing network emergency communication system. Only form self-organized successfully, can nodes in the network communicate with outside.

c) Communication

Mobile terminals on the ground and UAV in the sky can form a temporary communication network to realize local communication when the surrounding base stations and other communication facilities are damaged. There are many functions, including communicating real-time position and sending messages.

d) Communicating Across the Network

Mobile terminals can communicate across network by UAV when there are many self-organizing networks under the coverage of relay network composed by UAV. Nodes can exchange messages between different networks and share position and other files.

2) Role Definition in the System

The roles of the self-organizing network emergency communication system based on UAV include users of mobile terminals, UAV and some other users not in the self-organizing network.

a) Users of Mobile Terminals

Users of mobile terminals are the nodes of self-organized on the ground, and many adjacent nodes can form a network. The main functional requirements are following.

- The Function of Authentication

The main function is to do authentication in the system. Users can know all members' information in the network, which can let user to send messages to specific member securely. These methods can strengthen the security of self-organizing network.

- Function of Forming network

Mobile terminals on the ground can build a self-organizing network quickly when the base stations are damaged and search the network to get the member.

- Communication

After building self-organizing network successfully, members can send messages to others who also in network. Users can know about others situation when people in

emergency environment by sending messages, including voice messages and text messages.

- Positioning

People can get information about geographic position by positioning function when people are in earthquake and fire, which can be sent to other people. This kind of thing can reduce the rescue time.

b) UAV

UAV are the nodes of the relay network in the sky, which can cover the self-organizing networks of the ground. The main functions are as following.

- Function of Forming network

UAV can build a relay network quickly to do network communication.

- Safety certification

This way is to strengthen the security of relay network in the sky.

- Gathering Location

In order to provide better mobile relay communication, UAV will gather the location information of mobile terminals on the ground periodically to adjust the flight path and get the best position.

- Adjusting Flight Path

After gathering and analyzing the location information of the mobile nodes in the network, UAV can calculate the best location and adjust the flight path, then fly to there to keep up with the mobile nodes on the ground as far as possible. By this way, UAV provide moving relay communication for ground network nodes.

- Communication

The UAV in the relay network can send messages each other to do communication across network.

c) Users Out of the Self-organizing network

Users who are out of the self-organizing network means the users who can be communicated through base stations. If this kind of users are in the connected state with any node in the self-organized, people outside can send messages to all people in the network, including the rescue plan. The functions are the same with the mobile terminals which are mentioned above.

B. The Core Functional Requirements of the System

The core functional requirements of the system are that the users can realize network communication and exchange messages when base stations and other communication facilities are damaged. According to this plan, the core functions requirements of this system are forming network and communication. Then we will introduce two functions particularly.

1) Function of Forming Network

In order to build two kinds of self-organizing network, including mobile terminals and UAV, the functions of these two networks are different. Because of these reasons, there are some requirements for this function.

- Forming Network Quickly

As we know, time is very precious in some critical situations, so let information can be communicated at the first time through establishing network communication connection quickly is necessary.

- Information of Nodes Update in Time

Letting information of nodes' state update in time and quickly is necessary for network communication because all nodes of self-organizing network can join and quit freely. Only get the correct information, can the users of mobile terminals communicate with other smoothly.

Forming the network is the basis of the self-organizing network emergency communication system based on UAV, which is critical to the operation of the whole system. Only building network successfully, can we be in the network or across a network for further network communication.

2) Communication Function

Communication is a critical function for this system, and the main function is to guarantee send and receive messages normally in the network or across the network. The main requirements are as following:

- Timeliness

Message delivery in time is the most important thing in the emergency situation because this can reduce the rescue time for people.

- Comprehensiveness of the Types of Messages

After analyzing the existing messages' types, we can find the mainly message type include text messages, voice messages as well as images. On the other hand, the three kinds of messages are all critical for people, which explain why the types of sending messages should be multiple.

- Security

In this system, we should guarantee the security, which means the privacy of users is not known by other people.

C. Nonfunctional Requirements of the System

The self-organizing network emergency communication system based on UAV should realize network communication when the base stations are damaged in some critical situation like earthquake, and the nonfunctional requirements are as follows.

1) Security Requirements of the System

In order to ensure the security of the system, the safety mechanism of the system should be given at the beginning of operation, including how to improve the security and how to protect the system. And to ensure the normal operation of the system, we should fully consider the system security from the internal and external.

2) Environment Requirements

Some emergency situations such as earthquake usually has very bad environment like high temperature and low visibility, which will affect the flight of the UAV and gather information of nodes' location information, so the system will not work normally in these situations. To ensure the system can work well in special environment, some factors should be fully considered before design and reduce the influence of environment on the UAV flight.

3) Hardware Requirements

Because the UAV involve a large amount of data in collecting data and computing the optimal position, ensure a large number of processing data have no effect on work of this system is necessary. Given the hardware factors before design are powerful guarantee for system working.

IV. Overall Design of the System

A. The Massive Structure of the System

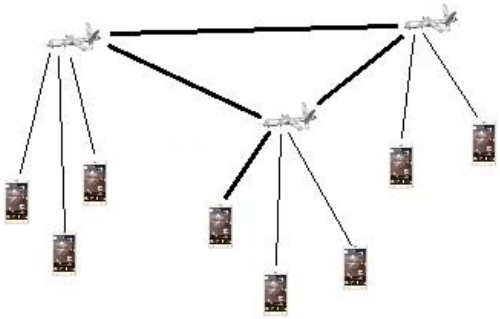

Figure 2 The massive structure of system

Figure 2 indicates that the system consists of two parts,o ne is the mobile self-organizing networks composed of mobile terminals nodes and the other one is relay network in the sky which composed of UAVs.

In the absence of UAV, mobile terminals can form multiple self-organizing networks on the ground and each node can communicate in respective self-organizing network but can't communicate across a network. In the case of an UAV, each one can override a self-organizing network on the ground and the node in the network can exchange messages with UAV. As for multiple UAV in the sky, a relay network can be built in the sky and the nodes on the ground can communicate across a net with the help of UAV.

B. Particular Design of the System

After analyzing the requirements which are mentioned above, we make the following particular design of the system.

Figure 3 indicates that the UAV have the modules of centroid calculation，data collection, safety certification and network routing. As for the mobile terminals on the ground, which can form multiple self-organizing network and they have the modules of searching the web, network communication，safety certification and network routing.

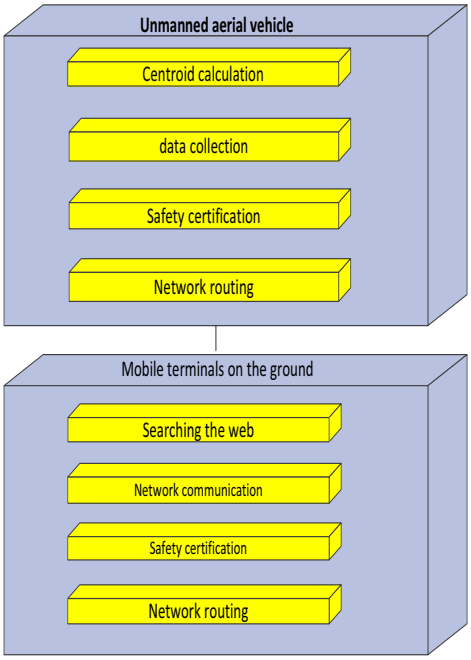

Figure 3 The particular design of the system

There are also some methods for UAV to find best location for mobile terminals on the ground. There are two situations when the system applies to some situations.

- Single UAV

Figure 4 shows the situation of single UAV in two adjacent cycles.

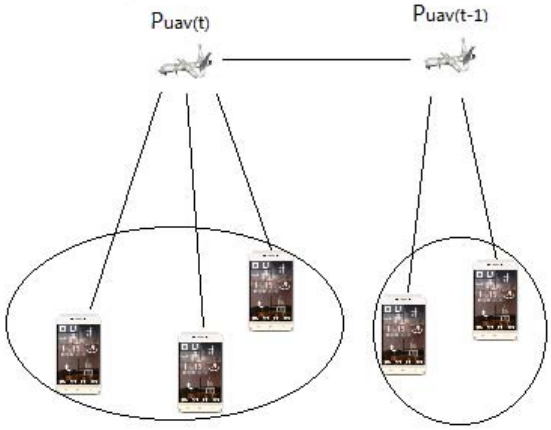

Figure 4 Single UAV

In order to simplify the problem, we assume that all the nodes are in the same horizontal plane, and $P_{UAV}(t-1)$ means the state of the UAV on $t-1$ moment.

To calculate the best location of unmanned serial vehicle, the problem can be classified as restricted problem [5].

$$min \quad J = \sum_{i=1}^{M(t)} w_i(t) \left|\left| P_i(t) - P_{UAV}(t) \right|\right|^2 \qquad (1)$$

$$s.t. \quad L_{min} \le P_{UAV}(t) \le L_{max} \tag{2}$$

$$\sum_{i=1}^{M(t)} w_i(t) = 1 \tag{3}$$

In these equations, and means the border of activity and $P_i(t)$ is the horizontal coordinate in t moment. is the weight of the node in moment. means the Euclidean distance.

Then we can get the best location as following.

$$P(t) = \sum_{i=1}^{M(i)} w_i(t)\, P_i(t) \tag{4}$$

- Multiple UAV

In this situation, besides the method in single UAV, there are also some other ways to improve network connectivity, including rejection, attraction, hover and random walk. Rejection means to avoid the collision between UAV, and attraction is planned to avoid the UAV' lost connection because of far distance. Hover and random walk are the ways to increase the probability of connecting with other UAV

V. SUMMARY AND PROSPECT

With the rapid development of mobile Internet, all kinds of portable mobile terminal emerge in endlessly like smart phones and watches and these electronic products occupy a large market share. The systems of the electronic equipment are in diversification and Android platform possess a large number of electronic products market share because of openness and don't be bound by the hardware. At present, the applications based on Android platform are becoming more and more important products on the Internet.

Meanwhile, the researches of Self-organizing network and introduce the UAV to mobile self-organizing network is still in its infancy at home and abroad. Existing research is on the analysis of its feasibility, which more focus on relatively static network scenarios of UAV layout problem and the simple application and complete network communication system has not forming, On the other side, related applications is also imperfect. Combined with the above points, a mobile self-organizing network emergency system based on UAV is particularly important.

The system we put forward can communicate by self-organized when base stations and other communication facilities are damaged in some emergency situation, which can be widely used in the future. The UAV we used in this system can improve network connectivity by gather location information of nodes on the ground and adjust the flight path to get the best point for the self-organized on the ground. At present, our study is not perfect, and there are some problems in bad environment of low visibility. We would tackle these problems in the future work to promote the development of the mobile terminal network and mobile internet.

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