NSOPNet: Dynamic Mode of Near Space Pseudolite Network

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Abstract. Near space aerostat has the advantages of all-weather, high maneuverability, easy arrangement, In extreme cases where unexpected events and satellites are unavailable, aerostat platform has become a fast and effective means to provide various communication services. A plurality of aerostat components into a network. Constructing a wide coverage near space network is a key link in the integration of space and ground. Due to the impact of high-altitude air and other environmental factors. The aerostat platform strong mobility and track control difficult. That aerostat is facing network topology changes quickly, routing design complex Based on this, this paper creatively puts forward non connection oriented dynamic opportunity routing in aerostat network-NSOPNet. With the moving of aerostat, In the light of sight, communication is realized by means of store and forward. At the same time, this paper designed routing algorithm- OP-NSR. It requires each aerostat platform maintains a message queue. When the two aerostat can communicate in the light of sight, exchanging messages that are not stored by the other aerostats, Iterate until the source messages are delivered to the destination. The simulation experiment with multi nodes of aerostat. Through the simulation of OP-NSR routing algorithm show that the method can effectively solve the aerostat networking and routing problem in near space.

Keywords: Aerostat · NSOPNet · OP-NSR

1 Introduction

At present, the ground network has been developed for nearly twenty years. Although the coverage of the network is comprehensive, communication services are faced with many challenges. [1] Some remote areas not fully cover the network, Communication services are not provided. Subject to the national territory limits, the ground network cannot be extended to land overseas, ships on the high seas cannot use the ground network for information services. In the event of natural disasters such as earthquakes and typhoons, ground communications facilities have been damaged; in the case of satellite unavailability, the breakdown of communications and navigation services will result in significant economic losses; [2] The near space vehicle because has the characteristics of all-weather, long-time, high mobility, easy arrangement [3], Not only can provide long-term service information in remote mountainous areas, but also to

Q. Yu (Ed.): SINC 2017, CCIS 803, pp. 173–183, 2018.
https://doi.org/10.1007/978-981-10-7877-4_15

provide information service for the public emergency. as an alternate mode, it can be fully deployed in a short time and take on most of the emergency tasks when in the satellite unavailable state. It costs low and easy to implement. [4] Aerostat is the tethered balloons and the airships as a platform for a lighter than air aircraft equipment. Including the capsule (used for filling gas lift), fairing, tail, nose, equipment rack, power supply system, pressure regulation system etc. The basic structure is shown in Fig. 1, Aerostat has the following advantages. (1) can all-weather work, long, strong endurance, suitable for the provision of emergency communication guarantee for public emergency. (2) High mobility, easy to control, can be arranged in remote areas and mountainous areas. (3) carrying capacity is big, survival ability is strong, can flexibly carry all kinds of communication resources, payload, providing diversified information services [5–7].

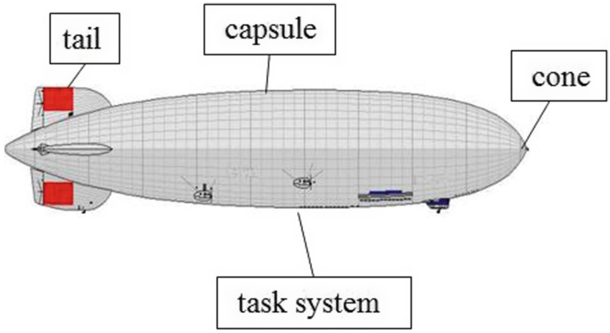

Fig. 1. Basic structure of airship

2 Related Work

2.1 Aerostat Communication

As In 2001, SKY Site company of the United States launched the space data platform, using wireless communication equipment installation of stratospheric aerostats on expanding the coverage of cellular network [9]. In 2009, scholars in Japan put forward the idea of using the ball borne wireless mesh network system for emergency network communication after disasters. The balloon floats at the height of 40–100 m and connects to the ground mobile nodes through the IEEE802.11b/g protocol to access the Internet [10]. At present, the more successful the aerostat application case is Google Project Loon. It is a network operating in the stratosphere. Designed to connect rural and remote areas to fill gaps in network coverage. Google also cited the use of balloons to provide communications services after natural disasters. After a natural disaster like Hurricane Sandy, communications infrastructure in the affected areas will be damaged and will take a long time to recover, while the Loon balloon will become a very useful alternate communication facility. Google balloons can be provided to wireless networks in corresponding areas, with speeds of about 10 Mbps. There are two communication links in the network: (1) the communication network between balloons;

(2) the balloon to the ground station network. ISM band 2.4G/5.8 GHZ [11] is currently in use. Users send signals to their nearest balloon at ISM band via a special antenna, final signal is transmitted to a balloon which connected to the ground network. As the balloon moves, the wireless mesh network will continue to adjust. The signal jumps between the balloons, thereby forming a network of at least 5 balloon nodes. Each balloon can be connected to a balloon within 48 km by radio receivers. Another radio transceiver guarantees that balloons can communicate with hundreds of antennas within 40 km in diameter on the ground. Theoretically, thousands of balloons can cover the whole world, [12–14].

2.2 Aerostat Network

In 2009, a research team at Iwate University in Prefectural, Japan, made a further attempt to form an air balloon network of Mesh mesh to provide a temporary emergency network for earthquake disaster [15]. The network structure of this vision is composed of balloons with wireless devices in the air, which form a network of autonomous networks. These balloons configure themselves by detecting the power density of electromagnetic fields, and they always choose the closest power density balloon to build connections. Once a balloon is blown or damaged by the wind, it is automatically connected with the new adjacent balloon, which ensures the stability of the Mesh network.

Google balloon is really using the air Mesh networking, divided into two parts: the balloon between the Mesh network, balloon and ground stations constitute user network [16], as shown in Fig. 2. Project Loon uses a frequency range of ISM unlicensed bands. The network structure is divided into two parts: horizontal Mesh network and vertical network. The Mesh network adopts IEEE 802.11j protocol, and the vertical network adopts IEEE 802.11b and G protocol. The specific parameters are shown in Table 1.

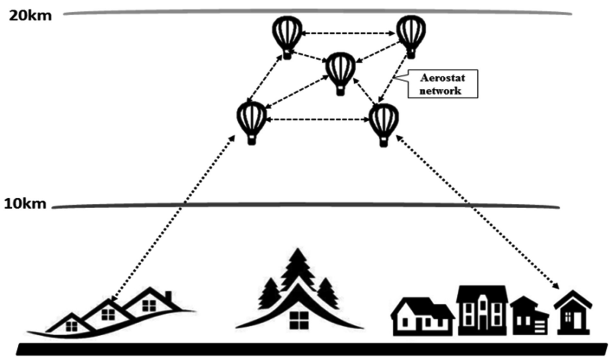

Fig. 2. Google aerostat mesh network

Wireless Mesh network is a good idea, but it is inconvenient to set up and maintain in some remote mountainous areas. In 2012, Simon Morgenthaler, of the University of

Table 1. Google balloon parameter configuration

	Mesh network	Vertical network
Standard	IEEE802.11j	IEEE802.11b,g
Frequency	2.4 GHz	4.9 GHz
Signal power	250 mW	10 mW
Trans speed	54 Mps	54 Mps
Max distance	600 m	100 m
Antenna	Octagonal plains	Co-linear

Bern in Switzerland, proposed a more advanced concept of using UAVs to build Mesh networks, which they call UAVNet. The principle is that the UAV uses the IEEE 802.11s standard to form an air Mesh network [17, 18]. The main contribution of the UAVNet concept is that they propose a networking algorithm for air Mesh networks. Probably the principle is that a drone from a first ground node starting off, and detection from another ground node, then their nearest, the drone to fly to the middle point of the two ground node, node to ground the starting point as the reference point to the direction of moving slowly, until it receives a signal from the starting point of the intensity of the ground node reaches a predefined threshold. Then, another UAV began to lift off, similar to the principle of movement, but the former UAV as a new reference point.

3 Networking System Model

Construction of near space vehicle network is facing many challenges. People cannot accurately control the aerostat move and stay. In many cases, the aerostat between light of sight, unable to realize data exchange, cannot realize the communication each other. The whole state of aerostat intermittent network. With aerostat drift, real-time change of network topology, network topology changes and increase the difficulty of routing, which will affect the entire communication process. Based on this, different from Google's Mesh network, this paper considers the aerostat is drifting continuously moving, put forward a new kind of aerostat network based on new opportunities routing [19]. Technical features is no path between the aerostat. With the movement of the aerostat. In the light of sight, the store-forward mode is adopted to communication under the condition of disconnected network.

3.1 NSOPNet Model

Aerostat movement, layout of sparse, NLOS, closed of RF and signal attenuation etc. Many times may lead to network cannot be connected. because of aerostats moving, that leads to routing problem, In this paper we use the opportunity routing to architecture a aerostat network, The essence of the network is a multi-hop temporary autonomous system. No fixed routers, Nodes in a network can move freely and communicate with each other in any way. Each node in the network does not need to be connected directly. Instead, it is possible to communicate between two NLOS nodes in a relay manner. Traditional wireless networks need to pre-establish routing between communication endpoints before transmitting user data. This work model implies an important assumption that most of the time the network is connected, and that there is at least one complete end-to-end communication path between any node pair. NSOPNet is constructed based on the move characteristics of aerostat. When the two aerostat into mutual communication range, data exchange. The topology of NSOPNet defined as $G(V,E)$,$G(V,E) \propto G(V,E'_{random})$. If the aerostat Vi to Vj in the in LOS, then $(V_{i,}V_j) \in E'_{random}$,$V_i \in \{V|1 \leq i \leq m\}$. m said the number of aerostat.

communicate_field
When part of aerostat is within the scope of communication, The definition of aerostat to form a communication domain field. The topology of the communicate_field is represented as $G'(V',E')$, then $V' \subset V$, is established randomly. The communication field must be able to communication between the two aerostat, Every time the data exchange is realized in Aerostat communication field.

The communication process of the NSOPNet is described as shown in Fig. 3. NSOPNet routing mode is “store-carry-forward”, it realizes the communication between the aerostat. When a link to the target domain is present, the message is forwarded, otherwise, the message is stored in the local persistent memory and then waiting for the available link.

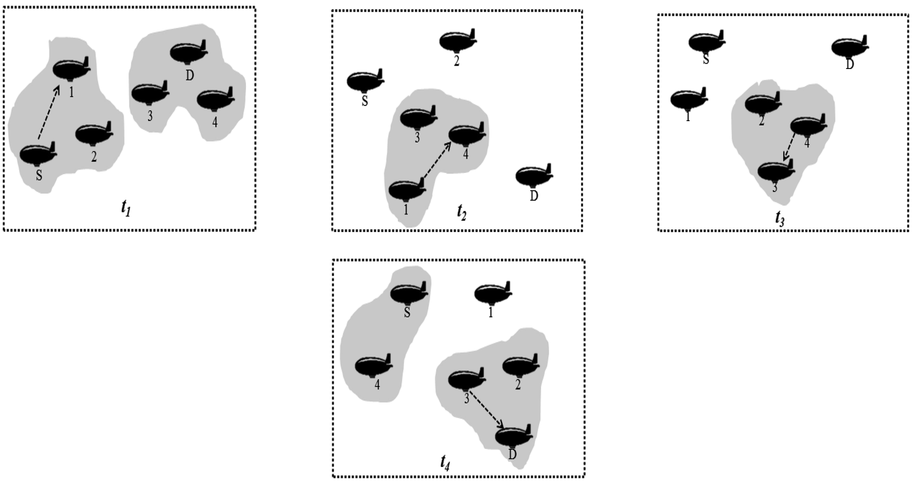

Fig. 3. Communication process of the NSOPNet

3.2 The Design of Aerostat Device Communication

Aerostat network mainly uses shortwave radio communications, The radio communication distance is limited by radio sight distance and link circuit. In the case of smooth link circuit, the radio distance becomes the key factor of communication. The function distance of wireless communication is closely related to the distance of sight. The radio sight distance refers to the maximum distance between the objects to keep barrier free communication monitoring. Relating to many factors such as atmospheric reflection, climate and topography [20].

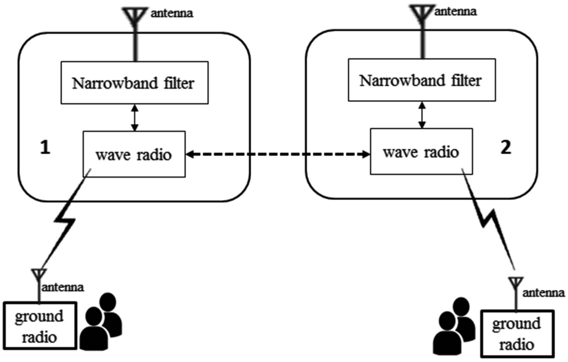

Fig. 4. Composition of aerostat shortwave communication link

As shown in Fig. 4, the composition of aerostat shortwave radio communication link, we must guarantee the surface shortwave radio and aerostat on shortwave radio parameters in the working process are equal. The list of basic devices is shown in Table 2.

Table 2.

Device	Number
Shortwave antenna	2
Narrowband filter	1
Shortwave radio	1
Ground station	Many

OP-NSR routing algorithm

OP-NSR works as a "store - carry - forward" mode. When a destination node is not present in the routing table, the message is cached at the current node. And wait for the appropriate forwarding opportunity as the current node moves. For each message, it is the key to design the efficient routing protocol to determine the best next hop forwarding node and select the appropriate forwarding time. The NLOS_Table format is shown in Table 3.

Table 3. Format of NLOS_Table

Vax	Count1	Count2	…	Countn
Times	2	3	…	1

(1) For each aerostat to maintain a record the times that non line of sight in NLOS_Table. Definition: County is a variable in NLOS_Table, County said the time that the disconnected between this aerostat and aerostat (i). Let n be the number of aerostat in the network, n-1 is the number of variables for NLOS_Table. Definition: once the aerostat disconnect that is not in the distance of a radio line of sight.
(2) OP-NSR algorithm is divided into two stages, (1) message replication, transmission, (2) find the destination node, direct transmission

In the message replication phase:
The algorithm is described as follows:

(1) aerostat forwarding node selection: (1) according to the description, in each copy of the aerostat distribution, according to the aerostat alternative in the visible range, check the NLOS_Table, select the smallest value represents the least number of disconnected from the candidate County, send a copy of the half forward to corresponding aerostat the.
(2) replication method forwarding information: the sender will have a copy of the message to m, distributed to m aerostat. Select the appropriate aerostat will distribute a copy of m/2 to it, then all have a copy of the aerostat will distribute copies of own amount of 1/2 to the aerostat new proper, before the aerostat and no message copies of the same. This cycle of operation, until all the aerostats are only one copy, said out. The distribution process can be seen as a construction of a two fork tree, as shown in the following Fig. 5, using two trees to represent the process of copying messages. In this process, there is a certain probability of passing the source information to the destination node. If successful, the algorithm is finished, otherwise, the second step is performed.

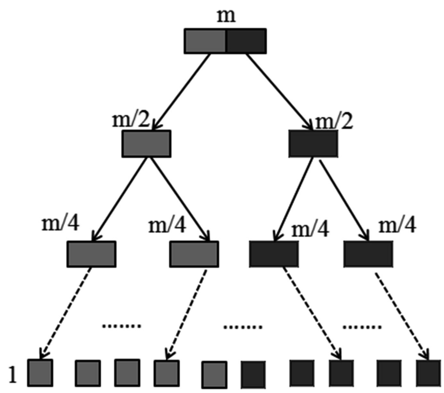

Fig. 5. Data replication distribution process

Find the destination node direct transmission stage:

In the same information m floating device active node, according to the random strategy, an arbitrary source information carrying aerostat can send signals to the target node. If the destination node is not found, communication fails and retransmission is requested.

The flow chart of the algorithm as shown in Fig. 6.

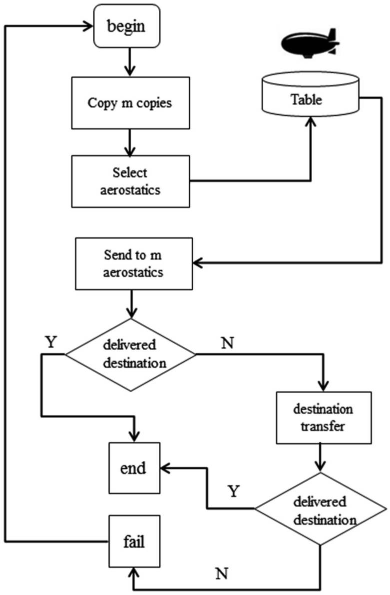

Fig. 6. Flow chart of the algorithm

3.3 Algorithm Delay Analysis

The process as a structure of two binary tree, aerostat to send a message is the root node, a copy of the final m message aerostats is a leaf node, the total number of nodes on this tree is $2^{(\log m + 1)} - 1$. The tree constructed by this method has the fewest number of layers. In a $\sqrt{N} \times \sqrt{N}$ grid, The number of the aerostat is X, the range of move was K, the average delay of the direct transmission is $ED_{dt} = 0.5(0.34 \log N - \frac{2^{k+1} - K - 2}{2^k - 1})$, Ideally, the minimum delay is $ED_{opt} = \frac{H_x - 1}{(X-1)} ED_{dt}$, Where H_x is the harmonic series of the N term of X, The average delay of OP-NSR algorithm is $ED_{op-NSR} \leq (H_{x-1} - H_{x-m}) ED_{dt} + \frac{X-m}{X-1} \frac{ED_{dt}}{m}$, At $m < x$, the equal sign is established.

Simulation experiment results

Performance evaluation criteria

The transmission delay and transmission success rate are chosen to evaluate the performance of the system.

(1) transmission delay

The data packet is transmitted from the aerostat node to the target node time required for aerostat. The average transmission delay is usually used to measure the transmission delay, which proves that the network performance is better, the routing algorithm has strong transmission capacity, high efficiency and less network resources.

(2) transmission success rate

The ratio of the number of packets sent from the sender to the destination and the total number of transmissions in a given time range. It is an important index to evaluate the packet loss rate of routing algorithms.

The experimental configuration design parameters are shown in Tables 4, 5 and 6 for the operating parameters of the aerostat set in Table 5 for the data set. The random motion mode of aerostat freedom movement (RWP).

Table 4. Operating parameters of the aerostat

	Parameter	Value
Aerostat operation set	Flight area/km	200*200
	Running time/h	12
	Mobility model	RWP
	Aerostat speed/(m/s)	[5, 10]

Table 5. Data set

	Parameter	Value
Communication parameter set	Packet size/KB	[1000,1500]
	Cache size/MB	10
	Transmission rate/(kbit/s)	500
	Transmission range/km	48
	Transmission mode	Broadcast

In accordance with the aerostat network scale is divided into 10, 20, 40, 80 simulation experiments, the corresponding forwarding copy number of 4, 16, 32, 64, as shown in Table 6.

Table 6. Experimental grouping

Aerostst size	10	20	40	80
Copy number	4	16	32	64

The results shown in Fig. 7, that by 6, by 10, in the transmission of aerostat network experiment success rate is about 80%, with the expansion of the scale of aerostat, transmission success rate increase, when the aerostat reaches 80, the success rate is about 90%.

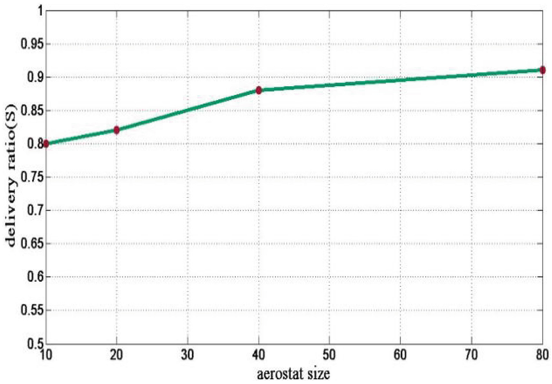

Fig. 7. Transmission success rate

The Fig. 8 shows that when the number of aerostat is 10, the average transmission delay of network maximum is about 0.3 s, when the number of aerostat is 80, the network delay is about 0.05 s.

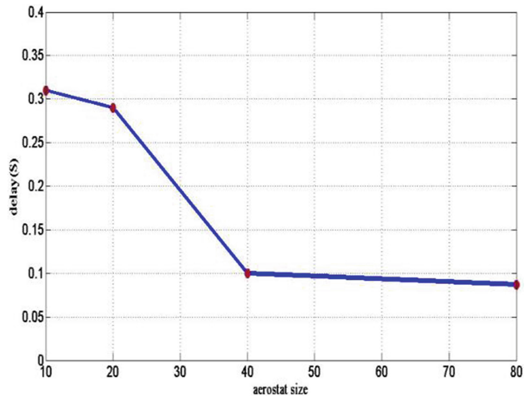

Fig. 8. Average delay of network transmission

It is necessary to point out that the experiment is based on the random motion of the aerostat model, the actual situation is the aerostat in track movement control words, the experiment would be better, because it is a random experiment, the experimental results did not achieve the optimal effect.

4 Conclusion

This paper presents a opportunistic routing method based on near space vehicle network, presents a NSOPNet opportunity network architecture, this architecture is designed on OP-NSR routing algorithm, and analyzed the performance of the algorithm from two aspects of transmission success rate and the average delay, verify the availability and efficiency the higher the method, provides a new research method for aerostat network communication. At the same time in the operation mode of aerostats, considering the flight status is not deep enough, great impact on all kinds of complicated weather conditions, network communication, research in the following work should focus on.

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