A Ballooned Wireless Adhoc Network System for Disaster Cases

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Abstract

Recently natural disasters such as earthquake, tsunami, typhoon and hurricane in addition to annual disaster have frequently happened at many places around the world. Once disaster happened, communication network and information system are seriously damaged and communication means for residents cannot be used in the disaster area. Therefore, it is required to prepare emergency network system which can be quickly reconstructed to recover from the network failure and used to confirm resident's safety and damaged area information.

In this paper, a ballooned wireless adhoc network is proposed to promptly insure communication means to grasp the information with disaster area, resident's safety and relief goods on the occurrence of disaster. By combining multiple ballooned wireless network nodes, a large adhoc network is organized in the sky on the disaster area and can cover shelters or interrupted communication area as urgent communication means. The system configuration and its function are described. A prototype system is constructed to evaluate its function and performance through several disaster applications such as WIide area Disaster Information and Sharing System(WIDIS), VoIP, and omni-directional video surveillance system.

1. Introduction

Recently natural disasters such as earthquake, seismic sea wave, typhoon, hurricane in addition to annual disaster have frequently happened at many places around the world. When disaster occurs, information networks infrastructure performs very important role as the resident's communication means. However, once a disaster occurred, failures of network equipments, cutoff of communication lines and traffic congestion cannot be avoided. More reliable and robust network environment is required even though the serious damaged by disaster occurred.

So far, we have developed effective Wide area Disaster information Network (WDN) using Internet over the combination of both wired and wireless network[1][2]. In this information network, two important functions including resident safety information system and bidirectional video communication system between evacuation places and disaster information center are provided [3][4][5]. However, in this WDN, system failure of network and computing facilities by disaster were not considered.

In this paper, a ballooned wireless network is proposed to promptly insure communication means to grasp the information with disaster area, resident's safety and relief goods on the occurrence of disaster. By combining multiple ballooned wireless network nodes, a large adhoc network is automatically organized in the sky on the disaster area and can cover shelters or interrupted communication area as urgent communication means. The system configuration and its function are described. A prototype system is constructed to evaluate its function and performance through several disaster applications such as WIide area Disaster Information and Sharing System (WIDIS) [9], Voice over IP telephone (VoIP), and omni-directional image surveillance system. Throughout the performance and functional evaluation, we could verify usefulness of the suggested system.

In the followings, the system configuration is described in section 2. The functions of the ballooned network are described in section 3. Applications which are useful on disaster using this system is explained in section 5. A Prototype system and its functional and performance evaluation is explained in section 6. Finally concluding remarks and future works are summarized in section 7.

2. System Configuration

Fig. 1 shows indicates a system configuration of our proposed system which is consisted of multiple ballooned wireless network nodes, the fixed access point, mobile note PCs, wireless IP telephones. A wireless ballooned network node is consisted of two highspeed wireless LANs such as IEEE802.11j in horizontal with octagonal patch antenna and IEEE802.11b,g in vertical with unidirectional communication antenna. Those wireless LANs are attached to a commercially available balloon and launched about 40-100 m high in the sky. In addition, our LAN has an auto configuration function to mutually and automatically connect to other LAN based on the power signal density. Therefore, by launching multiple ballooned wireless network nodes, in horizontal an adhoc network by IEEE802.11j is automatically organized in minimum spanning three configuration according to each power signal density its in the sky.

On the other hand, vertical communication service like hotspot on the ground level is provided by IEEE802.11g LAN from 40~100m high in the sky. The ballooned wireless adhoc network is finally connected to the fixed access point which is a gateway to Internet or wide area network where the disaster information servers (WIDIS) and other information services can be available.

The mobile note PCs provide functions to register the information with resident's safety, disaster information, relief goods at shelters to the disaster information servers on Internet through the adhoc network. VoIPs perform voice communication function between the residents or volunteers as telephones when the mobile telephone network is congested.

Furthermore, omni-directional camera system is also attacked to the balloon to observe the disaster area form the sky. The images from the omni-directional mages are transmitted to the disaster headquarter to grasp how the disaster is expanded.

Thus, the urgent information network infrastructure in disaster area quickly is organized using the suggested ballooned wireless adhoc network.

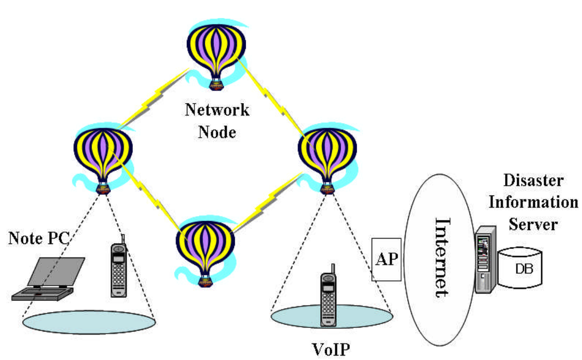

Fig. 1 Ballooned Wireless Adhoc Network in Disaster Area

3. Balloon Structure

Fig. 2 shows a structure of ballooned wireless network node. A commercially available balloon made by vinyl chloride is used by considering its simple structure, low cost and easy utilization even though the disaster happened. The volume size of a balloon varies depends on how much of a total weight of wireless LANs is loaded. In our case, the volume of balloon is 3.5 m^3 and filled up by helium gas which provides 28 Kg as buoyancy. On the other hand, the total weight includes the balloon (8.5Kg) and wireless access node (8Kg) and the supporting ropes (1.5Kg). Thus, the residual buoyancy is 10Kg which is enough to keep the balloon 40-100 m high in the sky.

The electric power for wireless network node is supplied from power battery for emergency or vehicle on the ground trough the very thin power cable.

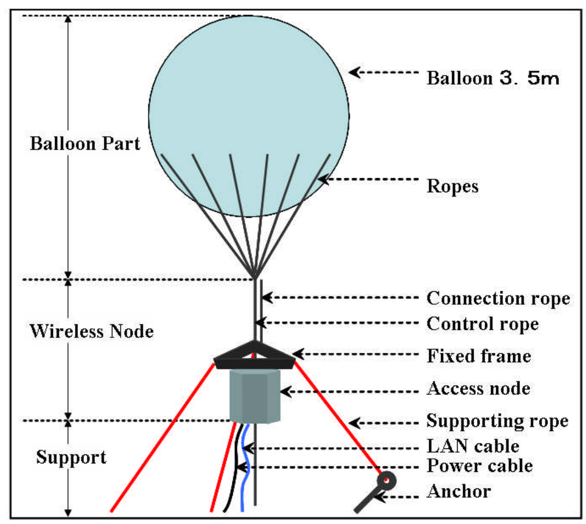

Fig. 2 Balloon Network Node

4. Wireless Network

Fig. 3 shows a wireless network which is used as a ballooned wireless network node. As horizontal communication facility between the wireless nodes in the sky, IEEE802.11j highspeed wireless LAN with (250mW power density, 4.9GHz transmission frequency, 54Mbps network bandwidth) access method is used, while as vertical communication facility between the wireless network node and mobile PCs, or VoIPs, a IEEE802.11b,g standard wireless LAN (with access method is used. Max 600m in distance between wireless nodes can be realized by hexahedral plain antenna in the sky. The 100m diameter area on the ground from 40m high can be covered by the diversity antenna. The more detail of wireless network node is shown in Table 1.

Table. 1 Specification of Wireless Network Node

Horizontal	
Standard	IEEE 802.11j
Frequency	2.4 GHz
Signal Power	250mW
Trans Speed	54 Mbps
Max. Distasnce	600 m
Antenna	octagonal plains
Virtical	
Standard	IEEE 802.11b,g
Frequency	4.9 GHz
Signal Power	10 mW
Trans. Speed	54 Mbps
Max. Distance	100 m
Antenna	co-linear
Max. Distasnce	100 m
Antenna	co-linear

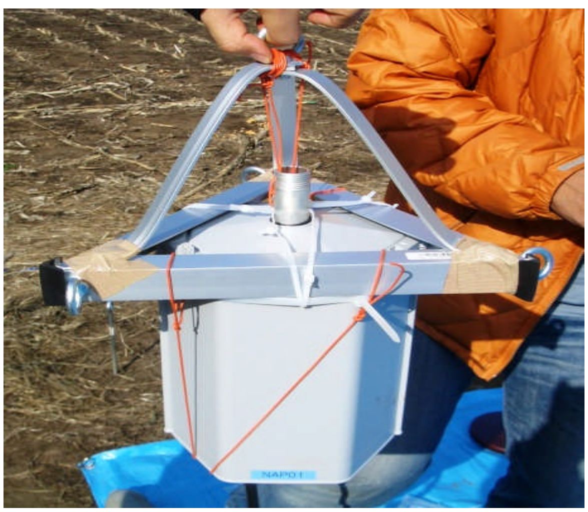

Fig. 3 Wireless Network Node

The multiple wireless network nodes are mutually and automatically connected by auto configuration function by which the links from one wireless node to the neighbor node whose electro-magnetic field power density is the strongest among them and repeating this procedure to organize minimum spanning tree network. Thus, an adhoc network is organized in the sky .

When a wireless network node moves or is failure, then the network node also automatically selects the best neighbor node as the same procedure. Thus, dynamically reconstructing communication links, an wireless adhoc network is maintained.

In the case of disaster, through this wireless adhoc network, the evaluated residents or volunteers can communicate with others and access to Internet using mobile node PCs or VoIP terminals.

5. Applications for Disaster Cases

We developed three different applications including widearea disaster information and sharing system, wireless IP telephone service system and wireless video surveillance system which are useful and required for residents and volunteers and local governmental personnel at shelters and in the disaster areas.

5.1. Widearea Disaster Information and Sharing System (WIDIS)

WIDIS system[9] was developed for residents and volunteers and local governmental personnel to easily register and retrieve disaster information such as resident's safety information, evaluation information, volunteer information and relief goods or life information etc. to/from disaster information server. WIDIS is implemented by Web based technology and GIS technology is shown in Fig. 4. Using WIDIS, not only the evacuated residents, volunteers and local governmental personnel can quickly, safely and properly take this information, but also ordinal persons outside the disaster areas can refer to insure the disaster information through Internet.

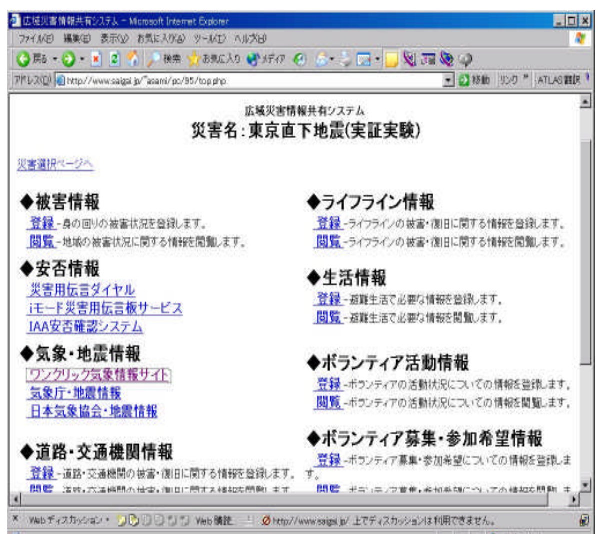

Fig. 4 Top Page of WIDIS

5.2 Wireless IP Telephone Service System

Just after an occurrence of disaster, since the traffic of conventional mobile telephone increases several ten times of ordinal case and leads to traffic congestion for a long time. In order to resolve this traffic congestion, by using wireless IP telephone network over and introducing VLAN or VPN functions, VoIP telephone service can be reserved in the evacuated areas[4][5].

5.3. Omni-directional Video Surveillance System

The wireless omni-directional video surveillance system[6][7][8] which is a combination of omni-directional camera and Pan/Tilt/Zoom control camera is attacked to a ballooned to be used to take video with states in the disaster area or around the evacuated area from the sky and transfers the state to the disaster headquarter in local government as shown in Fig. 5.

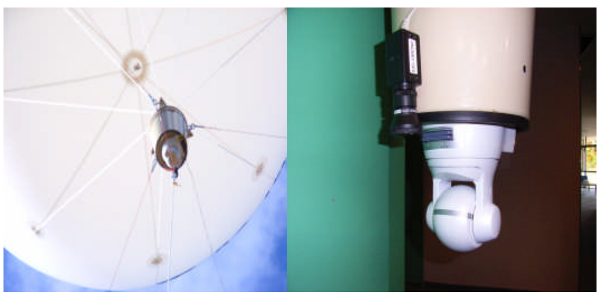

Fig. 5. Ballooned Omni-directional Camera System

While the Omni-directional camera takes wide vision of the disaster area, Pan/Tilt/Zoom control camera takes the more precise image specified on the omni-directional camera image by controlling pan, tilt and zoom operations by users as shown in Fig. 6.

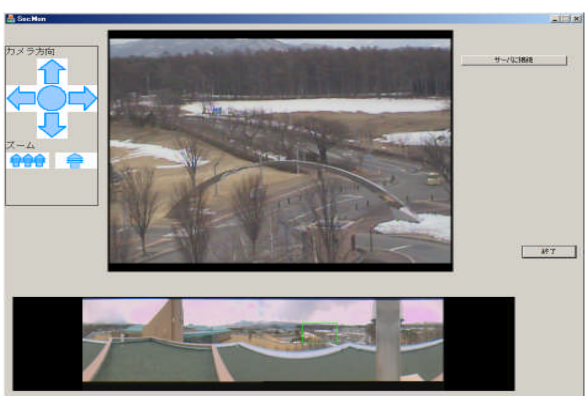

Fig. 6 Omni-directional Camera Image

6. Prototype and Evaluation

In order to verify our proposed system, a prototype system shown in Fig. 7 is constructed and its functions and performance are evaluated for three applications through field experiment. Five ballooned wireless network nodes were launched 40 m high in sky over the campus of Iwate Prefectural University to organize into an adhoc network and to be connected to Internet through access point.

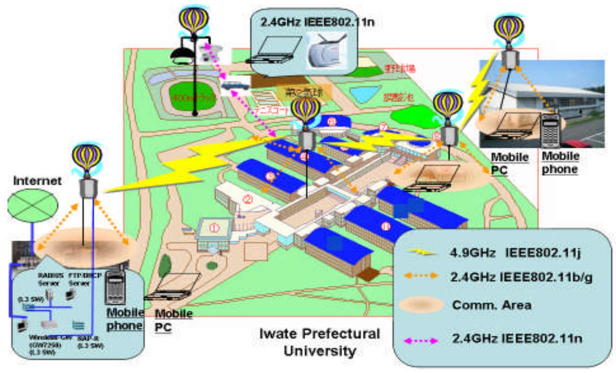

Fig. 7 Prototype System

Initially the Received Signal Strength Indicator (RSSI) [dB] and packet loss rate [%] were evaluated by changing the distance between two neighbor ballooned wireless network nodes. Fig. 8 and Fig.9 show the results of the performance. As can be seen, the maximum communication distance between two neighbor ballooned wireless network nodes was 600 m as expected. As result, by N-hopping nodes, the maximum communication distance of 600xN m can be attained.

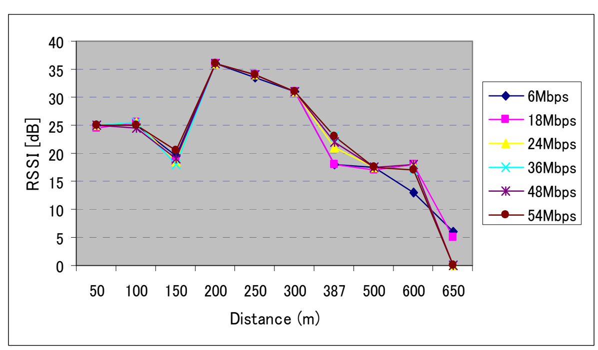

Fig. 8 RSSI [dB] between Ballooned Network Node

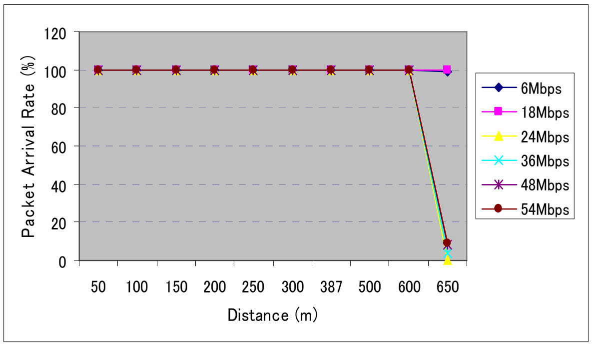

Fig. 9 Packet Loss Rate between Ballooned Network Nodes

Next, performance of end-to-end throughput and response time were evaluated by changing the number of hops while each distance between the neighbor nodes is maintained within 600 m. Fig. 10 shows the results of performance.

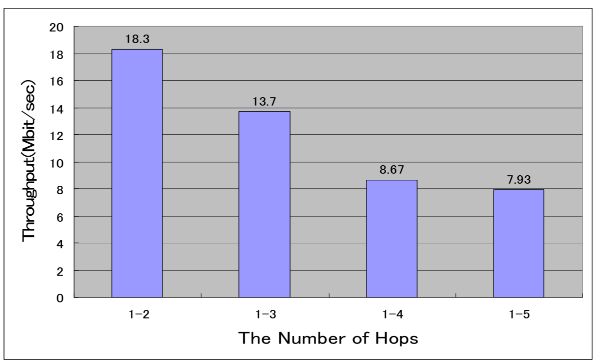

Fig. 10 End-to-End Throughput

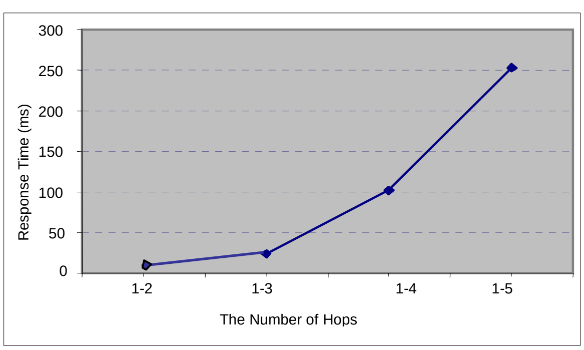

Fig. 11 End-to-End Response Time

As increase of the number of hop, the throughput decreased from 18.3 [Mbps] to 7.83 [Mbps]. This throughput was enough to interactively access to WIDIS server on Internet from the mobile note PC in realtime.

On the other hand, in the di-directional voice communication service using VoIP between the end-to-end point as shown in Fig. 12. As increase of the number of hops, the end-to-end response increased from 20 [msec] to 250 [msec] as shown in Fig. 11. This response time was also acceptable for users to interactively communicate each other with mobile IP phone.

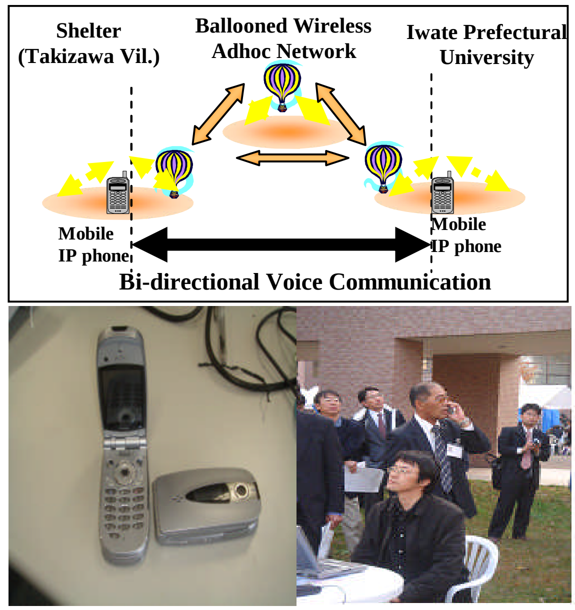

Fig. 12 Wireless IP Phone System

Third, we evaluated the end-to-end performance of Omni-directional Video Surveillance System in which both omni-directional camera and PTZ were used. The video images from both cameras attached to the balloon were captured from the sky on one end point and sent through the four-hopped ballooed network nodes to display to the other end point as shown in Fig. 13. The result of performance is shown in Table 2.

Table 2 Result of Video Performance

Video image	Omni-Directional	PTZ camera
Size	800x250	320x240
Format	WMV	WMV
Req. BW	2 Mbps	1 Mbps
Frame Rate	10˜15	10˜15

From this result, video performance by both cameras were enough to transmit the both video images to interactively control the PTZ camera in realtime and could display on the monitor with acceptable delay time because the end-to-end throughput with 7.83 [Mbps] and response time with 250 [msec] between both end-to-end points was enough to be supported. Thus, we could verify the usefulness of our suggested ballooned wireless adhoc network system.

Fig.13 Omni-Directional Video Surveillance System

7. Conclusions

In this paper, a ballooned wireless network was proposed to promptly insure communication means to grasp the information with disaster area, resident's safety and relief goods on the occurrence of disaster. By combining multiple ballooned wireless networks, an adhoc network is organized in the sky on the disaster area, shelters or interrupted communication area as urgent communication means. A Prototype system was constructed to evaluate its function and performance through three disaster application such as WIDIS, VoIP, and omni-directional video surveillance system. Through this evaluation of the prototype system, the usefulness of our suggested ballooned wireless adhoc network system could be verified.

References

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