A Wireless Relay System Based on Small Unmanned Aircraft for Disaster Situations

—Providing connections from the sky to isolated regions—

Ryu Miura
Director
Dependable Wireless Laboratory, Wireless Network Research Institute
National Institute of Information and Communications Technology

1. Introduction

The Great East Japan Earthquake not only damaged structures such as roads but also resulted in many areas becoming cut off from telecommunication services due to power outages and the loss of communication facilities. This made it impossible to assess the disaster situation in these regions, thereby delaying rescue efforts and making it impossible to check the safety of local residents or request necessary relief items. To help mitigate these issues, the NICT has developed a wireless relay system based on autonomous computer-controlled small unmanned aircraft that are small enough to be carried by hand and can be launched by throwing. This system is expected to provide a useful airborne means of accurately ascertaining the disaster situation in isolated regions and promptly re-establishing communications in these regions, enabling quick rescue efforts, and checking on the safety of people in isolated regions.

In recent years, there has been a growing amount of interest in small unmanned aircraft (or "drones") as a means of monitoring the disaster area from the sky, and bringing video cameras and environmental sensor equipment to the affected region. However, there have been very few instances (either in Japan or overseas) where this technology was used in the development of wireless relay systems for use in disaster-hit areas.

2. Overview of the wireless relay system

At the NICT, we have developed a wireless relay system based on small drone aircraft made in the United States (the world leader in this technology). This system is configured by a combination of drone-mounted wireless relays and simple ground-based equipment.

The system is equivalent to constructing a virtual relay radio mast hundreds of meters tall, allowing two locations on the ground to be connected without being blocked by intervening buildings or mountains. If two small drones are deployed simultaneously and interconnected by an air link, then it is possible to connect between locations that are even further apart. Our airborne wireless relay equipment (including its battery) fits entirely within a space measuring about 10 cm along one side, and at just under 500 g (including battery) it is also very light (Photo 1, lower right). The system operates in the 2 GHz band with a transmission output power of 2 W and an effective transmission rate of about 400 kbps, and can support communication for about an hour and a half. One of the two ground stations acts as a wireless LAN access point, while the other is connected to an Internet circuit. This makes it easy to set up a drone-based wireless LAN (Wi-Fi) zone in isolated regions. This LAN supports the sort of Internet applications that people use every day, allowing them to exchange emails, make IP phone calls, check up on friends and family and use electronic bulletin boards. It also supports the transmission of video pictures, albeit at limited resolution. The ground station can operate from its own power source such as a mini generator or battery during power outages or when there is no mains electricity available nearby.

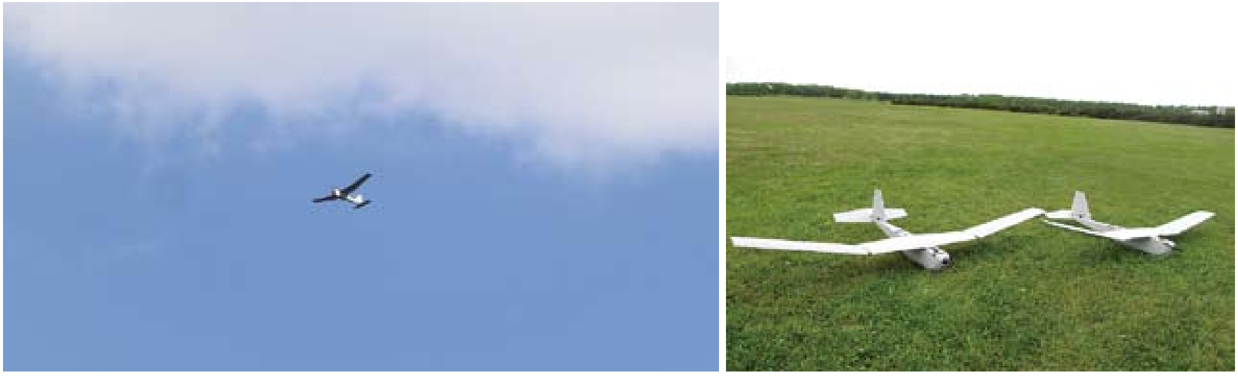
The drones used by this system are electrically powered fixed-wing propeller planes with a wingspan of 2.8 m, an overall length of 1.4 m, and a mass of 5.9 kg. Depending on the air conditions, they can stay aloft for between 2 and 4 hours. As long as a suitably large clear plot of land is available, they can be put in flight by simply throwing them, so there is no need for a runway (Photo 1). The drones have detachable wings and can be packed into special bags for ease of portability, which means they can be carried to places where the roads have become impassable to traffic. They are equipped with GPS receivers and various sensors, and are fitted with an on-board microcomputer that cooperates with a ground-based control terminal so that the drone can continue flying along a predetermined course without the need for a human operator constantly interacting with the control terminal. The drones are almost inaudible when in flight, and can fly further and for longer periods than multi-rotor type drones, which have become commonplace in recent years.

Photo 1: Launching a small-scale drone by hand, and a close-up view of the on-board wireless relay

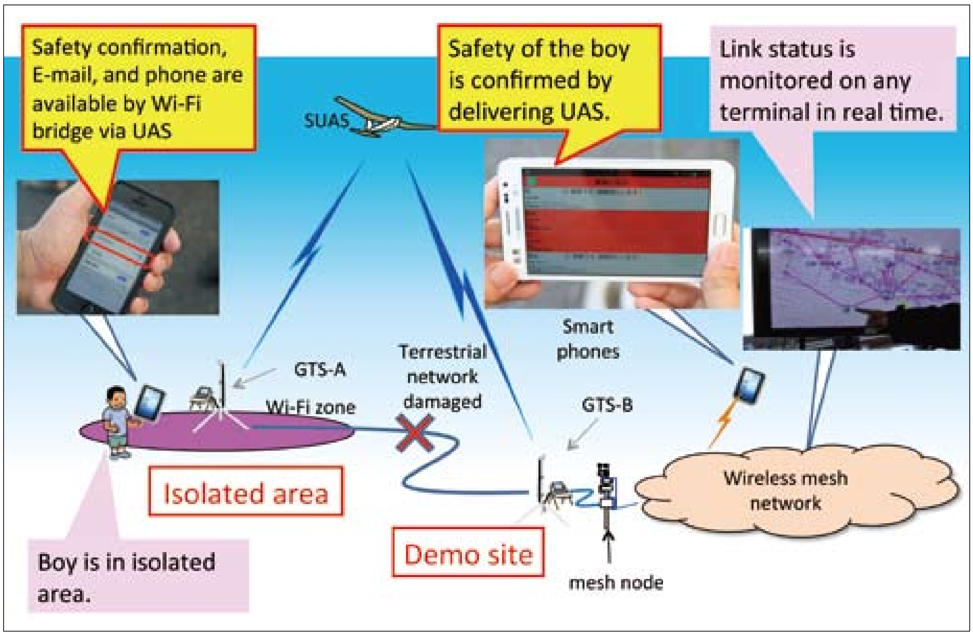
3. Flight testing

In March 2013, the first large-scale test was performed in

■ **Photo 2: A drone performing a turning maneuver autonomously**



■ **Figure 1: Demonstration of how a miniature drone system can be used to check a person's safety in a disaster situation**



the campus of Tohoku University (Sendai City, Miyagi Prefecture). There have since been over 100 flights, not only in Sendai but also in Taiki (Hokkaido) and Shirahama (Wakayama prefecture), where communication tests were performed using the drones under the conditions expected during a disaster (Photo 2 and Figures 1). In these tests, we verified that it is possible to use the drones in the event of a large-scale disaster to provide isolated areas with communication services including checking up on friends and family, making IP phone calls, and sending videos. We also confirmed that they support communication over a range of up to 20 km between the ground-based station and drone, depending on conditions. This is equivalent to a total range of 40 km, and shows that a single drone can provide a wireless LAN zone around a ground station in places where there are intervening obstacles such as mountains. It should be possible to extend this range to at least 50 km if signals are relayed using two drones instead of one. However, this distance varies with the conditions on the ground (forests, farmland, built-up areas), and we are currently on detailed analysis and modeling of their effects.

4. Applications of the wireless relay system

When settlements and refuge centers have become isolated after a natural disaster like an earthquake, tsunami or landslide, our wireless relay system can be used alongside other means of communication such as satellite links to provide emergency communications during the period until roads and communication infrastructure have been restored (typically 2–3 weeks). The drones can also use their miniature on-board cameras to acquire aerial video showing the isolation and damage caused by the disaster, and can relay these pictures wirelessly in real time. If there are places beyond the range of a single drone, another drone can be used as a relay so that video pictures can be sent without having to increase the transmitter power. There are many other possible applications for which this system could be used. These include tracking wild animals in mountainous areas, performing radiation measurements over a wide area, monitoring volcanoes in environments where piloted aircraft would be unable to enter due to the risk of engine damage by volcanic ashes, observing the growth of agricultural crops or the spread of wildfires, policing crowds at large-scale events, and patrolling international borders out at sea.

5. Conclusion

We hope that this system will become part of the standard disaster relief equipment held by local authorities, and that it can be used for disaster monitoring and environmental monitoring as well as for the provision of prompt communications in the event of a large-scale disaster. At the World Radiocommunication Conference 2012 (WRC-12), it was agreed that the 5030–5061 MHz band would be made available for the navigation of unmanned aircraft including control and non-payload communication (CNPC) links. The NICT is therefore working on using these frequencies effectively to develop technologies that can improve the reliability of drones with limited wireless resources.