International Journal of Control and Automation
Vol. 9, No. 9 (2016), pp.353-362
http//dx.doi.org/10.14257/ijca.2016.9.9.34

Unmanned Aerial Vehicles-based Health Monitoring System for Prevention of Disaster in Activities of the Mountain

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Abstract

Recently, interest in unmanned aerial vehicle as drones is increased, the utilization field has expanded. A FANET (Flying Ad-hoc Network) is a network for transferring data using unmanned aircraft in three-dimensional space, and a WBAN (Wireless Body Area Network) is a network formed around the human body. Until now, studies on the fusion of FANET and WBAN were not done much, therefore, in this study, as research on the fusion of WBAN and FANET, we study how to collect people's health data through the WBAN and transfer the collected data to a base station through the FANET. Specifically, we study a method for monitoring human-life disasters in areas that are vulnerable to communication difficulties, e.g., mountains and islands, and we design and implement an efficient data-transmission system.

***Keywords**: Wireless body area networks, Flying ad hoc networks, Data collection, Health monitoring, Prevention of disaster*

1. Introduction

Recently, as interest in health has increased while celebrating the well-being era, efforts to use science and technology for health promotion have increased. As an example, studies have been con-ducted to monitor a person's health by attaching various sensors to the body that can measure its health condition. A network formed by attaching a variety of sensors to the human body to collect and transfer data is called a WBAN (Wireless Body Area Network) [1].

In addition, as interest in three-dimensional networks has increased, as opposed to the flat, two-dimensional networks that have been in use for the last two-thousand years, network technology that utilizes unmanned aircraft (Unmanned Aerial Vehicles) has been developed. Currently, many at-tempts have been made to use a drone as a type of unmanned aerial vehicle in various applications [2]. Particularly, studies of FANETs (Flying Ad-hoc NETworks), for transferring data collected using a plurality of unmanned aircraft [3], have been actively conducted.

This study investigates the fusion of WBAN and FANET. In it, we study how to collect people's health data through a WBAN when they conduct their leisure activities in areas that are vulnerable to communication problems, *e.g.*, mountains and islands, and transfer the collected data to a base station through a FANET. In particular, by collecting the health data of an adult patient who has a chronic disease, monitoring whether the health status is at a dangerous level or whether an accident has occurred in real time in a no-communication area, and sending alarm information, we can help ensure the stability of the patient as soon as possible.

In Section 2, related work is reviewed. In Section 3, the proposed system is introduced and the design is discussed. In Section 4, the proposed implementation is presented. In

ISSN: 2005-4297 IJCA

Section 5, the experimental environment is introduced, and the study is concluded in Section 6.

2. Related Researches

A WBAN is a network configured to transmit and receive information about the human body. Its application fields can be classified as in-body (internal sensors) application, on-body (body-surface sensors) applications, and on-body non-medical applications [1]. On-body applications, as the field with the most applications, are utilized to monitor body information, *e.g.*, blood pressure, body temperature, and breathing. On the other hand, remote medical diagnoses [4], military / sports training [5], and interactive games [6] are also important application areas utilizing WBANs. These examples operate in a normal network environment provided with a nearly constant communication infrastructure. If the communication environment is not functioning, the service does not work properly.

On the other hand, FANET is a type of ad-hoc network that uses unmanned aircraft. Applications that use unmanned aircraft can be classified as fire monitoring [7], traffic monitoring [8], agriculture observation [9], road recognition [10], and environmental monitoring [11] [3]. Studies using these applications mostly collect data from the ground using an unmanned aircraft with a camera sensor, process it, and utilize it for specific purposes.

Further, recent studies [12] have also begun to collect data scattered on the ground by expanding existing wireless sensor networks utilizing unmanned aircraft. However, a study that uses a WBAN to collect specific data from the body and passes the data through an unmanned aircraft, as a fusion of WBAN and FANET, has not been conducted until now.

Therefore, this study considers a fusion of WBAN and FANET for monitoring a person's emergency data as they pursue outdoor activities in mountainous terrain, i.e., a typical space where communication is vulnerable [13]. In other words, this study attempts to overcome the communication disruption so as to quickly convey alarm data for anyone who falls into danger, and ensure safety at an early stage by using the WBAN to collect urgent data and the FANET to transfer the data.

3. Design of the Proposed System

3.1. Main Objectives of the System

In this paper, we propose a system for monitoring life disasters to ensure safety at an early stage by collecting health information for people who are active in a mountain area, and transmit it through unmanned aircraft. The conceptual diagram of the proposed monitoring system is shown in Figure 1. The goal of the proposed system can be summarized as follows.

First, to collect health information from an active body, we construct a gateway to collect data from sensors attached to the body. In this study, electrocardiogram (ECG or heart rate sensor), body temperature, and position information sensors, as well as an emergency buzzer, are attached to the body to obtain important health and emergency information. Moreover, a gateway is built for the collection, storage, and transmission of data to a Raspberry Pi micro-controller.

Secondly, we build a system that can pass the collected information using unmanned aerial vehicles (drones) to transfer data in mountainous or island areas that are vulnerable to communication loss. In this study, we investigate passing data by connecting two or three unmanned aircraft units. Considering the time and cost of research, we will first arrange the drones linearly to transfer the data. We will extend the delivery range in the future by adding more drones.

Thirdly, we construct a base station to collect the transferred data and build an application system for the notification of emergency data. After the normal health index of the user is stored in a data-base, when the data collected via a sensor is outside the allowable range, it generates an alarm. The data collected through the drone is reported to the medical staff, family, and emergency personnel, allowing them to take appropriate measures. The system is built as an application so it can be easily operated from a mobile device.

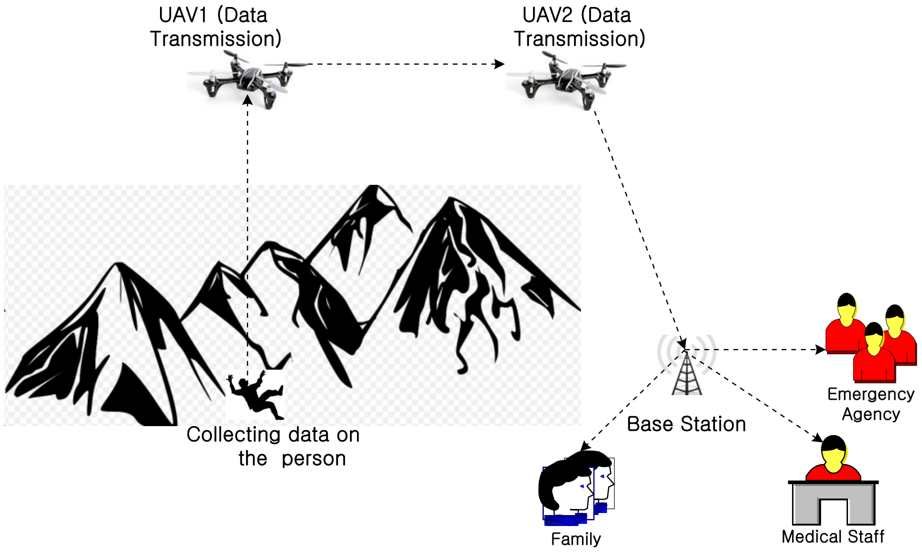

Figure 1. Conceptual Diagram of the Proposed System for Monitoring Human-Life Disasters

3.2. Structure of the Proposed System

The structure of the proposed system for monitoring life disasters is shown in Figure 2. As shown in the figure, the proposed system may be partitioned into the physical data collection device, the un-manned aircraft, and the base station. The physical-data collection device constantly monitors the body data of persons on the mountain, compares it to previously obtained individual healthy data, and monitors whether it is equal to or greater than a predetermined threshold value.

The base station records the received data in the emergency-recording database (DB) and informs people such as the family, medical staff, and 911 emergency personnel. An application is mounted so that the transmitted information can be received via the user's mobile device.

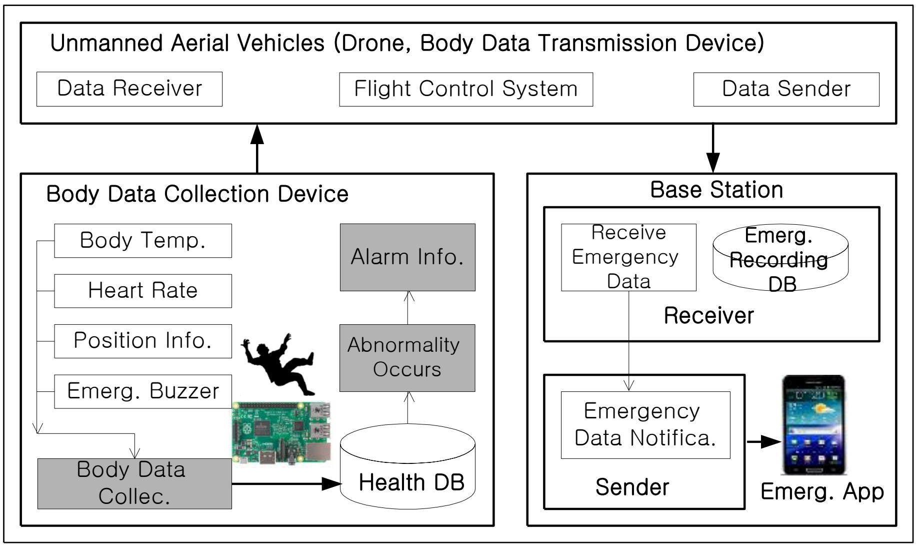

Figure 2. Structure of the Proposed System for Monitoring Life Disasters

4. Implementation of the Proposed System

The hardware components for implementing the proposed disaster-monitoring system are shown in Table 1. In the body-data collection device, as the core component of the system, a Raspberry Pi micro-controller is at the center of the body, and is composed of various types of sensors for measuring the body data.

Table 1. Table Label

Category		Specification	Functions
Sensors	Temperature	Thermistor NTSF-4/DHT 22	Thermistor Thermometer
	ECG/Heartbeat	MICAz /MCU sensor	ECG/Heartbeat Data Gathering
	GPS	NEO-6M (GY-GPS6MV2)	GPS Module
Micro-controller (Data Gathering)		Raspberry Pi 3	Base Station for Data Gathering and Communication
UAV (Drone)		DJI Phantom 3 Standard	Unmanned Aerial Vehicle (Drone)
Language for App.		Android API	App. Development Language
Wireless Technology	ECG↔Controller MCU↔Controller	Zigbee Bluetooth	Data Transmission
	Controller↔Drone	WiFi	Data Transmission
	Drone↔Drone	WiFi	Data Transmission
Base Station		Samsung laptop	Base Station

We use MICAz sensor nodes to obtain electrocardiogram data. A Zigbee communication module is installed for sensor-communication purposes. The sensor can be replaced with an MCU (microcontroller unit) sensor for measuring the heart rate. A thermistor temperature sensor is used to determine the temperature, and a GPS (global positioning system) module to determine the user's location is attached. Zigbee and Bluetooth communication are used within the WBAN, and a WiFi signal is used between the data-collection device, the drones, and the base station.

The hardware configuration of the human-life disaster-monitoring system is as shown in Figure 3. Several sensors, *e.g.,* heart rate, body temperature, and position sensors, are attached to the human body for mountain activities; an emergency buzzer is also configured. Unmanned aircraft transfer the data through the transceiver unit to the other unmanned aircraft. The base station collects, processes, and transmits the data to the user's application.

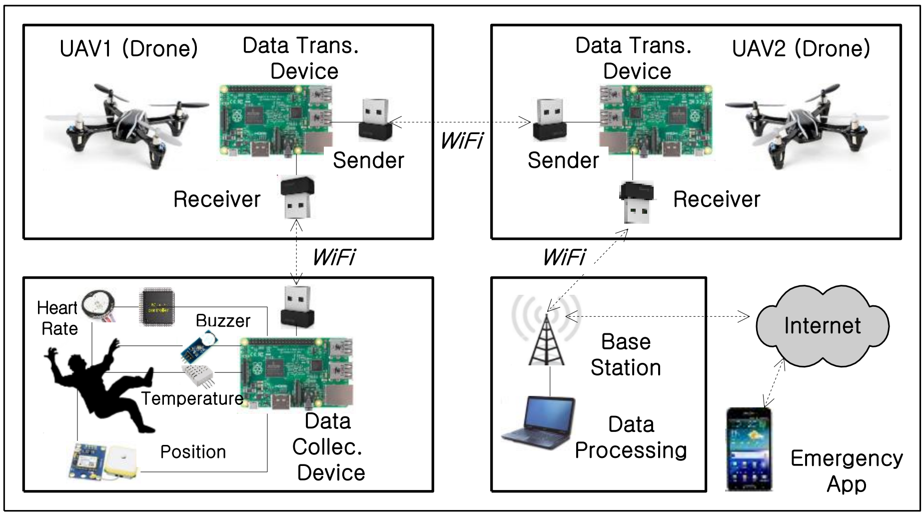

Figure 3. Hardware Configuration of the Human-Life Disaster-Monitoring System

Figure 4 shows an implemented part of the proposed system. The left side of the figure shows the WBAN built around DCD (Data Collection Device), the upper part of the figure shows the data trans-ceiver module that is attached to the UAV. The right side of the figure shows a base station with the access point.

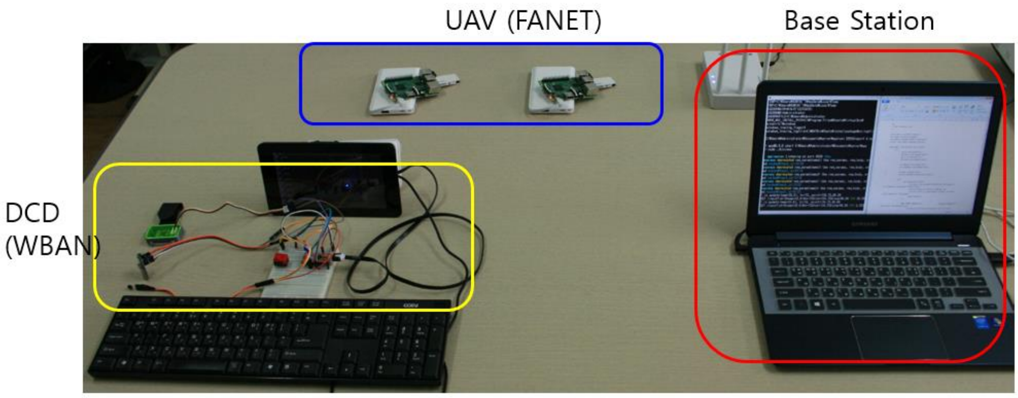

Figure 4. An Implemented Part of the Proposed System

Figure 5 shows the data transmission modules that will be attached to the UAV and a UAV. The left side of Figure 6 shows the finally received data in base station, and the right side of the figure show an example app for end user such as family, medical staff and emergency agency.

Figure 5. The Transmission Module that will be attached to the UAV

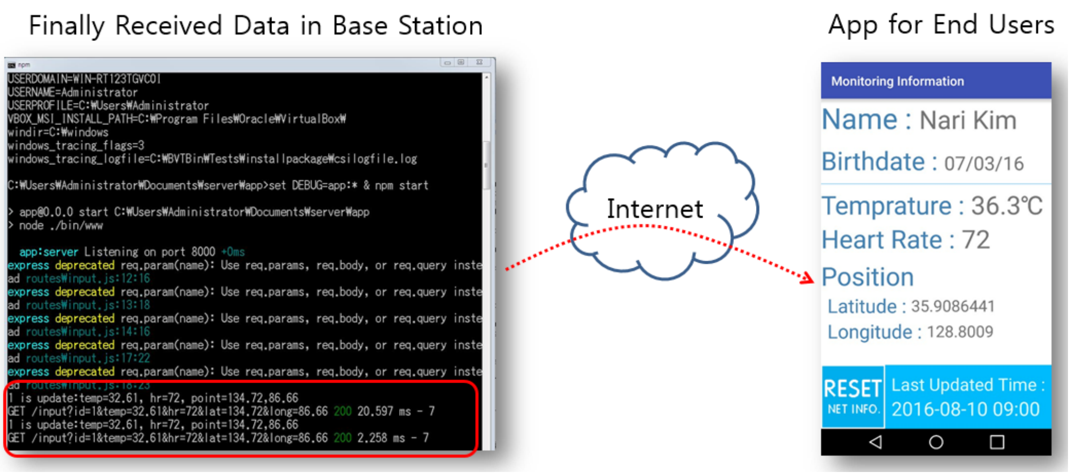

Figure 6. Finally Received Data in Base Station and an App for End Users

Those experiments were performed indoors and outdoors. The distance between the transmission module of UAV and the DCD, and the base station and UAV in laboratory experiments was about 1 meter respectively. Outdoor experiment was carried out by attaching a transmission module to the UAV. The weight of one transmission module including the battery was about 250 grams. The distance between UAV and DCD, the distance between UAV and UAV, and the distance between UAV and base station were set to about 15 meters respectively in the outdoor experiment. Success and failure of experiments has been determined according to the distance between devices. For more about 20 meters, reception of data was impossible. It is analyzed that the failure is due to the low performance of the transmission module and the signal collisions between health data and drone control signal.

5. Efficient Data-Transmission Model

In this section, we will discuss the method for efficient data transmission in the fusion architecture of WBAN and FANET. The data-transmission architecture used in the proposed system is composed of three communication areas, as in Figure 4. We discuss an efficient data-transmission method in each communication area.

5.1. Intra-WBAN Area

Many studies have proposed methods considering human-body characteristics for effective data transmission in a WBAN [14, 15, 16]. In this study, we omit a discussion of WBAN data transmission because we wish to focus on the fusion communication of WBAN and FANET. However, efficiently transferring large amounts of body data, which frequently occur in response to a change in time, becomes a problem. One method transfers body data at a fixed time interval. Another method involves transferring gathered data if it passes a threshold value.

5.2. WBAN-FANET Area

WBAN and FANET have two possible communication methods. First, the WBAN-specific DCD (data-collection device) collects data from the nodes of each WBAN and transmits it to the UAV by communicating directly with the FANET. This method is advantageous and can be easily used with a relatively small number of people on the mountain. Second, if the number of people on the mountain is large, another method clusters the WBAN nodes.

In this method, the designated head of each cluster collects data from the WBAN nodes and transfers it to a FANET UAV. Various clustering methods are possible, including LEACH (low-energy adaptive clustering hierarchy) [17]. It is possible to select an efficient method in accordance with the distance between the WBAN data-collection device and the UAV, and the number of WBANs in the communication area.

5.3. Intra-FANET Area

This is an internal FANET communication area. Two methods are possible in FANET internal communication, depending on whether the UAV position is static or dynamic. In the first method, the UAV gathers data from a static position that is defined previously. In a dynamic position method, the UAV collects data while moving autonomously and communicating with the WBANs. Further, two link methods are possible, depending on the type of link between the UAVs: multi-hop or routing.

In the multi-hop link, the UAVs are arrayed linearly. However, routing is an alternative method used between the UAVs. A variety of internal FANET routing methods [18, 19] have been proposed for application to ad hoc networks. Sometimes, it is possible to use a method that organizes UAVs in a hierarchical communication structure to collect data from the sub UAV and transfer it to the upper UAV.

5.4. Communication Models

In Figure 7, typical communication models are presented for the fusion of WBAN and FANET. The simplest method, communication model 1 on the left side of the figure, has each WBAN data-collection device transfer data directly to the UAV. Then, the UAV collects data at a static location within the FANET and transfers the data to a UAV close to the base station on a straight line.

Communication model 2 on the right side of the figure selects a CH (Cluster Head) between WBANs, assembles the data at the cluster head, and transmits the data to the UAV. The UAV in this model has dynamic motion. It collects the data by communicating with the WBAN CH, utilizes the routing method between the UAVs, and transmits the data to the base station. Communication model 2 is a communication model for more complex situations [20]. Communication models 1 and 2 can be used to fuse the communication methods for each area, depending on the circumstances.

In this study, the proposed system is implemented in accordance with communication model 1. However, in a future study, we expect to conduct simulations to compare the above communication models.

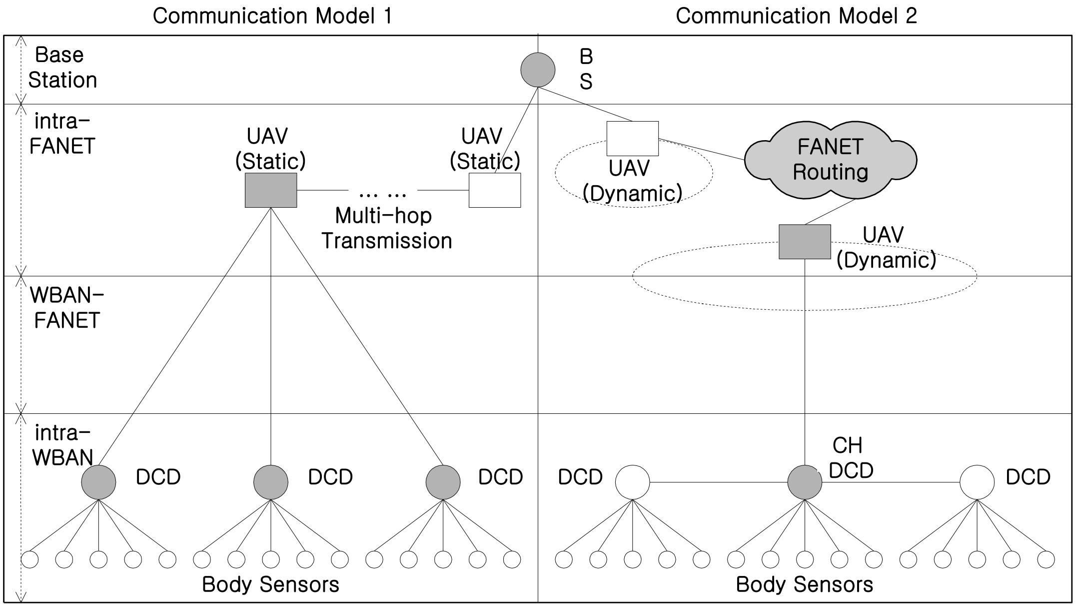

Figure 7. Communication Models for the Fusion of WBAN and FANET

6. Conclusions

In this study, we studied a method for monitoring human-life disasters in areas that are vulnerable to communication difficulties, *e.g.*, mountains and islands using unmanned aerial vehicles such as drones, and we designed and implemented an unmanned aerial vehicles-based health monitoring system for prevention of disaster in activities of the mountain.

The health monitoring system proposed in this study included an important key object that ensured safety at an early stage by monitoring the emergency data of a person who was active in an area that is vulnerable to communication loss, such as a mountain. The proposed system could be utilized as a device to ensure safe leisure outdoor activities. Moreover, the system can be utilized, not only in the mountain activities assumed in this study, but also a variety of areas, such as the sea and islands, where communication is vulnerable.

We believe that we can develop a more sophisticated system in the future if additional sensors are mounted on the body, in accordance with a further study of efficient data-routing methods for a number of drones.

Acknowledgments

This work was supported by the Korea Foundation for the Advancement of Science & Creativity (KOFAC), and funded by the Korean Government (MOE) (Ilkyu Ha). This research was partly sup-ported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) [NRF-2015R1D1A1A01059623] (You-Ze Cho).

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