A Networking Framework for Multiple-Heterogeneous Unmanned Vehicles in FANETs

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Abstract — **Unmanned aerial vehicles (UAVs) and Unmanned ground vehicles (UGVs) cooperation scenario has gained a great amount of interests because it is possible to support various scenarios based on their different characteristics of unmanned vehicle systems. For this purpose, in this paper, we develop the networking framework for Flying Ad-hoc Networks (FANETs), where heterogeneous multiple unmanned vehicles conduct ground-air cooperative missions. To support this scenario, communication path should be maintained among UAVs, UGVs and ground control station, therefore guaranteeing a reliable ad hoc network is an important issue. Regarding this, we provide development of flying ad hoc networks (FANETs) routing protocol and unmanned vehicle-based testbed environments which can be used for the experimentation for the developed routing protocol in which they consist of ground control station (GCS), multiple heterogeneous unmanned vehicle system, network topology monitor, and FANET communication modem.**

Keywords— **Flying Ad hoc Networks (FANETs); Unmanned Aerial Vehicles (UAV); Unmanned Ground Vehicles (UGV); Autonomous Cooperation Management System (ACMS)**

I. INTRODUCTION

Recently, many service scenarios based on unmanned aerial/ground vehicles (UAV/UGV) have received a great interest. These multi-UAV/UGV involved scenarios can shorten a mission execution time and increase the mission success ratio. [1,2] However, in order for a large number of unmanned vehicles to share their tasks and carry out collaboration, it is necessary to construct a reliable and stable network. Considering these considerations, it would be possible to exchange a mission information and transmit/receive a command between the ground control center and unmanned vehicles.

Cooperative unmanned vehicles on the ground and in the air require a reliable communication and networking technology suitable for the dynamic topology changes. In addition, we need to consider these characteristics, in which three-dimensional space environments and UAVs flying at high speed with an autonomous network. In this paper, we describe the flying ad-hoc network routing protocol technology and for testing the developed technology, provide testbed environments which support cooperation of unmanned aerial/ground vehicles. [3-5].

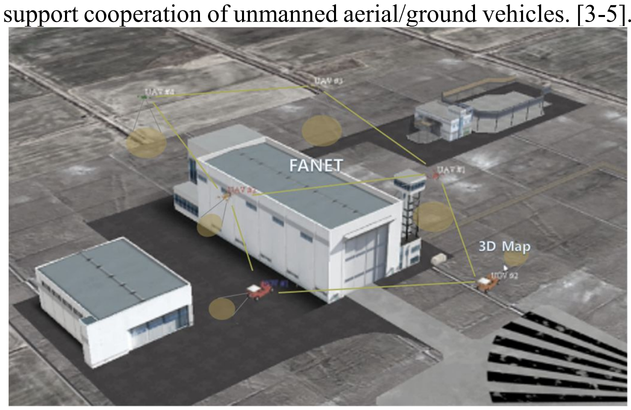

Fig. 1: Scenario of Cooperative Multiple Unmanned Vehicles

II. SYSTEM ARCHITECTURE

Multiple unmanned vehicles conduct a cooperative mission scenario as in Fig. 1. There is a mission area where several unmanned vehicles perform 3D point cloud map through 3D scanning and UGV provide a battery charging facility to UAV system to enlarge mission execution time of UAVs. In addition, Fig. 2 shows the system architecture of autonomous cooperation management system for multiple-heterogeneous unmanned vehicles. This system is divided into UAV/UGV components with flying ad-hoc networks (FANETs), ground computer system (GMCS), data logger system (DLS), image generation computer (IGC), and UV monitor for vehicle status monitoring.

III. NETWORKING FRAMEWORK

A. Relative Velocity-based Geolocation Routing Protocol

To support network delivery path construction in an ad-hoc manner, we provide a routing protocol on top of FANET HW

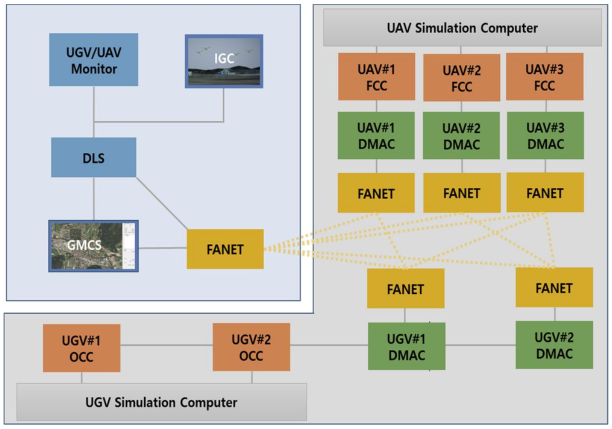

Fig. 2: Architecture of Unmanned Vehicles Management System

modem. For this, in the environment where the unmanned vehicles are operated, each unmanned vehicle broadcasts a navigation information which includes the position, speed, and direction of them for anti-collision and monitoring surveillance information at the ground control center. The ad-hoc routing technology for configuring the unmanned vehicle networking needs to be developed considering routing performance and control message overhead. However, state-based ad-hoc routing networks, storing routing information, can be affected by a large variation in its topology and this results in frequent data delivery failure. Therefore, the routing path configuration method regarding the mobile unmanned vehicles should operate with the stateless-based technology which is geolocation-based routing method being adaptive to dynamic topology changes and minimizing the control overhead. [6]

Relative velocity-based geolocation unmanned vehicle routing technology works as follows. Each unmanned vehicle broadcasts its navigation information with a certain period. The neighbor unmanned vehicle that receives this information records the ID, navigation information, and time in the neighbor and position table. In this configuration, to build a routing path, the neighbor and position table are only considered therefore, routing overhead could be minimized. In addition, when sending the data, next-hop node is selected based on the neighbor table which is closed to the destination node in greedy manner. Furthermore, since the relative velocity and link quality for the neighbor nodes at the current time is considered, it could show more reliable routing path selection. These reflect the characteristics of very high-speed mobility and dynamic topology of the unmanned vehicle in the routing mechanism.

Moreover, path/trajectory, speed, and mobility are different, and it depends on the mission scenario and the type of applied mission unmanned vehicles. Accuracy of this information is very important because proposed relative velocity-based geolocation routing protocol is based on navigation information which is broadcasted by neighbor nodes. Therefore, a mechanism for adjusting the broadcasting period of the navigation information is based on the mobility of the unmanned vehicles. For that, period setting control message delivered from the ground control center, each unmanned vehicle sets an initial broadcasting period and adaptively adjusts the broadcasting period of the navigation information according to the speed information when it becomes to change of the mobility according to mission execution.

B. Testbed and Experimentation

In our development, the routing daemon runs on an embedded Linux system configured for routing protocol operation and testing, and the utilized radio communication technology is PHY/MAC protocol over an 802.11p WAVE standardization. [7] The communication FANET board as in Fig. 3 is mounted on the ground control center and the unmanned vehicles. Through the serial interface in the communication board, the application data can be exchanged between the communication board and the ground control center computer, the communication board and the unmanned vehicles computer.

In the environment where the unmanned vehicle moves and performs mission, the topology among nodes varies with time elapsed because the positions of every node changes dynamically. Therefore, for the routing test, it is an important consideration we need to check the routing path of the application data to the destination through the developed FANET geolocation routing protocol and to monitor the topology configuration dynamically among the unmanned vehicles. To enable the topology to be monitored, in this testbed, the location information of the node and the neighbor node table information of every node are delivered to the ground control center. Then, the ground control center is configured to translate each information to the corresponding data format for the oneM2M standard based platform.

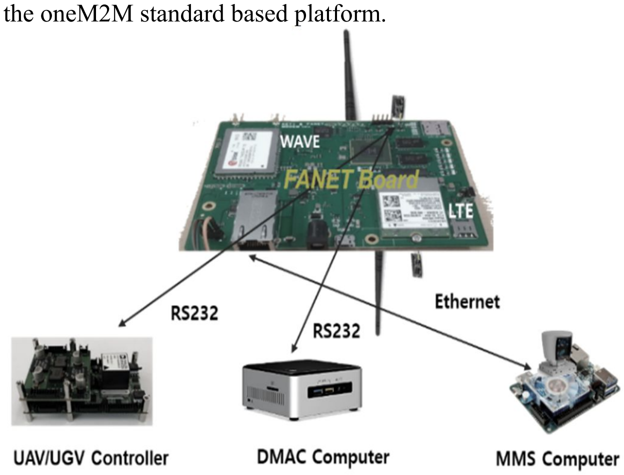

Fig. 3 Communication Modem of FANET

oneM2M platform, which is used here, is a standard-based software platform being able to accommodate various use cases in the internet of things (IoT) services, and it has a feature of great scalability, which provides an interworking proxy interworking with various legacy systems. [8,9] In our test environment, the FANET translated to oneM2M interworking proxy is installed in the communication FANET board and then it is linked to the ground control center for the topology monitoring. The interworking proxy entity is responsible for converting the FAENT application message to oneM2M standard message format, and through the oneM2M resource browser, it is possible to monitor the unmanned vehicles' location and topology information over the oneM2M platform in real-time. For our FANET routing testbed environment, the topology monitor was developed and applied as a tool that can visualize the topology each unmanned vehicle, which location and neighbor table information were collected through the ground control center. The topology monitoring tool supports the registration of unmanned vehicle nodes on the testbed and displays the topology status via a graph structure with nodes and links as in Fig. 4.

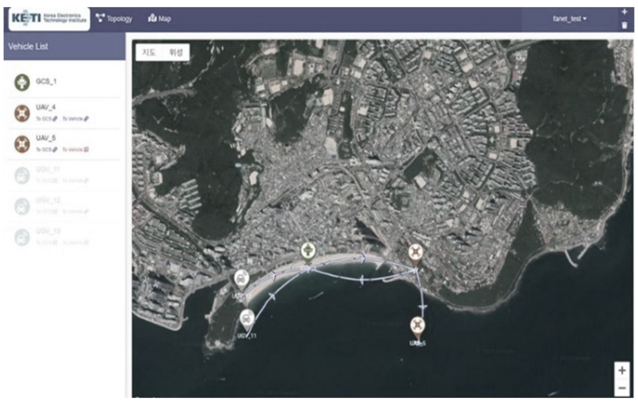

Fig. 4: Topology Monitoring System

IV. CONCLUSION

The development of networking framework for multiple heterogeneous unmanned vehicles in FANETs has been introduced. Furthermore, we propose relative-velocity based geolocation routing protocol which can support ad-hoc network without infra network environment operated over our routing testbed environment. In the future, we plan to integrate each developed component for autonomous cooperative platform which includes UAV, GMCS, DLS, IGC, 3D Mapping, UGV, MMS, landing pad and FANET modem.

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