Hello-Message Transmission-Power Control for Network Self-Recovery in FANETs

Geon-Hwan Kim
School of Electronics Engineering,
Kyungpook National University,
Daegu, Korea
kgh76@ee.knu.ac.kr

Imtiaz Mahmud
School of Electronics Engineering,
Kyungpook National University,
Daegu, Korea
imtiaz.tee@gmail.com

You-Ze Cho
School of Electronics Engineering,
Kyungpook National University,
Daegu, Korea
yzcho@ee.knu.ac.kr

***Abstract*—** ultiple UAV-based researches have attracted much attention in recent years. For the UAVs to perform their missions appropriately in a given environment, a reliable connection between the UAVs and the ground control station (GCS) is most important. To connect a disconnected UAV to the network, the UAV must move within the transmission range of the other UAVs connected to the network. In this regard, broader neighbour discovery can increase network recovery success rates. In this paper, we propose a broader neighbour discovery scheme for network recovery by increasing the transmission power of Hello messages. The proposed scheme can improve performance in terms of packet-delivery ratio and overall network disconnection time.

Keywords*— *UAV; FANETs; network self-recovery; Hello message; transmission power; power control

I. Introduction

In recent years, various applications using unmanned aerial vehicles (UAVs) have been introduced. Although a single UAV has been in use for decades, there are a variety of applications using multiple UAVs [1]. Because UAVs typically operate in a dynamic environment, network disconnection between UAVs can occur frequently. An isolated UAV needs to know the location of a UAV in the network to return to the network. In an isolated situation, the location information of the UAV in the network can not be obtained with normal Hello message transmission power. However, by increasing the transmission power of the hello message, the location information of the far UAV can be obtained, and the network recovery can be performed by moving in this direction.

The idea of adjusting the transmit power of ad hoc nodes has been introduced in many literatures [2, 3]. However, these schemes apply power changes to all transmission packets or power adjustments to find the optimal transmission power.

In this paper, we propose a broader neighbour discovery scheme for network recovery by adjusting the transmission power of the hello message, but all data packets are always transmitted with normal power. After acquiring the location information of the far UAV included in the network, the transmission power of the hello message is returned to the normal level.

In our previous work [4], we proposed a technique for returning to the network through sequential movement using neighbour information. This technique performs recovery based on past neighbour's locations, however, probability of recovery failure increases when the neighbour UAV's mobility is high. Also, because the isolated UAV performs the neighbour discovery with normal transmission power, it does not know the exact location of the neighbour until it reaches within the transmission range of the neighbour.

Therefore, in this paper, we propose a new method of obtaining the far UAV location information and recovering the network by adjusting the transmission power of the Hello message, which is a periodically exchanged for maintaining communication links with neighbouring UAVs. The proposed scheme was evaluated in terms of packet-delivery ratio and total network disconnection time.

This research was supported in part by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2015R1D1A1A01059623) and by the Next-Generation Information Computing Development Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (no. NRF 2017M3C4A7083676, 2017M3C4A7066010).

II. PROPOSED SCHEME

A. *Power control of hello message for broader neighbour discovery*

In our previous work [4], each UAV periodically transmits a Hello message containing its ID and GPS data. In that case, the Hello message is transmitted at a normal power level, and the neighbour discovery is performed until the recovery UAV is within the communication range.

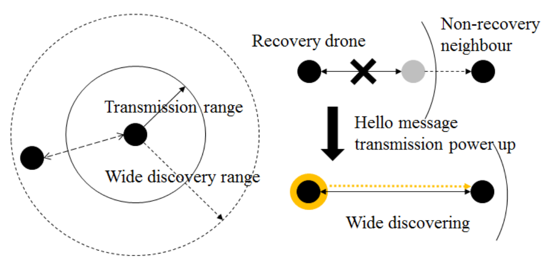

Fig. 1. Transmitting controlled-power Hello message to neighbour discovery.

In this paper, we propose to transmit Hello message at high power level in recovery mode. Therefore, it will be possible to know the location of the UAV which is further than the current transmission range, and the movement to the neighbour location for the recovery can be achieved in a shorter time. The data packet is transmitted at a normal power level after successful network recovery. Figure 1 shows the extended discovery range according to the increase of the transmission power, and it is able to obtain the new location information for the recovery by transmitting the Hello message to the broader range. The Hello message consists of a UAV ID, location information, and two flags as shown in Table I. The recovery flag indicates to the neighbour whether the UAV is in recovery mode or not. The tx-level flag indicates at what power level this message was sent from the sender.

B. Role of recovery and tx-level flags

The recovery UAV sends high-power Hello messages with recovery_flag = 1, tx-level_flag = 1. When a non-recovery UAV receives such a Hello message, it sends a high-power Hello message with recovery_flag = 0, tx-level_flag = 1 in response. When the recovery UAV receives this Hello message, it moves to the new neighbour's location. If it receives a Hello message with recovery_flag = 1, tx-level_flag = 1, it discards the message because it was sent by the other recovery UAVs. Similarly, in the case of a non-recovery UAV, it discards Hello messages with recovery_flag = 0, tx-level_flag = 1. This is because a UAV that sends high-power message during non-recovery mode just sends a response to help the network recovery of the isolated UAVs. In a typical communication between non-recovery UAVs, both flags are set to 0.

TABLE I. EXAMPLE OF HELLO MESSAGE

UAV ID	Location (*latitude, longitude, altitude*)	Recovery flag	Tx-level flag
192.168.3.3	35 °, 128 °, 14.8 m	1 : recovery 0 : non-recovery	1 : high 0 : normal

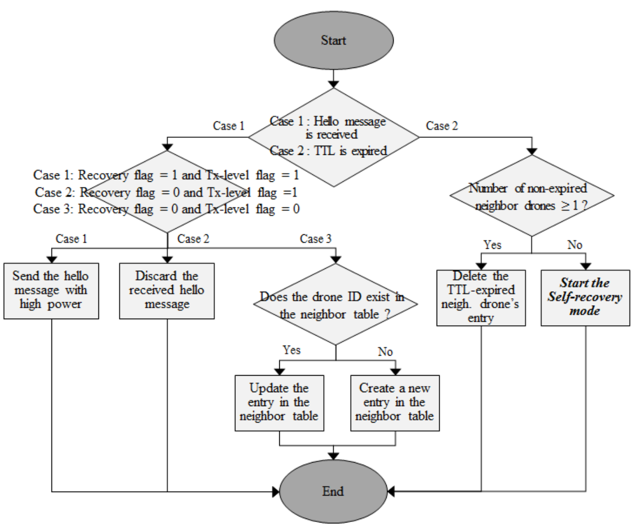

Fig. 2. Flowchart of the main operation of the proposed scheme.

All UAVs operate according to the main operation flowchart shown in Fig. 2. When a UAV receives a Hello message from its neighbour, it checks the flags to determine what action to take. If both flag values are 1, it transmits at high power to aid the network recovery. In case of recovery flag is 0 and tx-level flag is 1, it discards the received message. If both flag values are 0 (communication between non-recovery UAVs), the neighbour table is checked whether the UAV ID exist in the table and the entry is updated or created. If the TTL value of a particular entry expires while information about other neighbours remains in its neighbour table, the expired entry is deleted. If the entry whose TTL has expired is the last neighbour, it is in a state of being disconnected from the network and begins the network self-recovery procedure.

C. Network self-recovery procedure

The self-recovery is performed in three steps. The difference from the previous proposal is that the transmission power of the Hello message is increased when each step is performed. When moving to its previous location for the first recovery attempt, it transmits a high-power Hello message, sets power back to normal, and moves. Upon receiving a response to the high-power message, it moves in the direction of its new neighbour. If it reaches its destination without receiving any response, it sends another high-power Hello message for the second recovery attempt. When it starts moving to the last neighbour's position for the second attempt, the process from the first attempt is repeated. If the second attempt also fails, it moves to the GCS for the final attempt.

III. PERFORMANCE EVALUATION

To evaluate the controlled-power Hello message scheme, we simulated a specific scenario. The performance metrics were packet delivery ratio and total network disconnection time. Network-Simulator 3 (NS-3) was used as the simulation tool.

A. Simulation environment

TABLE II. SIMULATION PARAMETERS

Parameter	Values
Map size	5,000 x 5,000 m
Simulation time	1,800 s
Routing protocol	OLSR, AODV
Number of UAVs	3
UAV velocities	15, 25, 35, 45, 55 (m/s)
Relay UAV velocity	30 m/s
Transmission range	1,000 m
Transmission power	16 dBm, 26 dBm
Loss model	Friis propagation loss model
Message size	1,000 bytes
Transmission rate	1 Mbps
Data packet interval	1 s

In the simulation scenario, three nodes are used: GCS, relay UAV, and mission UAV. The GCS is stationary at (1500, 1500), and the relay UAV moves at a fixed speed of 30 m/s along a square-shaped path within the transmission range of the GCS's normal power. The mission UAV is randomly moved according to the Random Waypoint Mobility Model and goes into recovery mode when network disconnection occurs. The basic transmission power of the UAV is set to 16 dBm, and the increased power level has a value of 26 dBm. The GCS transmits 1,000 byte packets at intervals of 1 s.

We ran the simulations and compared the packet-delivery ratio of the source to the destination through the relay UAVs using the Optimized Link State Routing Protocol (OLSR) and Ad hoc On-demand Distance Vector Routing (AODV) routing protocols [5, 6]. In addition, we compared the total network disconnection time of the mission UAV. The simulation parameters are presented in Table II.

B. *Simulation results*

The performance was evaluated in terms of packet-delivery ratio and total network disconnection time. For each metric, OLSR and AODV routing protocols were used.

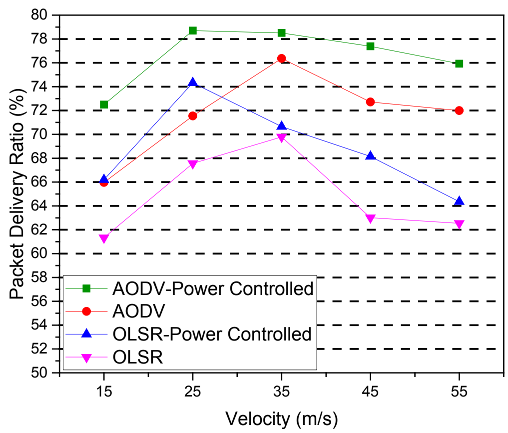

Fig. 3. Packet-delivery ratio according to mission UAV velocities.

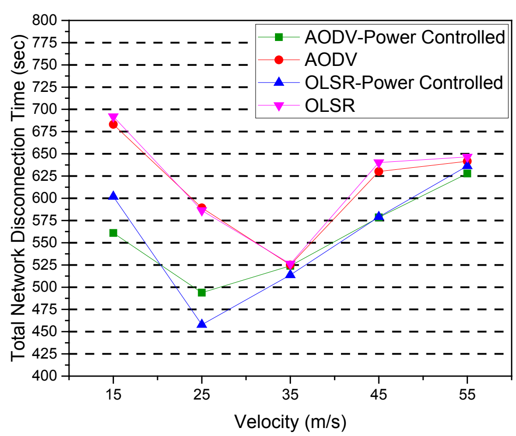

Fig. 4. Total network disconnection time according to mission UAV velocities.

Fig. 3 shows the packet-delivery ratio for the Hello-message transmission-power control scheme and the previous scheme, for different routing protocols. The power-control scheme with AODV showed the best performance. When the mission UAV is at low speeds, the recovery movement is slow; thus, it has a relatively low packet-delivery ratio. It shows the highest value at 25 m/s and gradually decreases as the velocity increases. On the other hand, the previous scheme showed the highest performance at 35 m/s and gradually decreased as the velocity increased as well. Overall performance with OLSR was lower than that with AODV. Even the power-control scheme with OLSR gave much lower performance after 35 m/s than the previous scheme with AODV. The power-control scheme with OLSR showed the highest value at 25 m/s and showed better performance than the previous scheme with OLSR.

Fig. 4 shows the total network disconnection time for the mission UAV over the velocities. The total network disconnection time represents the sum of the time when the mission UAV separated from the network consisting of the GCS and the relay UAV. Therefore, the lower the disconnection time, the longer the time included in the network. In the case of the previous scheme, the disconnection time was almost the same regardless of the routing protocol, and the lowest was observed at 35 m/s. On the other hand, the power-control scheme showed better performance in low-velocity environments, and the lowest disconnection time at 25 m/s. In the high-velocity environments, the proposed scheme and the previous scheme have similar results.

In summary, the proposed scheme showed the highest packet delivery ratio when AODV was applied. And the simulation results demonstrated that the proposed scheme improves performance for both simulation metrics.

IV. Conclusion

In this paper, we proposed a Hello-message transmission-power control scheme for network self-recovery in FANET environments. Its main purpose is to increase the network performance by changing the transmission power of the Hello message based on the network self-recovery scheme proposed in our previous study. Simulation results showed that the proposed scheme exhibits better performance for packet delivery ratio and total network disconnection time.

Acknowledgment

This research was supported in part by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2015R1D1A1A01059623) and by the Next-Generation Information Computing Development Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (no. NRF 2017M3C4A7083676, 2017M3C4A7066010).

References

[1] L. Gupta, R. Jain, and G. Vaszkun, "Survey of important issues in UAV communication networks," IEEE Commun. Surveys Tuts., vol. 18, no. 2, pp. 1123-1152, 2nd Quart., 2016.

[2] E. S. Jung, N. H. Vaidya, "A Power Control MAC Protocl for Ad Hoc Networks," in proc. of ACM/IEEE MobiCom, 2002.

[3] S. Harold and A. Vija Y Alakshimi, "Enhanced Power Control MAC Protocol for Wireless Ad Hoc Networks," in proc. of Communications and Signal Processing (ICCSP), 2012.

[4] G. H. Kim, I. Mahmud, and Y. Z. Cho, "Self-Recovery Scheme Using Neighbour Information for Multi-UAV Ad Hoc Networks," in proc. of 23rd Asia-Pacific Conference on Communications (APCC), 2017.

[5] T. Clausen, and P. Jacquet, "Optimized Link State Routing Protocol (OLSR)," RFC 3626,. 2003.

[6] C. E. Perkins, and E. M. Royer. Ad Hoc On Demand Distance Vector (AODV) Routing. Draft-ietf-manet-aodv-02.txt, 1998.