A Simulation Study for Typical Routing Protocols in Aircraft Ad Hoc Networks

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Abstract

Followed by our previous works, a study for performance evaluation of existing typical routing protocols for aircraft ad hoc networks is presented in this paper. The main objective of this evaluation is to figure out the impact of high speed movement and spare deployment over well-known routing protocols with new mobility pattern for aircraft ad hoc networks. The chosen protocols are three major protocols according to general categorization, this is, AODV, DSDV, and GPSR. By analyzing the result of performance evaluation, we demonstrate the suitability of those in aircraft ad hoc networks in the terms of packet delivery ratio, end-to-end delay and control overhead and discuss further works in this research area. Finally, rough conclusion is made that it is necessary to develop new routing protocol based on DTN for aircraft ad hoc networks.

Keywords: aircraft ad hoc networks, mobility model, performance evaluation

1. Introduction

In the pure mobile ad hoc networks (MANET) [1], participating nodes are willing to construct self-organizing networks without any help of centralized point whenever it is needed. Thus, a node should collaborate with other nodes to build networks autonomously in a distributed way. One of the most outstanding features in this kind of networks is mobility support. Thus, each node is allowed to move anywhere and anytime freely in this network. As compared to existing network technology, the need of mobile ad hoc networks increases rapidly because many applications are demanding it. Example of communication environments for mobile ad hoc networks includes communication in tactical area as well as disaster area where infrastructure network is not available or rapid network deployment is required. Moreover, both telecommunication and teleconference are good examples for application in these environments.

Recently, AANET [2] (Aircraft Ad Hoc Networks) have been proposed. In these networks, aircraft is envisioned to participate as a self-aware node and communicates with ground infrastructure and other aircrafts. Thus, these networks show different features with typical ad hoc networks in that information becomes available through in-aircraft, aircraft-to-ground and aircraft-to-aircraft communications. With help of these networks, traffic between aircrafts can be distributed and is regarded to have improved reliability as well as scalability. Based on this property, the need of aircraft ad hoc networks increases due to an unprecedented increase in air traffic, fuel costs and environmental pollution.
Since the topology of the network is constantly changing, the issue of routing packets between any pair of nodes becomes a challenging task. Routes between nodes may potentially contain multiple hops, which is more complex than the single hop communication. For the routing protocol, much research has been conducted to establish the path between source and destination. Thus, when it comes to develop routing protocol, performance evaluation of the existing protocols can be good approach to analyze the properties of networks as well as understand the requirement of new protocol. Based on above demand, in this paper, we will conduct simulation study of existing ad hoc routing protocol for aircraft ad hoc networks. For the study, three famous protocols are concerned. They are AODV[3], DSDV[4] and GPSR[5].

To precede the simulation study for AANET, it is strongly recommended to take previous case, evolving from pure ad hoc networks to vehicular ad hoc networks. When research for VANET (Vehicle Ad Hoc Networks) started, first of all, the study for simulator became one of important research challenges[6] because we need to gain insight into the operation of those systems. Even though traditional the formal modeling of systems via a mathematical model that attempts to find analytical solutions to problems as well as enables the prediction of the behaviors of the system from a set of parameters and initial conditions are possible in VANET, however sometimes it is even painful and inaccurate. Thus, it is very important to prepare related components for simulator. But, current networks simulator does not include the corresponding components at all. Among those, the mobility model or movement trace is essential one because each network has the significant different mobility pattern. This indicates that the realistic mobility model for aircraft should be obtained. For the mobility model, we implemented new software which is connected with commercial flight simulator[7]. The detail software architecture will be explained in following section.

By analyzing the suitability of three routing protocol, we can recognize the impact of mobility model in AANET as well as presents design principle for new routing protocol for AANET. The performance of routing protocol is evaluated by varying the mobility speed or different mobility pattern which follows the two kinds of missions. One is random walk mobility model and the other is mission based mobility model.

The rest of this paper is organized as follows. The software architecture to get realistic mobility model is presented in Section 2. And then, the performance evaluation of routing protocols are described and analyzed in Section 3. Finally, conclusions and further works are given in Section 4.

2. Realistic Mobility Model for AANET

In this section, we propose how to generate realistic mobility scenarios for each simulator. Instead of mathematical model, we propose how to develop software which makes use of commercial flight simulator, Microsoft Flight Simulator [8]. This software provides an artificial re-creation of aircraft flight and various aspects of the flight environment. Under the architecture, a user can place multiple aircrafts at anywhere. And then, the position of this aircraft is converted to corresponding position on Flight Simulator. After configuration for waypoint of aircraft and speed is done, actual movement is achieved on the Flight Simulator in a way automatic aviation. The position information of aircraft on Flight Simulator is traced and then converted to corresponding format for each simulator. As a result, realistic mobility model is achieved by using the actual model for aircraft and environment.
Figure 1. Software Architecture for Generating Mobility Trace

Figure 2 shows the software component to obtain mobility model. New software has five components and their detail description is shown below.

Figure 2. Component Diagram

- Topology Configuration: In this component, a user creates aircraft and sets its type. Also, some information for speed is initiated and the consecutive waypoints are determined. It also includes function to start and stop simulation.

- Object Creation: When the topology configuration events are passed to object creation component, actual aircraft is created in Flight Simulator. Also, passed information form topology configuration is used to set up simulation scenarios in Flight Simulator.

- Data Record: During the aviation in the Flight Simulator, all position information along the waypoint is recorded. The information includes the latitude, longitude, speed, and the simulation time.
• Movement Display: For the validation, new software includes component for displaying movement. For the movement, recording data is converted to corresponding data in a component which uses different system for position and speed.

• Data parsing: According to the networks simulator, this component parses the data file obtained in Data Record component and creates the corresponding formats.

3. Performance Evaluation

In this section, we present the simulation results for three routing protocols with gathered trace file by our new software. The simulation is conducted by ns-2[9] simulator and other parameters for scenarios are described in Table 1. Since there is not standard protocol for MAC layer, we introduce IEEE 802.11 as similar to AeroRP [10].

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAC protocol</td>
<td>IEEE 802.11</td>
</tr>
<tr>
<td>Propagation model</td>
<td>Two-ray model</td>
</tr>
<tr>
<td>Aircraft type</td>
<td>F-18</td>
</tr>
<tr>
<td>Initial position</td>
<td>Uniform distribution</td>
</tr>
<tr>
<td>Traffic</td>
<td>CBR over UDP</td>
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</tbody>
</table>

4.2 Simulation Results

We evaluated the three routing protocol as a function of nodes. The total number of nodes is 10, 20, 50 and 100. We measure the packet delivery ratio and end-to-end delay with number of nodes and realistic mobility model. Figure 3 illustrates the packet delivery ratio.

In Figure 3, all protocols show the low packet delivery ratio. The main reason for this result is caused by the following fact that the current routing protocols cannot cope with such a high mobility. Moreover, sparse deployment is another main source of low packet delivery ratio. More detailed, GPSR shows the better performance than other two protocols. Since the GPSR uses the geographic information to determine the next hop, the effect of dynamic topology is not great as compared to other two protocols. Also, since the waypoints used in our scenarios are not changed significantly, the less impact is considered in the packet delivery ratio. On the other hand, DSDV shows the worst performance in packet delivery ratio. Due to spares deployment, the topology information is not propagated into the whole network adequately. Thus, the routing information based on this topology cannot contain the last information. In a case of AODV, it shows the better performance than DSDV in a usual case. However, due to high mobility speed and sparse deployment, a path established by the RREQ message is not maintained until the RREP message is arrived. This means that different paths between source and destination are established. For all protocols, there are similar pattern for enhanced packet delivery ratio as the density of nodes increases. This fact implies that it is very hard to guarantee packet delivery in sparse environment.
In addition to packet delivery ratio, end-to-end delay is another parameter to evaluate the performance of routing protocols. As you can see in Figure 4, GPSR shows the shortest end-to-end delay by no additional overhead to construct routing table. However, since the simulation model in ns-2 does not include the time to get the geographical information, their actual end-to-end delay including control packet will increase. On the contrary, AODV shows the longest end-to-end delay because it needs to establish the path on demand way. In addition, as described in analysis for packet delivery ratio, it takes longer time for path setup than typical movement pattern to find the same path for forward and reverse link. Thus, a node should wait for long time until path setup procedure is accomplished. On the other hand,
the end-to-end delay of DSDV is shorter than AODV because packet forwarding procedure does not include additional delay for constructing table. This means that if a packet is delivered to the destination correctly, its end-to-end delay is shorter than other protocols even though end-to-end delay of many lost packets is not computed at all.

![Diagram showing control overhead as a function of number of nodes.]

**Figure 5. Control Overhead as a Function of Number of Nodes**

In addition, we compare control overhead in three protocols. Control overhead is measured how many control packets are issues as compared to data packets. This is measured by dividing total number of data packets into total number of control packets. Generally, one of key feature of GPSR is control packet is not required because routing information based on table is not built. However, in order to use geographical information, it is necessary to exchange information the current position information between source and destination, we include this procedure into control overhead. Even though the procedure is additionally concerned in measurement, the control overhead of GPSR is relatively low. Thus, we illustrated the relative value for other protocols when control overhead of GPSR is set to 1. Figure 5 shows the simulation results for control overhead. When we compare two protocols, AODV and DSDV, very different pattern is observed. In case of DSDV, control overhead increases as the number of nodes does. This is caused by the basic operational principle, proactive way. When the number of nodes increases, many links are connected and disconnected very frequently. Since DSDV rely on this frequent events, the control overhead becomes bigger and bigger. On the other hand, the control overhead of AODV becomes smaller and smaller as the number of nodes increases. When AODV is employed in sparse area, there is large number of attempt to find the path between source and destination. Also, even though path is established, the link is highly likely to be broken at early time in sparse area. This fact increases the number of control overhead. However, when the number of nodes increases, the path is easily established and maintained with lower control overhead. Based on above analysis, two protocols reveals different pattern for control overhead in aircraft ad hoc networks.
4.2. Discussion

Due to outstanding properties such as high dynamic topology and sparse deployment, it is very hard to guarantee sufficient performance for AANET through current routing protocol. This fact implies that a new routing protocol should be developed for AANET. Also, throughout analysis for simulation results, we can identify that geographic routing protocol will be good candidate rather than topology based one. Since all aircraft make use of geographic position information for aviation, it is not difficult task to get it. With above reason, it seems reasonable to extend the current geographical routing protocol for AANET. Furthermore, since AANET is deployed in a three dimensional area, an extension of existing protocol is required.

Another issues worthwhile mentioning is to introduce DTN architecture for high packet delivery ratio. Even though some DTN applications are allowed in AANET, sparse deployment accelerate to employ this architecture since network partition frequently happens in this networks. However, as mentioned before, only adequate application can be deployed over this architecture.

4. Conclusion and Further Works

Simulation study is one of essential procedures while developing protocols in networks. Since each network has the different properties with other networks, a simulator should employ and include the special component. Among many components, mobility is one of key features to distinguish each network. In this point, many research works have been conducted to analyze their pattern. In this paper, we propose how to get the realistic mobility model for AANET. And, a study for performance evaluation of existing routing protocols is shown to analyze the impact of realistic model over them. Finally, we present the discussion for the simulation results.

For the further works, a new routing protocol mentioned in discussion section will be studied and developed. Also, other issues for realistic mobility model such as avoiding crash remains.

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References

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