A Novel Method to Improve Performance of Major Nodes in Military MANET

Vu Khanh Quy, Nguyen Dinh Han, Dao Manh Linh, Le Anh Ngoc

***Abstract*—Mobile Ad-hoc Network has been deployed in many aspects of science and human life. The fifth generation of mobile ad hoc networks is coming to provide us with a better and convenient communication tool. The characteristics and capacity of mobile ad hoc networks have been studied insightfully; in reality, it is still a hot research topic. In this paper, we introduce a novel approach to improving the performance of mobile ad hoc networks in areas such as military and security. We consider a model of mobile ad hoc networks in which nodes have different roles. We distinguish two types of nodes: major nodes (important) and ordinary nodes. Indeed, this distinction aims at forcing prior policies to support major nodes. We propose a new routing protocol, named SRPMM for this purpose. Simulation results (based on NS2 ver 2.34) showed that our protocol is very efficient. The simulation results show that our proposed protocol works effectively to improve throughput, reduce latency, save energy as well as improve packet delivery ratio at major nodes.**

***Index Terms*—Mobile Ad-hoc Network, Routing Protocol, SRPMM, Military MANET.**

I. Introduction

In recent years, Mobile Ad hoc Networks (MANET) have been strongly applied in many fields such as industry, commerce, healthcare, and rescue. Thanks to the outstanding advantages such as flexible connectivity, fast deployment, and no dependency on fixed infrastructure, MANET is expected to be very popular in the future [1-2]. However, due to the relatively low network performance, the application of MANET in the military and security fields is still a very current and urgent research topic [3-4].

When applying MANET in the military domain, one of the most concerned research problems today is improving network performance [5, 6]. Due to the requirements and operating conditions, in addition to the ability to operate similarly to conventional MANET, the MANET used in the military must have other capabilities. In this study, we consider a unique MANET model, which has features suitable for the actual operational conditions. For the convenience of reference, we called this network is the military MANET. First of all, we analyze to clarify the need to use military MANET. In Fig. 1, we give an example of an electronic tactical system consisting of multiple entities (soldier, commanders, military equipment, UAV relay link). Each system entity is equipped with radio transceivers to exchange information. An entity can communicate directly with neighboring entities or indirectly communicate with remote entities through intermediate entities. As such, the entities of the aforementioned electronic warfare systems act as network nodes in a military MANET.

Note that, in a traditional MANET, the network nodes move freely and independently of each other. On the other hand, communication between MANET nodes is peer-to-peer and there is no distinction between the roles or the priority of the network nodes. However, military MANET often require network nodes to cooperate and adhere to tactics. For example, the mobility of a specific network node may depend on other nodes or must strictly obey the control signal from the system. Besides, under many conditions, the role of some nodes becomes more critical than others (e.g. node plays a command role, the node has a favorable operational position). At that time, the operation of a military MANET network will be quite complex and may require unique processing mechanisms to prioritize vital network nodes (primary nodes).

From the above analysis, we confirm that the known peer-to-peer communication mechanism is not entirely suitable for military MANET. For example, if we apply AODV [12] or DSR [13] protocol to a military MANET, there is no way to improve the performance of major nodes because they are no different from the common nodes. Therefore, in our proposed military MANET model, we clearly define the roles of network nodes.

Aim to focus on describing the main approach and concept, we only define two types of network nodes: the major nodes (commanders, operational equipment has an important role), called a Super-Peer (SP) and a regular node (soldier or military device), called a Peer (P). Obviously, in military MANET, SP_S have a more critical role and must be given priority over P. For example, messages originating from SP or messages delivered to SP often contain important information to control battle direction. These messages could be a request to move up, withdraw, or report the situation on the front lines for advice on the move up or withdrawing, etc.

In contrast, messages between P_S often aimed at mutual

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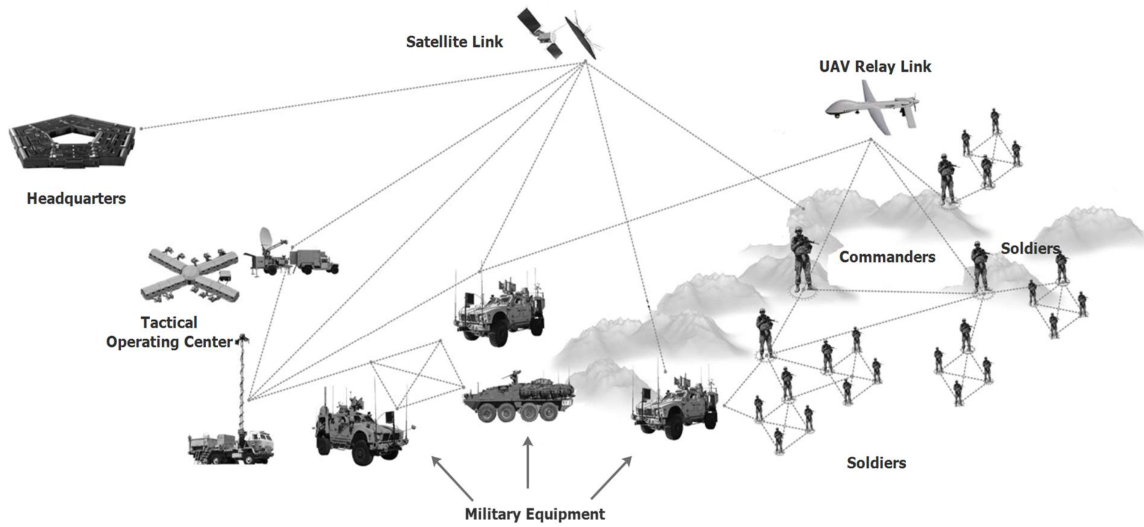

Fig. 1. An Illustration of the applied MANET in the Tactical Communication.

support or local combat. Aim to prioritize improving the performance (delay, throughput, power consumption) of SPs in a military MANET, we designed a unique routing protocol called SRPMM (Special Routing Protocol for Military MANET). The SRPMM protocol implements a policy that prioritizes messages (packets) originating from the SP or destined to SP.

The rest of this paper is organized as follows: In the next section, we present a survey of related studies. In section 3, we present the proposed SRPMM routing protocol. In section 4, we evaluate the performance and analysis results of the proposed protocol with the traditional protocol for MANETs, and section 5 is Conclusion.

II. Related Works

In realistic harsh environments such as a battlefield, the complexity of a vulnerable environment due to unpredictable physical and cyber-attacks from the enemy would seriously affect the effectiveness and practicality of these network routing protocols. Aim to solve this problem, over the years, the communication field of military MANET has been attracted the interest of both academia and industry.

According to energy efficiency direction, Evripidis Paraskevas $et\,al.$ [14] introduced a novel multi-metric routing protocol aim saving energy (called Modified OLSR), improved from OLSR. The focus of this proposal is a cost function based on three parameters: MAC queue size, node energy remaining, and the node degree. The simulation results on NS2 show that the proposed protocol achieves a significant increase in network lifetime (5-20%), without loss of performance in terms of packet delivery ratio.

Aim to enhance the reliability of network nodes in tactical MANET, according to this study direction, Lee $et\,al.$ [15] introduced a novel solution to enhances the reliability and survivability of the unmanned vehicle systems in tactical MANET. The authors used a centralized TDMA slot and power scheduling schemes to maximize energy efficiency and support QoS for the tactical MANET. The results indicated that the proposed protocol improved aspect on QoS and energy efficiency compared to existing protocols for tactical MANET scenarios.

According to improve performance direction for tactical MANET, Kim $et\,al.$ [16] introduced a routing protocol aim limited the effects of the friendly jam. Friendly jamming is occurred by the friendly mobile nodes but are hidden from all enemy mobile nodes. In this study, the authors proposed a solution that allows the routing protocol to freeze during jamming, then, it resumes when it non-jamming. Experiment results demonstrated that this proposed protocol significantly improved the packet delivery ratio and other metrics compared to existing OLSR-based routing protocols, include the single-path or multipath routing protocols.

Also according to this direction, Feng $et\,al.$ [17] introduced a novel routing protocol, the so-called GT-SaRE-MANET (Game-Theoretic Situation aware Robot Enhanced Mobile Ad hoc Network). In this study, the focus of the proposal includes two main tasks. Firstly, the authors use the online game theoretic reinforcement learning technique to control and monitor the movement of autonomous robots at tactical edges based on a new set of game-theoretic mission-oriented metrics to describe the interrelation among network quality, the movement of robots as well as potential attacking activities. Secondly, they have developed a distributed multi-agent game-theoretic reinforcement learning algorithm. This algorithm not only optimizes the proposed routing protocol and the movement of autonomous robots but also reduce attacks from the enemy by applied the game-theoretic mission-oriented metrics. Experiment results demonstrated that the proposed protocol improved performance metrics and optimal movement ability of autonomous robots in tactical MANET scenarios.

In a practical real tactical MANET environment, there will be some network nodes that have a vital role than other nodes. It can be command nodes. These nodes are essential than other nodes in tactical MANET; therefore, it needs to be prioritized over other nodes. This problem poses the issue of having a MANET model with priority nodes. The approach in this direction, Li $et\,al.$ [18] proposed the modelling

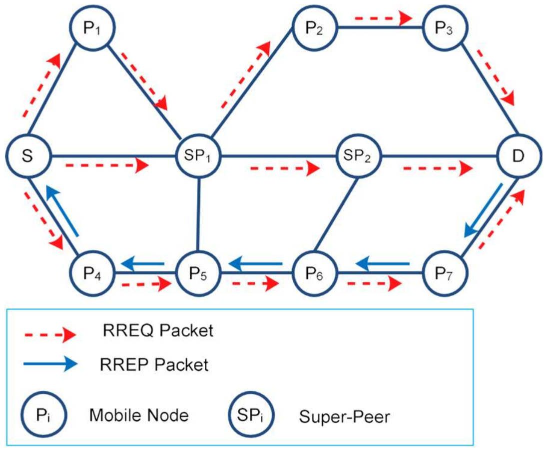

Fig. 2. An Example of military MANET model with nodes which have a heterogeneous role.

anonymous MANET communication using super-nodes. The focus of this study presents the concept of the super-nodes model and a novel routing metric based on distances, historical distance records, and hop numbers. Then, authors combine super-nodes and this routing metric to categorizes nodes into clusters. Experiment results demonstrated that this solution improved the accuracy aspect of recovering cluster formation based on super-nodes..

The survey results show that, in recent years, the military MANET has received much attention from researchers and can be divided into several main directions such as network security [19], improving performance [20-21], saving energy [22]. Besides, recent works [23-29] also show that research directions in general MANET and military MANET are very exciting and received notable interest from researchers.

III. Proposed Routing Protocol

A. System Model

According to the analysis above, we define a military MANET structure as follows: network nodes are divided into two categories, includes Super-Peer nodes (called SP) and Peer nodes (called P), where the SP_S are important network nodes, and Ps are common network nodes. Aim for messages sending to/receiving from SP_S have a minimum delay, the highest throughput as well as to save energy aim to preserve network communication, we proposal an outing protocol, called SRPMM. This protocol has communication principles are as follows:

(1) Packets sending to/receiving from SP nodes will be followed the shortest route.

(2) Packets sending and receiving from P nodes will be restricted to travel through the SP nodes unless it is the only path.

In Fig. 2, we consider an example of how the SRPMM protocol works using the two principles above of a node pair (S, D). We consider two cases.

Case 1: nodes *S* or *D* is an *SP* node. Then, the path from node *S* to *D* include nodes: *S*, SP_1, SP_2, *D*.

Case 2: both nodes S and D are P, then the path from S to D include nodes: S, P_4, P_5, P_6, P_7, D or *S*, P_1, P_2, P_3, *D*.

B. SRPMM Routing Protocol

The reality show, the prioritising the routing of messages sent/received from the *SP* nodes to vital messages can be sent/received to the commanding officers is an indispensable requirement of a military MANET. In this subsection, we present the specifications of the SRPMM protocol. The main purpose of the SRPMM protocol is to improve the

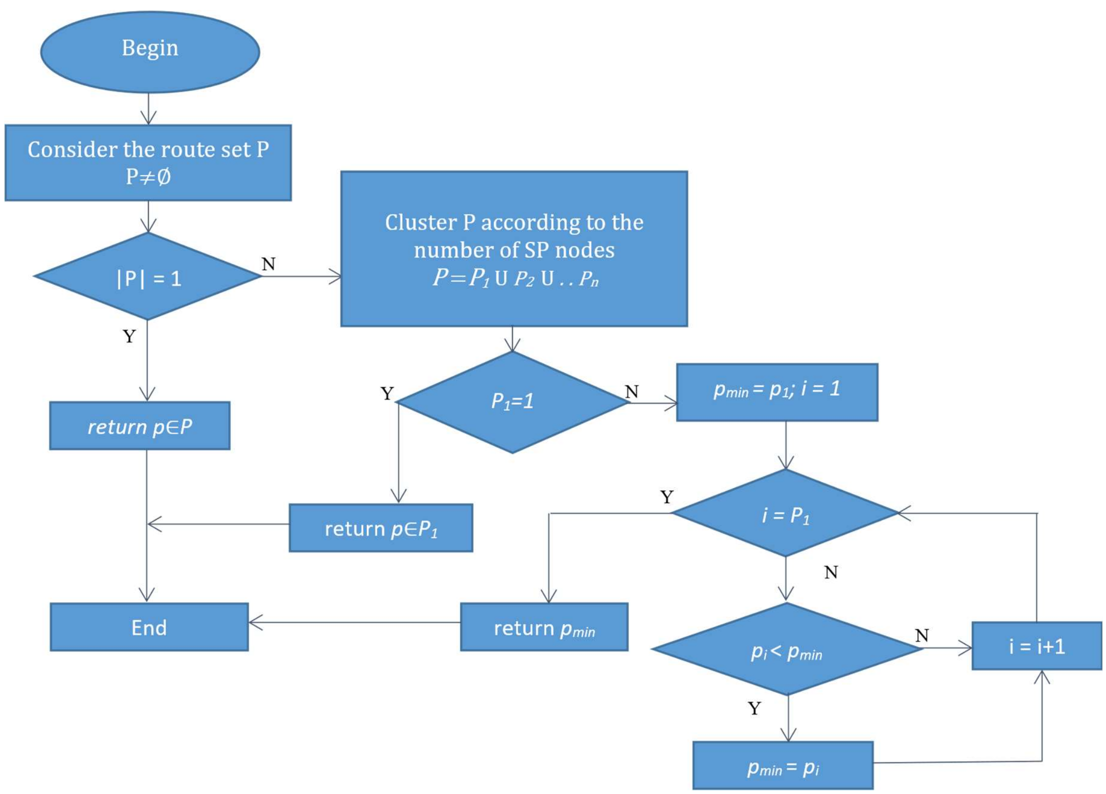

Fig. 3. Algorithm flowchart of route determination principle (2) of SRPMM protocol.

performance of SP nodes in a Military MANET aims to meet the two communication principles we proposed in Section 3. We assume that each P or *SP* node has all the features of a traditional MANET node. Furthermore, the management and control information for the network will be updated by a secret channel through private communication channels, called control channels. For example, the list of SP nodes will be updated to the entire network by the tactical operating center when there is a change, such as when the command node is destroyed, changed, or added. The network control and management information are stored temporarily and locally at P or SP nodes.

The SRPMM protocol consists of three phases to set up a route from the S node to D node, as follows:

Phase 1: S establishes the routes to D.

- S sends the RREQ packets broadcast to determine the route;
- The D or a node that contains the route to the D will send RREP packet to S;
- The S building the route to the D.

Phase 2: S determines the fit route from S to D.

- If S or D is an *SP*, then call the principle route determination algorithm (1).
- If S and D are both P, then call the principle route determination algorithm (2), described in detail in Fig. 3.

Phase 3: Pair of *S-D* nodes transmit/receive data.

Fig. 3 shows the algorithmic flowchart to determine a route between a pair of nodes (*S, D*) according to the principle (2). First, consider the set of routes (P) between the pair of nodes (S, D). If $P = 1$, equivalent, there is only one route going from S to D, the algorithm chooses this route and ends. In contrast, P cluster into a set of paths $\{P_1, P_2, \ldots, P_n\}$ according to the number of *SP* nodes. Consider P_1 (set of routes with equal and smallest *SP* number). If P_1 has only one path, the algorithm chooses that route and ends, else case, choose the most cost-effective path and ends.

IV. Simulation Results and Analysis

A. Performance Metrics

Packet Delivery Ratio of Super-Peer ($PDRSP$): Defined as the ratio of the number of delivered packets to the destination nodes SP_s over the number of sent packets by the source nodes SP_s:

$$PDRSP_{avg} = \frac{SP_r}{SP_s} \times 100\% \quad (1)$$

Average End-to-End Delay of Super-Peer ($DelaySP$): Defined as the average period to transmit a packet from source to destination:

$$DelaySP_{avg} = \frac{\sum_{i=1}^{n}(SPt_r - SPt_s)}{PSP_r} \quad (2)$$

$ThroughputSP$: the average throughput of the network is determined by multiply the packet numbers are transmitted and the packet size:

$$ThoughputSP_{avg} = \frac{PSP_r \times KT}{T} \quad (3)$$

where:

SP_r, is the received packet number by the destination node.
SP_s, is the sent packet number by the source node.
SPt_r, is the time the received packet at the destination node.
SPt_s, the time the packet is sent at the source node.
T, the time of the measurement process.
KT, the size of the packet.

B. Simulation and Results Analysis

In this subsection, we set up the simulation and performance evaluation of the system based on the following criteria: Average Delay, Average Throughput and Average Packet Delivery Ratio on NS2 simulation software, version 2.34 under two scenarios as follows:

1. *Performance evaluation of traditional MANET;*
2. *Military MANET model, as proposed in Section 2* (with the proposed SRPMM routing protocol), has 10 *SP* nodes.

In all scenarios, the simulation system consists of 500 nodes that play a role as P nodes. The P nodes are randomly arranged in an area of 1.000m × 1.000m. The number of CBR connections is set up equal to 50 (source-destination) pairs. The mobile nodes are set a random speed value in the range $[0, 2]$ (m/s). The points of measure are determined at the seconds: 50, 100, 150, 200, 250, and 300 (s) of each simulation. The remain simulation parameters are presented as in Table 1.

TABLE 1
SIMULATION PARAMETERS

Parameters	Value
Simulation area	1000m × 1000m
Number of nodes	500
Number of SP nodes	10
Time simulation	300 (s)
Type traffic	CBR
Throughput	11 (Mbit/s)
Size of Packet	512 (byte)
MAC Layer	802.11
Transport Layer	UDP
Mobility Modern	Random Waypoint
Transmission Area	250 (m)

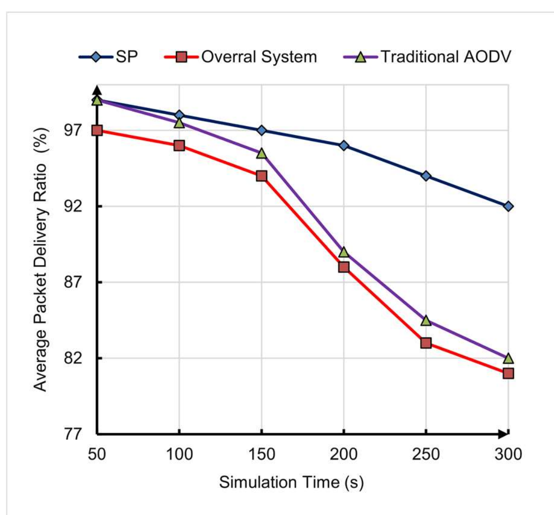

Fig. 4. Average Packet Delivery Ratio.

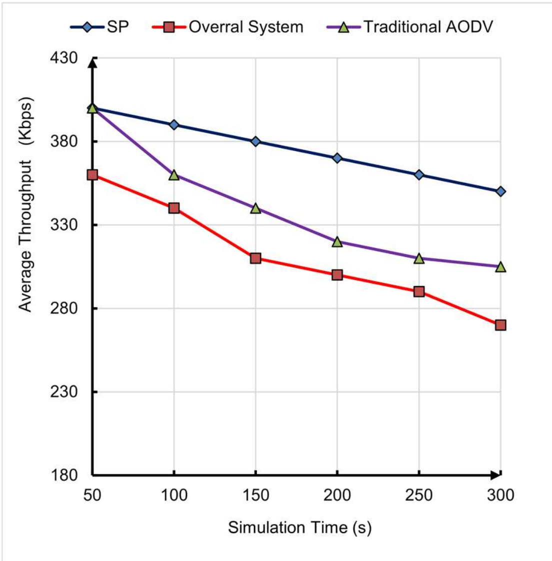

Fig. 5. Average Throughput.

Fig. 4 presents the results of the performance evaluation on the aspect of the packet delivery ratio. Simulation results of two scenarios indicated that the delay time increase according to the simulation time. In all scenarios, the packet delivery ratio of SP nodes is always high and stable despite the PDR of the entire network is lower than the traditional MANET. The experiment results are fully suitable with calculation and the principle of priority routing of SP nodes in our proposed military MANET model. Because data packets with source or destination SP are received and processed by the SP, the packet distribution rate of the SP nodes is very high and stable. As the network simulation time increases, along with the increasing network traffic, the PDR of the SP nodes tends to decrease, but still very high compared to the entire network.

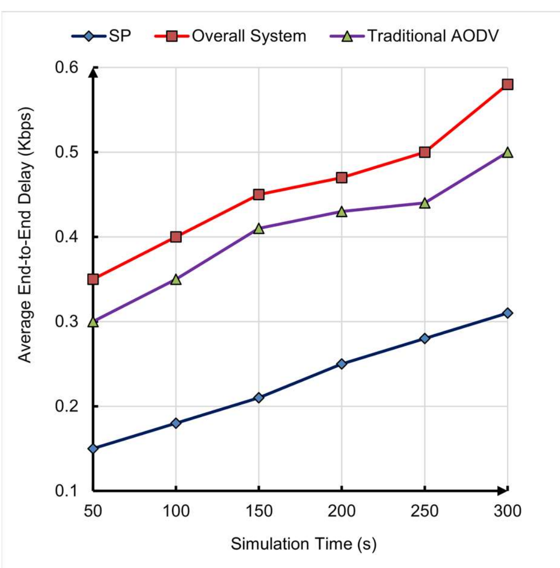

Fig. 6. Average End-to-End Delay.

Fig. 5 presents the results of the performance evaluation on the aspect of the average throughput. Experiment results indicated that the average network throughput tends to decrease as the simulation time increases. This result is inevitable because as simulation time increases, conflicts and congestion in the MANET tend to increase. However, the throughput of SP nodes in our proposed military MANET model always reaches the highest value and remains stable during the simulation.

Fig. 6 presents the results of the performance evaluation on the aspect of the average end-to-end delay. Experiment results indicated that the average end-to-end delay of the entire network increase with the simulation time. However, the delay of the SP nodes in our proposed network model is always the lowest and much lower than the delay of the traditional MANET.

V. Conclusions

In this work, we study and propose a military MANET model consisting of two types of network nodes with a heterogeneous role: a normal node, called a Peer (P), and a major node, called a Super-Peer (SP). We analyze to show that, with the military MANET model, the existing routing protocols for the traditional MANET need improvement to obtain the best network performance. Based on these, we propose a new routing protocol called SRPMM, improved from the AODV protocol. The simulation results show that the SRPMM protocol gives a higher performance of SP nodes while considering the performance of the whole network (including P and SP nodes), it gives lower results. These results are fit the fundamental requirements of the military MANET environments.

Author Contributions

Dr. Vu Khanh Quy made the system model, performed the simulation, and wrote this manuscript; Dao Manh Linh formatted the manuscript; Professor Nguyen Dinh Han and Le Anh Ngoc proofreading this manuscript. All authors had approved the final version.

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