Energy Efficient IDS Node Distribution Algorithm using Minimum Spanning Tree in MANETs

Sung Chul Ha*, Hyun Woo Kim**

Abstract

In mobile ad hoc networks(MANETs), all the nodes in a network have limited resources. Therefore, communication topology which has long lifetime is suitable for nodes in MANETs. And MANETs are exposed to various threats because of a new node which can join the network at any time. There are various researches on security problems in MANETs and many researches have tried to make efficient schemes for reducing network power consumption. Power consumption is necessary to secure networks, however too much power consumption can be critical to network lifetime. This paper focuses on energy efficient monitoring node distribution for enhancing network lifetime in MANETs. Since MANETs cannot use centralized infrastructure such as security systems of wired networks, we propose an efficient IDS node distribution scheme using minimum spanning tree (MST) method to cover all the nodes in a network and enhance the network lifetime. Simulation results show that the proposed algorithm has better performance in comparison with the existing algorithms.

Keywords : MANETs|IDS|Power Control|Minimum Spanning Tree

I. INTRODUCTION

Mobile ad hoc networks(MANETs) have gained much attention by the convenience of building wireless networks without need of any pre-existing infrastructure [1]. MANETs consist of mobile hosts which has limited resources, calculation abilities and information. Therefore, in MANETs, network security and survivability is an important issue. Many researches have proposed schemes considering the number of monitoring nodes to provide secure routing or the remaining battery power of nodes to enhance network lifetime [2]-[5].

An intrusion detection system(IDS) has been widely employed for security purpose in MANETs, because illegal attackers can destroy whole networks. Therefore, some networks nominate some nodes as monitoring nodes of IDS [6]. However, because the nominated nodes should monitor all the packets within communication range, they undergo additional resource consumption of batteries, time and so on. As resources such as power and bandwidth of nodes are limited in MANETs, an efficient IDS node distribution is needed to use resources effectively and enhance network lifetime [7], [8].

In MANETs, power control is an important issue. Co-channel interference can be reduced by using a judicious power control mechanism and the channel spatial reuse and network capacity can be improved, consequently [9]. As every node in MANETs has limited power, MANETs need an efficient power control algorithm to enhance network lifetime.

In this paper, we focus on energy efficient monitoring node distribution to enhance network lifetime in MANETs. For this, we apply minimum spanning Tree(MST) method to solve IDS node distribution problem. We develop an efficient distribution algorithm with battery consuming indicators based on MST method and the proposed algorithm has better performance.

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Manuscript: 2016. 12. 19
Revised: 2016. 12. 26
Confirmation of Publication: 2016. 12. 29
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This paper is organized as follows. Section 2 presents the discussion on related works. In section 3, we describe the proposed scheme. Section 4 contains simulation results and we conclude in section 5, finally.

II. RELATED WORKS

In MANETs, all communication is conducted in an open air environment. Therefore, MANETs have no fixed and well-protected communication mediums. In MANETs, network monitoring is performed at all nodes [6], [7]. Because this is not an efficient way, many researches have tried to make more efficient way for nodes to use their resources effectively.

Kachirski and Guha [6] proposed a distributed intrusion detection system(DIDS) for MANETs based on mobile agent technology. DIDS allocates total packet-monitoring task to a small subset of mobile nodes with high connectivity. However, network lifetime is quickly reduced since the load is concentrated to the selected mobile nodes. As a result, the monitoring nodes suffer from a shortage of battery power.

Kim et al. [7] proposed a lifetime-enhancing monitoring node selection(LES) scheme of choosing adaptively a node, for intrusion detection, which has a maximum remaining battery power between adjacent mobile nodes. In LES scheme, if there is a node which has relatively more battery power than a IDS node, the monitoring right is shifted to the new monitoring node. By distributing the battery power consumption with the nodes with relatively high remaining battery power, LES scheme can enhance the network lifetime. However, the monitoring node change can be too frequently in LES scheme.

In MANETs, network lifetime is defined as the duration of time until the first node is dead by whole battery out [7]. Because a single node failure means further communication services may be impossible in MANETs, network lifetime is highly significant measure.

As every node in MANETs has limited resources, all the nodes have to save battery power when they communicate with the other nodes. Bergamo et al. [1] proposed distributed power control(DPC) algorithm which acts in combination with the routing layer for energy efficient routing in MANETs. DPC algorithm estimates the amount of power which is needed for reliable communications. And the power is used to transmit packets over the link, and to search the minimum-weight path. Lin et al. [9] proposed a new power control medium access control(PCMAC) protocol. PCMAC protocol can eliminate the negative effects caused by the asymmetrical links. In PCMAC protocol, to avoid data packet collision at receiver, a separate channel for power control is used. All the packets which have CTS, RTS, ACK, and DATA are transmitted at the most profitable power level.

As MANETs are distributed system, these researches mainly consider MAC protocol and distributed scheme for transmission power control. Consequently, whenever one node communicates with the other nodes, it estimates the necessary power to reach its destination node and save battery power. Therefore, power control has an effect on the overall network lifetime. In MANETs, network lifetime is one of the most significant factors as an indicator to judge network quality.

In this paper, we propose an efficient IDS node distribution scheme for intrusion detection to enhance network lifetime. The scheme uses MST method [10] to find the most appropriate IDS node location. IDS nodes locate on MST of whole network and it is guaranteed that IDS node is the nearest node among the relative nodes. This means we can select transmission range and power control level which is appropriate to reach a target node. By transmitting power level control algorithm and using MST, the proposed scheme enhance network lifetime compare with DIDS and LES scheme.

III. PROPOSED ALGORITHM

1. Assumptions

We will concentrate our discussion on MANETs. MANETs are assembly of mobile nodes that dynamically establish a communication protocol. A new node can join the network any time and communicate with all the nodes in an entire network via the neighboring nodes. As there are no base stations, each node is responsible for managing accurate routing information, and should take part in routing decisions. We consider all nodes are distributed in limited area and have limited resources. Because of the properties of mobile nodes, they have limited battery power, transmission range and move dynamically. So, we consider that the distribution of nodes is randomly adopted and power consumption of nodes occurs whenever a node sends and receives a packet, overhears a packet and especially operates packet monitoring service as an IDS node [7].

2. Node Properties

In assumption, we define packet sending, receiving, overhearing and monitoring consume resources of nodes. These activities have all different power consumption level. Packet sending uses the most power because node uses power in proportion to distance value. In 3-dimensional space, the power increment caused by distance may be little. however, if communication environment is not stable, power will be dramatically larger. And then packet receiving, overhearing, and monitoring are in that order. Therefore, we need to take care of it not to waste resources of nodes.

3. A Basic Process to Make MST

Making MST is the start of node distribution in our proposed algorithm. Followings are the steps of making MST. Before making MST, we can think the nodes in a network are randomly distributed such as Fig. 1. The line means that communication is available and all the nodes are within 1 hop range.

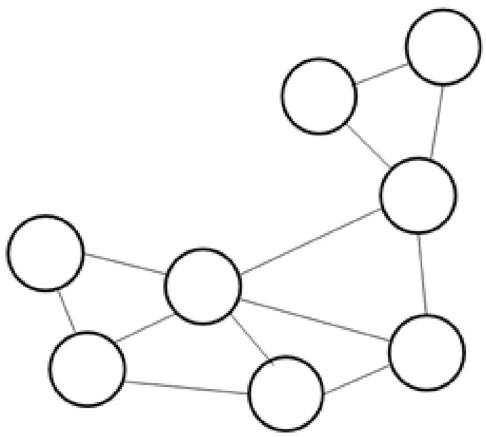


Fig. 1. Random node distribution

(1) All nodes in the network send their beacon messages.
(2) Each node detects its neighboring nodes and calculates the distance to neighbors.
(3) The calculated distance is used to select a bridge which is the nearest node of node i.
(4) After selection of the nearest node, a solid line is drawn between node i and the selected node as in Fig. 2.
(5) If all the nodes are connected by solid lines which can have some side branch, the process of making MST is finished. If not, the network may have many groups that consist of some nodes. Then go to (6).
(6) In Fig. 2, we can find 3 groups consisted of some nodes. Each group can find the nearest group and this step is similar with (2) to (3). After selection of the nearest group, a dotted line is drawn between 2 groups as in Fig. 2.
(7) If all the groups are connected by dotted lines, this process is finished.

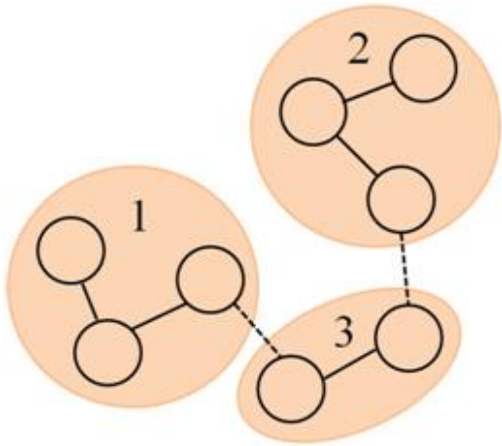


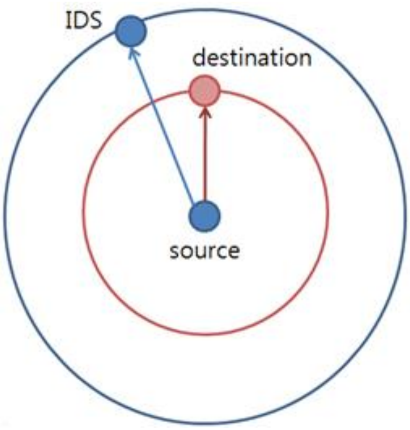
Fig. 2. MST of mobile nodes

This process can make MST, even though there are some small groups within the network. After finishing all the MST making process, all the nodes have their own bridge node. In the proposed algorithm, connection with the nearest node is very important point

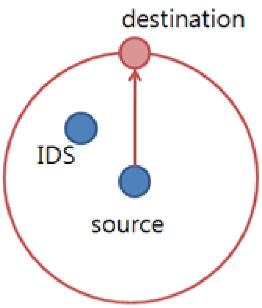
4. IDS Node Distribution Strategy

In the proposed algorithm, we need to reduce sending power to enhance network lifetime, because sending power constitutes to 1/2 to 1/3 of the total consumed power of a node. The lifetime enhancing of normal nodes is the best way to enhance entire network lifetime.

In MANETs, as mobile nodes are randomly distributed, there appear to be two relative distance cases between IDS node and normal node (see Fig. 3). Case 1 is that IDS node is farther from the normal node than a destination node. Case 2 is reverse. In case 1, the source node should reach its packet to IDS node, but in case 2, it is not. Therefore, in case 1, a source node needs additional power for its security. In case 2, a source node can always get secure communication, because IDS node monitors all the packets. Actually, there is little difference between case 1 and case 2. However, because of simulation convenience, we assume that IDS nodes are distributed effectively and all the nodes are in case 2.



(a) Case 1



(b) Case 2

Fig. 3. Relationship

5. IDS Node Selection

Neighboring nodes of node i are nodes that can be reached by one−hop from node i. One−hop from node i means it is within maximum transmission range from node i. Let N_i be the set of neighboring nodes of node i including node i itself and D_i is the distance from node i. The candidate bridge node i_* is selected for every node i such that

$$i^* = \arg\min_{j \in N} D_j \qquad (1)$$

Every node sends a control packet containing the distance value to its neighboring nodes. All the nodes always know the distance to their neighbors. Based on a control packet, each node connects the first bridge with its nearest neighbor. We operate this process for all the nodes. When all the node complete first connection, each group makes its second bridge within maximum transmission range. Before connecting second bridge, the node which has more than three bridges nominates IDS node. When all nodes make complete MST, we finish this process.

As an example, we consider a ten−node connection graph given Fig. 4. And Fig. 5 shows complete MST. In Fig. 5, highlighted nodes are IDS nodes. We can see that three IDS nodes can monitor entire network.

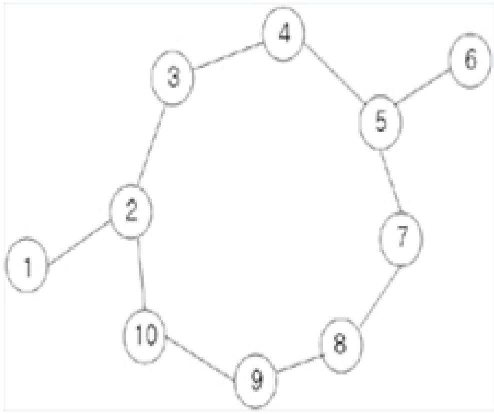


Fig. 4. Node distribution in MANETs

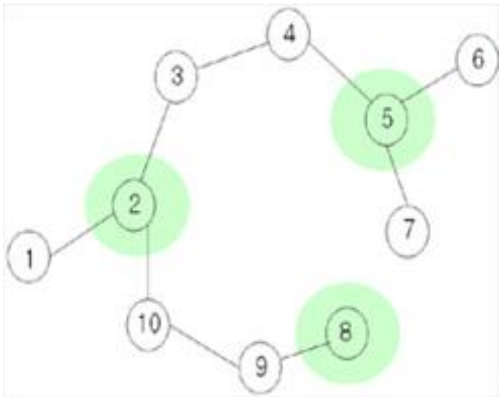


Fig. 5. IDS node selection

6. 3−Bridge

When some nodes are selected as IDS nodes, we can check the number of bridges of each node. Specially we select the node which has more than 3 bridges due to the property of MST. MST tends to make a line with no side bridges. Therefore, if some nodes have more than 3 bridges, they may have many nodes closely. Fig. 6 shows when we establish 3−bridges, the number of IDS nodes are minimized.

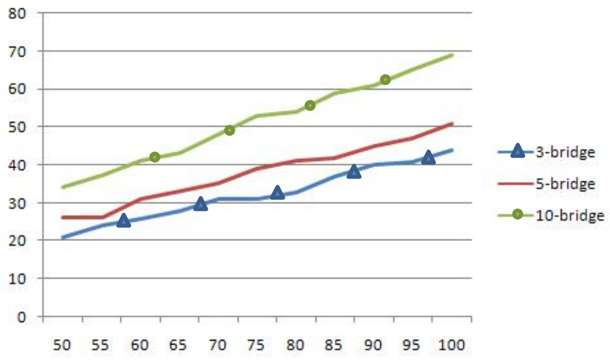


Fig. 6. The number of bridges and IDS nodes

7. Transmission Power Level Control

After making MST, we should control transmission power level of each node. We selected some IDS nodes which are the nearest node. Because the IDS node of each node locates closer than the other nodes, all the sending packets from each node are monitored by the IDS node. Some nodes may have no IDS node in its nearest area. We consider this case is exceptional, because it is too small portion to make some problem. The node distribution in MANETs including the transmission power level control algorithm is shown in Fig. 7.

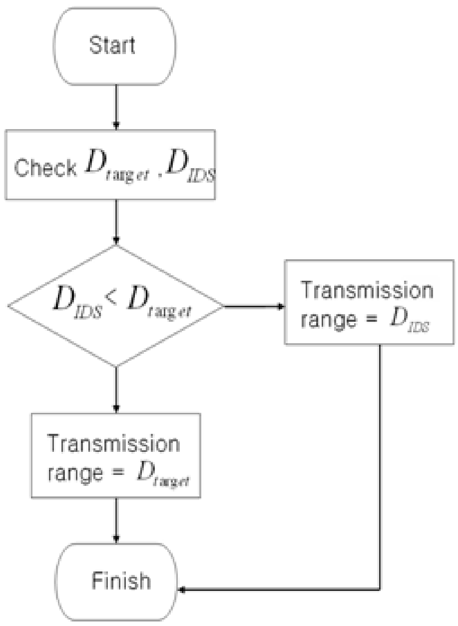


Fig. 7. Node distribution in MANET

As discussed above, MST guarantees that IDS nodes locate the nearest area of most nodes. Therefore, most nodes can decide a transmission range with D_{target}. Every node which have made a decision of a transmission range with D_{target} can sends its packet to a target node. Simultaneously, IDS node checks all the packet. In exceptional case, nodes use D_{IDS} which is the transmission range of exceptional nodes. If all nodes in MANETs follow transmission power level control algorithm, they can send any packets under watching of IDS nodes and reduce their sending power.

8. Node Communication Strategy

Since IDS node distribution based on MST guarantees that most IDS nodes are the nearest node of each node, we can apply transmission power control algorithm when communications are taken place between nodes in MANETs. Therefore, each node can save its power. Fig. 8 shows the energy saving range between appropriate transmission power and full power as possible as it can.

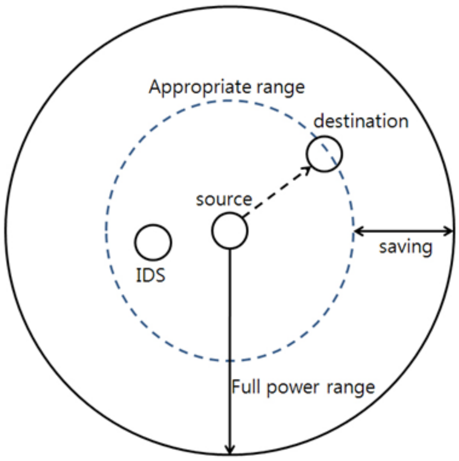


Fig. 8. The energy saving range

IV. SIMULATION RESULTS

In order to evaluate the proposed algorithm, we simulate MANETs with visual C++. We simulate the proposed IDS node distribution algorithm based on MST and transmission power control algorithm and the other previous algorithm such as DISD [6] and LES scheme [7]. In this simulation, simulation implemented 100 times. There are 50 to 100 mobile nodes which are randomly distributed. Every node consumes its power whenever packet sending, receiving, overhearing and monitoring performed. The network topology is 100m x 100m and every node has low mobility.

In MANETs, transmission coverage of each node has to occupy at least 10.91% of the whole area in order to communicate successfully among nodes, [11]. And then, they can have 98.2% successful communication with the other nodes. So we set the standard transmission range to 35m.

1. Power Consumption of Whole Networks

The key factor of network lifetime is power consumption. If whole networks consume too much power, they quickly become dead state. In MANETs, as every node has limited resources, it spends the more power, its lifetime is reduced the faster. To enhance network lifetime, the network must reduce their total power consumption.

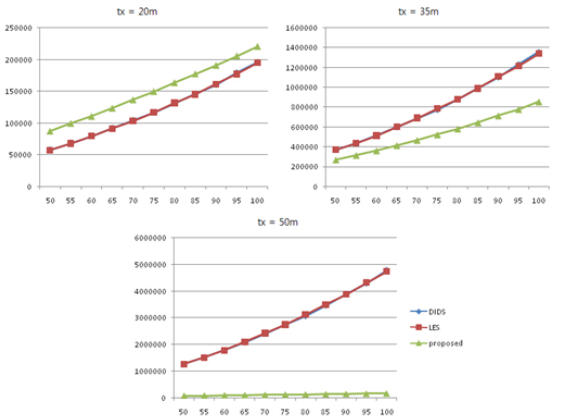


Fig. 9. The network power consumption

Fig. 9 shows the proposed algorithm is better to the existing algorithms. The x axis is number of nodes and the y axis is amount of power consumption. We can find the gap between the proposed algorithm and the other existing algorithms. The proposed algorithm can control transmission range of each node, therefore, if destination node is located closely from a source node, the source node can reduce significantly their transmission power.

2. Network Lifetime

Enhancing network lifetime is the main goal of this paper. In MANETs, if the nodes consume all the power because of limited resources when they are communicating with the other nodes, the network topology may collapse.

Fig. 10 shows how long the network can live in variety situations. The x axis is number of nodes and the y axis is iteration number. The iteration means that all nodes send their packet to the other node. Every node spends their power whenever packet sending, receiving, overhearing and monitoring performed. After one iteration, all the nodes spend their power only once for transmission, but several times for receiving, overhearing, and monitoring.

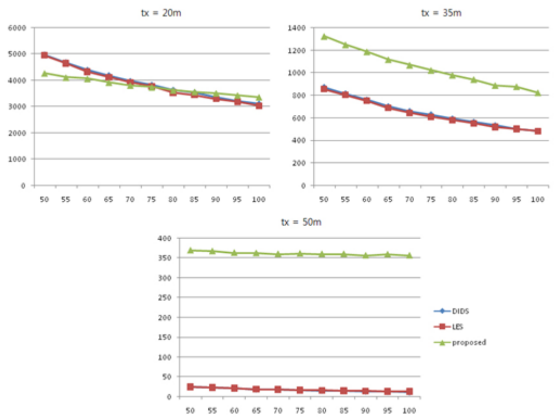


Fig. 10. The network Lifetime

We can find the difference between the proposed algorithm and the other existing algorithms. TABLE 1 shows that network lifetime based on the proposed algorithm is much longer than the other algorithms. The proposed algorithm lives 0.9 to 21 times than DIDS, LES scheme. The nodes using DIDS and LES scheme always consume additional power to communicate with each other. However, the nodes using the proposed algorithm only use the power when the transmission can be available to reach destination. And when transmission range is short, the proposed algorithm is similar. And because the sending power occupies the largest portion of whole power consumption, the proposed algorithm aims to reduce sending power using MST to enhance network lifetime. As a result, the network lifetime significantly increases when MANETs use the proposed algorithm.

Table 1. Network Lifetime Ratio

Ratio between proposed and DIDS				Ratio between proposed and LES			
	tx range				tx range		
nodes	20m	35m	50m	nodes	20m	35m	50m
50	0.86	1.52	14.80	50	0.86	1.55	14.80
55	0.88	1.53	16.00	55	0.89	1.55	16.00
60	0.92	1.56	17.33	60	0.94	1.58	17.33
65	0.93	1.59	19.11	65	0.95	1.62	19.11
70	0.96	1.62	20.06	70	0.97	1.66	20.06
75	0.98	1.62	21.29	75	0.99	1.68	21.29
80	0.99	1.65	22.56	80	1.02	1.68	22.56
85	1.01	1.67	24.07	85	1.03	1.70	24.07
90	1.04	1.66	25.50	90	1.06	1.71	25.50
95	1.07	1.74	27.69	95	1.08	1.75	27.69
100	1.08	1.70	29.75	100	1.10	1.70	27.46
average	0.97	1.62	21.65	average	0.99	1.65	21.44

V. CONCLUSION

In this paper, we proposed an efficient IDS node distribution algorithm using MST method to cover all the nodes in a network and enhance the network lifetime. Nowadays, MANETs are becoming necessary communication system and there are many researches to protect MANETs from network attackers.

The IDS service is the effective network protection methods. However, because of the limited resources in MANETs, we need the energy efficient IDS node distribution algorithm to enhance network lifetime.

In this paper, we used MST to place IDS nodes as possible as closer to all the nodes. This could guarantee IDS nodes were always in transmission range of source nodes whenever each node sent some packets. Moreover, we could reduce sending power using transmission power level control algorithm. The source node did not need to use its full power to send packets. It used just as much as reachable to its destination.

Consequently, simulation results showed that the proposed algorithm has better performance in comparison with the existing algorithms.

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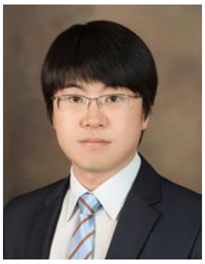

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