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An Interference-aware multi-path routing protocol for Mobile Ad hoc Network

Phu Hung Le, Guy Pujolle, Thi-Mai-Trang Nguyen

Abstract— A Mobile Ad hoc NETWORK (MANET) is a network without any pre-existing communication infrastructure. Wireless mobile nodes can freely and dynamically self-organize into arbitrary and temporary network topologies. There have been many challenges on the dynamic structure of MANET. One of those is to find the path from a source node to a destination node in the network.

In this paper, we propose a formula of interference and a node-disjoint Interference-Aware Multi-Path OLSR routing protocol (IA-MPOLSR) which is based on the Optimized Link State routing protocol (OLSR) for MANET to increase the stability and reliability of the network. From our simulation results, we show that the IA-MPOLSR' packet delivery fraction is remarkably higher than the one of IA-OLSR, the original OLSR and OLSR-feedback. We also show that IA-MPOLSR' normalized routing load is lower than the corresponding results from IA-OLSR, the original OLSR and OLSR-feedback protocols.

I. INTRODUCTION

In recent years, there have been many researches on MANET to apply its applications in disaster recovery situations, defence (army, navy, air force), healthcare, academic institutions, corporate conventions/meetings, to name a few.

Currently, there have been many multi-path routing protocols that were proposed, on-demand protocols such as AOMDV [13], or proactive protocols such as SR-MPOLSR [14], MP-OLSR [16]. However, there have been not many multi-path protocols addressing the reduction of interference of the paths from a source to a destination. In a MANET, the influence of interference is very significant for the network performance such as data loss, conflict, retransmission and so on. Therefore, interference is one of the factors that has the greatest impact to network performance. Reducing interference on the path is a critical problem in order to increase network performance.

In MANET, when a node transmits data to the others, this can cause interference to neighbor nodes. There are many definitions of interference but there have been still no unified definition of it. Our objective in this study is to introduce one definition of interference coined by [2], to

propose a formula of interference and to build a new node-disjoint multi-path routing protocol that minimizes the interference impact.

The paper is organized as follows. Section II introduces the detail structure of IA-MPOLSR protocol. In section III, we compare the IA-MPOLSR protocol with the interference-aware routing protocol (IA-OLSR), the original OLSR [1], and OLSR-feedback (OLSR-FB) [6]. Finally, we conclude the paper in section IV.

II. INTERFERENCE-AWARE MULTI-PATH ROUTING PROTOCOL

A. Topology information

In the OLSR protocol, the link sensing and neighbor detection are performed by “Hello” message. Each node periodically broadcasts “Hello” message containing information about neighbor nodes and the node' current link status.

Each node in the network broadcasts the “Topology Control” (TC) message about the network topology. The information of network topology has been recorded by every node. OLSR minimizes the overhead from flooding of control traffic by using only selected nodes, called Multipoint Relays (MPRs), to retransmit control messages.

We proposed an interference-aware multi-path routing protocol (IA-MPOLSR) which inherits all above characteristics. Moreover, IA-MPOLSR also updates the position of all nodes, the interference level of all nodes and links.

B. Definition of interference

In a MANET, each node has two radio ranges, one is the transmission range (R_t) and the other is carrier sensing range (R_{cs}). Transmission range is the range that a node can transmit a packet successfully to other nodes without interference. The carrier sensing range is the range that a node can receive signals but can not correctly decode the signal.

When a node transmits data, all nodes within the carrier sensing range will be interfered. The level of the interference of a node depends on the distance from the transmitting node to the received node.

The more two nodes in the network are close to each other, the more interference is high and vice versa.

The total interference on one node in the network is the sum of the received interferences from other nodes to this node. If the total interference are small enough, the node can expect a successful transmission.

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In contrary, if the interference level of a node exceed a certain threshold, the data will be in error or lost so, the interference is one of the most important factors affecting network performance. Therefore, interference reduction need to be considered to increase network quality and performance. In [2], the interference of a node is defined as the total useless signals that is transmitted by other nodes within its interference range. The interference of link or path is total useless signals transmitted by other nodes within their interference ranges. In other word, the interference of a node is total interference of the nodes within its interference range. Link interference of network is the average of the total interference of the nodes forming the link. Interference of a path is total interference of the links forming the path.

C. Measurement of interference

As we known interference of a node depends on the distance from the node to other nodes within the its interference range. To exactly calculate the interference of a node, a link and a path we divide the whole interference region of a node into smaller interference regions. The interference calculation will be more precise when we divide interference area of a node into more smaller areas. However, the calculation complexity increases .

In this paper, we divide the interference area into three zones to calculate the interference of a node. This choice is a compromise between the precision and the calculation complexity. The whole interference of a node can be considered as a circle with a radius of R_{cs} with the node in the centre. The three zones are determined by R_1 , R_2 and R_3 as follows (Figure 1).

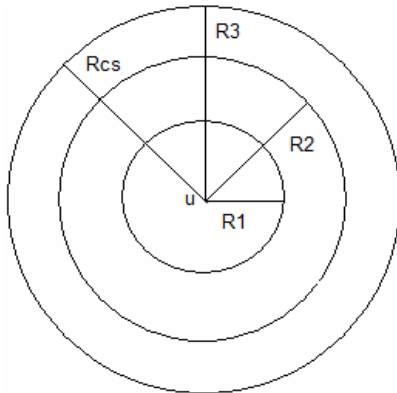


Fig. 1. Illustration of radii of interference

zone1: $0 < d \leq R_1$, $R_1 = 1/3 R_{cs}$

zone2: $R_1 < d \leq R_2$, $R_2 = 2/3 R_{cs}$

zone3: $R_2 < d \leq R_3$, $R_3 = R_{cs}$

where d is the distance between transmitter and receiver.

For each zone, we assign an interference weight which represents the interference level that a node present in this zone causes to the considered node in the center. If the weight of interference of zone1 is 1, the interference weight of zone 2 and zone 3 are α , β respectively ($\beta < \alpha < 1$), we can calculate the interference of a node u in MANET as follows.

$$I(u) = n_1 + \alpha \cdot n_2 + \beta \cdot n_3 \quad (1)$$

where n_1 , n_2 and n_3 are the numbers of nodes in zone 1, zone 2 and zone 3 respectively.

According to [9], in Two-Ray Ground path loss model, the receiving power (P_r) of a signal from a sender d meters away can be modeled as equation (*).

$$P_r = P_t G_t G_r h_t^2 h_r^2 / d^k \quad (*)$$

In Eq.(*), G_t and G_r are the antenna gains of transmitter and receiver, respectively. P_t is the transmission power of a sender node. h_t and h_r are the heights of the transmitter and receiver antenna respectively. Here, we assume that the MANET is homogeneous, that is all the radio parameters are identical at each node.

$$\alpha = (P_t G_t G_r h_t h_r / R_2^k) / (P_t G_t G_r h_t h_r / R_1^k) = 0.5^k$$

$$\beta = (P_t G_t G_r h_t h_r / R_3^k) / (P_t G_t G_r h_t h_r / R_1^k) = 0.33^k$$

We assume that common path loss model used in wireless networks is the open space path loss which has k equal to 2. Therefore, $\alpha = 0.25$, $\beta = 0.11$, and

$$I(u) = n_1 + 0.25n_2 + 0.11n_3 \quad (1')$$

Based on the formula of interference of a node we can calculate the interference of a link. For a link interconnecting two nodes u and v , $e=(u,v)$, $I(u)$ and $I(v)$ are the interferences of node u and node v respectively, we have:

$$I(e) = (I(u) + I(v)) / 2 \quad (2)$$

Based on the calculation of interference of a link, we can calculate the interference of a path P that consists of links e_1, e_2, \dots, e_n as follows.

$$I(P) = I(e_1) + I(e_2) + \dots + I(e_n)$$

D. IA-MPOLSR protocol design

1) IA-OLSR

In order to find multiple paths with interference consideration, we determine a single with minimum interference with an algorithm called IA-OLSR (Interference-aware OLSR) as follows.

A MANET can be considered as a weighted graph (Figure 2) where nodes of MANET are vertices of the graph and the edges of the graph are the links between any two neighbor nodes. We calculate the interference of each node based on the formula (1'). To determine n_1 , n_2 , n_3 for a node we calculate the distances from the considered node to the other nodes of the network. Then the interference of

each link is determined by the formula (2). The weight of each edge is the interference of the corresponding link. Using the Dijkstra algorithm, we can get the minimum interference path from a source to a destination.

2) Algorithm of node-disjoint multi-path

In MANET, multi-path can be divided into three following categories:

- Node-disjoint multi-path: the paths have only common source and destination.
- Link-disjoint multi-path: the paths can share a few common nodes but not links.
- Hybrid multi-path: the paths may have some common links and nodes.

To build the node-disjoint multi-path algorithm for OLSR, we perform the following steps.

Step 1: Over a topology, find the single path with minimum interference based on the IA-OLSR algorithm.

Step 2: The second minimum interference path is found by applying the Dijkstra algorithm again while avoiding all nodes between the source and destination along the path found in step 1.

Step 3: Dijkstra algorithm is repeated for a number of times k ($k=3, \dots, n$) while continuing to avoid the nodes between the source and destination along the paths found in the previous steps to find k -minimum interference path.

In the Figure 2 we illustrate an example for a MANET which is considered as a weighted graph.

When using the Dijkstra algorithm at the first time for this weighted graph with source S and destination D we get the minimum interference path S - A - F - D that has the path interference value of 3.

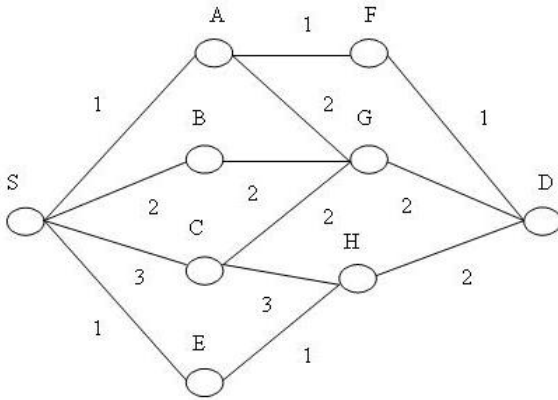


Fig. 2. IA-MPOLSR example

Using the Dijkstra algorithm once more, we get the second minimum interference path S - E - H - D with the path interference value of 4. We continue to apply the Dijkstra algorithm and find the third path S - B - G - D with the

interference value of 6. As we can verify in Figure 2, the path S - A - G - D has the interference value of 5 but vertex A belongs to the path S - A - F - D found previously. Therefore, this path is eliminated.

3) Route recovery and packet forwarding

In IA-MPOLSR, topology of network is always maintained and updated by each node thanks to “Hello” messages and TC messages. IA-MPOLSR also updates the position of all nodes, the interference levels of all nodes and links.

When a node wants to forward packets to the next hop in a found path, one more check has been conducted by sent node to confirm the received node. The packets will be transmitted without any problem. Otherwise, the node will use immediately a different path to transmit the packets. When there is no available path for a destination, the paths will be recomputed. This mechanism could help to enhance the stability and reliability of the network.

III. PERFORMANCE EVALUATION

A. Simulation environment

The protocol is implemented in NS-2 with 2Mbps 802.11 channels. The traffic source is Constant Bit Rate (CBR). The distributed coordination function (DCF) of IEEE 802.11 for wireless LANs is used as the MAC layer. The Two-Ray Ground and the Random Waypoint models have been used as propagation model and mobility model respectively. The number of nodes is 40. These nodes move within an area of 600m x700m.

B. Simulation results

In the simulations, we compare the performance between IA-MPOLSR, IA-OLSR, the original OLSR and OLSR-feedback (OLSR-FB). The performance metrics are packet delivery fraction (PDF) and normalized routing load (NRL).

In the first simulation, the nodes move randomly within the area of 600m x700m, the packet size is 512 bytes and the CBR varies from 0.125Mbps to 0.5Mbps.

As shown in Figure 3, the PDF of IA-MPOLSR can be 8% higher than IA-OLSR, 18% higher than the original OLSR, and 15% higher than OLSR-FB. The PDF of IA-MPOLSR is higher than IA-OLSR, the original OLSR and OLSR-FB because IA-MPOLSR uses multiple paths with lowest interferences and corruption.

Figure 4 shows that the NRL of IA-MPOLSR is 13% lower than IA-OLSR, 25% lower than the original OLSR and OLSR-FB. This is because the number of lost packets of IA-MPOLSR was less than those of IA-OLSR, the original OLSR and OLSR-FB.

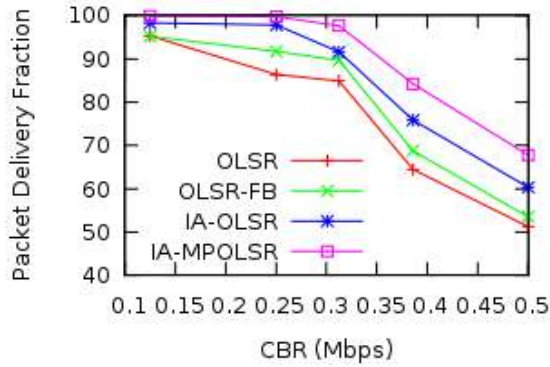


Fig. 3. Packet delivery fraction, packet size of 512 bytes

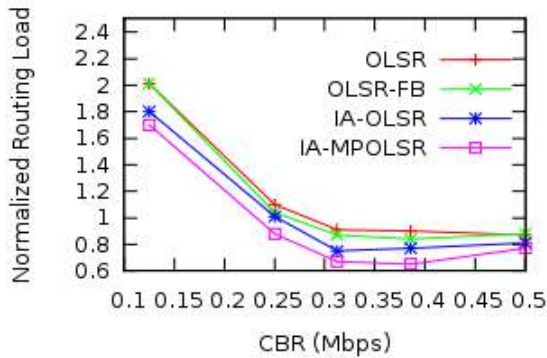


Fig. 4. Normalized routing load, packet size of 512 bytes

In the second simulation, the nodes move randomly within the area of 600m x700m, the packet size increases to 1024 bytes, and the CBR varies from 0.125Mbps to 0.5Mbps.

The PDF of IA-MPOLSR is 10% higher than IA-OLSR, 24% higher than the original OLSR and OLSR-FB as shown in Figure 5. This is because packet size is bigger and the time to transmit data is longer. Therefore, the influence of interference and corruption raises but IA-MPOLSR avoids high interference area by selecting the paths with minimum interference.

The NRL of IA-MPOLSR is 15% lower than IA-OLSR, 30% lower than the original OLSR and also OLSR-FB as shown in Figure 6.

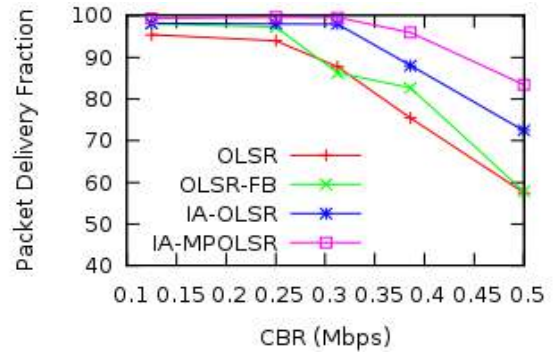


Fig. 5. Packet delivery fraction, packet size of 1024 bytes

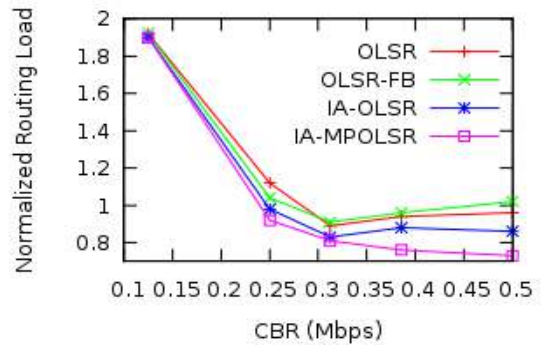


Fig. 6. Normalized routing load, packet size of 1024 bytes

In the third simulation, we compare four protocols with packet size of 1024 bytes, the CBR is kept at constant rate and the nodes move with the speed varying from 1m/s to 10m/s.

In Figure 7, the PDF of IA-MPOLSR can be 10% higher than IA-OLSR, 33% higher than the original OLSR and OLSR-FB.

Figure 8 shows that the NRL of IA-MPOLSR can be 15% lower than IA-OLSR, 40% lower than the original OLSR and OLSR-FB when the nodes move with the speed varying from 5m/s to 10m/s.

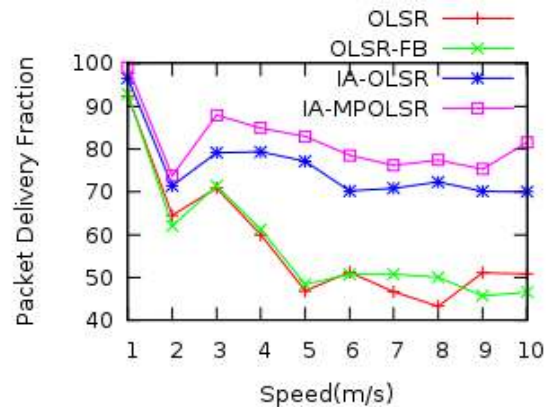


Fig. 7. Packet delivery fraction

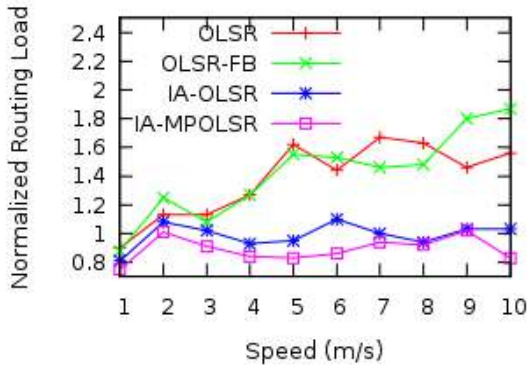


Fig. 8. Normalized routing load

IV. CONCLUSION

In this paper, we proposed a formula to calculate interference and a new multi-path routing protocol based on OLSR for mobile ad hoc network. This protocol, IA-MPOLSR, uses multiple node-disjoint paths with minimal interference to increase the performance of data transmission between a source and a destination. IA-MPOLSR has been shown remarkably better than IA-OLSR, the original OLSR and also OLSR-feedback for the packet delivery fraction and normalized routing load. In future works, we seek to improve our protocol to enhance network performance.

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