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Performance Analysis of Interference-Aware Routing Protocol for Mobile Ad hoc Networks

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Abstract: In Mobile Ad hoc NETwork (MANET), interference is one of the important problems in research. Interference reduces significantly the network performance such as data loss, conflict, and retransmission and so on. In this paper, we analyze performance of our Interference-Aware Routing Protocol (IA-OLSR) by comparing to the famous protocol OLSR in terms packet delivery fraction, delay and routing overhead when RTS/CTS (Request to Send / Clear to Send) turns on or turns off. Simulation results show that the IA-OLSR' packet delivery fraction significantly outperforms that of the OLSR. Our results also show that IA-OLSR' delay and routing overhead are lower than the corresponding results from the OLSR.

Keywords: Mobile Ad Hoc Networks; Routing Protocol; OLSR; Interference.

I. INTRODUCTION

A mobile ad hoc network (MANET) is the network that wireless mobile nodes can freely and dynamically self-organize into arbitrary and temporary network topologies. An ad hoc network has not also any pre-existing communication infrastructure.

MANET has many applications including disaster recovery situations, defence (army, navy, air force), healthcare, academic institutions, corporate conventions/meetings. In MANET, routing protocols are divided into three categories:

On-demand routing protocols are protocols that only calculate a path when they need data transmission. Some on-demand protocols are AODV [4], DSR [5], TORA [6].
Contrary to On-demand routing protocols, in proactive (table-driven) protocols each node maintains the routing table and topology of network. These protocols have low delay when an application needs to send packets because a path to the destination is immediately available. Some famous proactive protocols are OLSR [1], Destination-Sequenced Distance-Vector (DSDV) [3] .
And the third category is hybrid protocols that use both periodic and on-demand routing, for example, the Zone Routing Protocol (ZRP) [8] .

Data transmission in MANET always exists interference. Interference reduces performamnce of network as data loss, conflict, retransmission and so on. Therefore, interference is an important factor to study. Reducing interference on the path is a critical problem in order to increase the network performance. Currently, there are some interference-aware routing protocols for MANET but interference region is only two-hop. In this paper, we evaluate our interference-aware routing protocol by comparing to the prominent protocol OLSR.

This paper is organized as follows. Section II introduces the detail structure of IA-OLSR. Section III we compare the IA-OLSR to the OLSR [1] and conclusion in section IV.

II. INTERFERENCE-AWARE 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 is 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. The interference-aware routing protocol (IA-OLSR) also inherits all characteristics above. Moreover, IA-OLSR updates the position of all nodes, the interference level of all nodes and links.

B. Interference

In a MANET, each node has two radio ranges: transmission range (R_t) and carrier sensing range (Rcs). Transmission range is the range that a node can transmit a packet successfully to other nodes without interference. The carrier sensing range is a region that a node can receive signals but cannot correctly decode the signal.
When a node sends data, all nodes within the carrier sensing range will be interfered. The interference level 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.
A node in the network can be interfered from many other nodes . If the total interference is small enough, the node can receive successful signals.
In contrary, if the interference level of a node is high, the data will be in error or lost thus, the interference affects network performance greatly. Therefore, interference

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reduction is necessary to study for increasing network quality and performance. In [2], the interference of a node is the total interference that causes by other nodes within its interference range. The interference of link or path is total interference that causes by other nodes within their interference ranges. In other word, link interference 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. Interference evaluation

We define an interference region of a link e = (u,v) (unidirectional or bidirectional) as follows:

$I(e) = | \{w \in V \mid w \text{ is covered by } D(u, Rcsu)\} \cup$

$\{w \in V \mid w \text{ is covered by } D(v, Rcsv)\} |$

Here, V is the set of all nodes of network. Rcsu and Rcsv are carrier sensing range of u and v, respectively. D(u, Rcsu) and D(v, Rcsv) are circles that the centers are u and v, the radii are Rcsu and Rcsv, respectively.

In Manet, interference level of a node depends on the geographic distance beetwen nodes within the its interference range. To exactly evaluate the interference level of a node, a link and a path, the whole interference area of a node is divided into smaller interference areas. If interference area of a node is devided into smaller areas then the interference calculation will be more precise. However, the calculation complexity increases.
To compromise between the precision and the calculation complexity, in this paper, we divide the interference region into four zones to calculate the interference of a node. The whole interference region of a node can be considered as a circle with a radius of Rcs with the node in the centre. The four zones are determined by R_1, R_2, R_3 and R_4 as follows (Figure1).

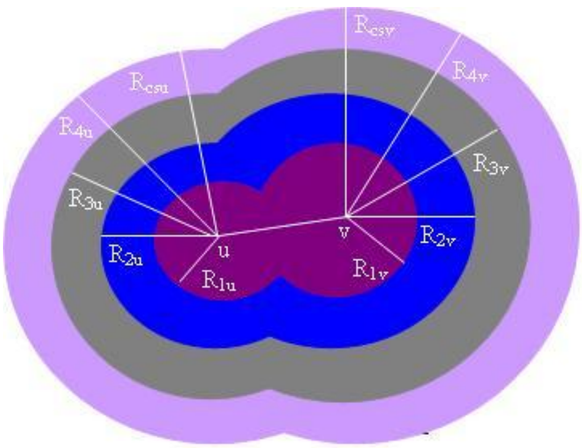

Fig 1. Illustration of radii of interference

Where,

$R_{1u} = 1/4Rcsu$, $R_{1v} = 1/4Rcsv$

$R_{2u} = 2/4Rcsu$, $R_{2u} = 2/4Rcsv$

$R_{3u} = 3/4Rcsu$, $R_{3v} = 3/4Rcsv$

$R_{4u} = Rcsu$, $R_{4v} = Rcsv$

Four zones are specified below.

Zone(0) = Ǿ (empty)

$Zone(i) = \{w \in V \mid w \text{ is covered by } D(u, Ri_u)\} \cup$

$\{w \in V \mid w \text{ is covered by } D(v, Ri_v)\} \setminus Zone(i-1), i \in [1,4]$

For each zone, we assign an interference weight which represents the interference level that a node in this zone causes to the considered link. The Zone (1) (violet) has the highest interference level. The Zone (2) (blue) has a higher interference level than the Zone (3) (gray). The interference level of Zone (4) (lavender) is smallest.

If the weight of interference of zone1 is 1, the interference weight of zone2, zone3 and zone4 are α, β, Ɣ respectively (Ɣ <β<α<1). We can calculate the interference of a node u in MANET as follows:

$$I(u) = n1 + \alpha.n2 + \beta.n3 + \gamma.n4 \quad (1)$$

where n1, n2, n3 and n4 are the number of nodes in zone 1, zone 2, zone 3 and zone 4 respectively. Parameters α, β and Ɣ are determined as follows. According to [7], 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

Eq.(2).

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

In Eq.(2), 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.

$\alpha = (P_t G_t G_r h_t h_r/R_2^k)/(P_t G_t G_r h_t h_r/R_1^k)=R_1^k/R_2^k = 0.5^k$
$\beta = (P_t G_t G_r h_t h_r/R_3^k)/(P_t G_t G_r h_t h_r/R_1^k)=R_1^k/R_3^k=0.33^k$
$\gamma = (P_t G_t G_r h_t h_r/R_4^k)/(P_t G_t G_r h_t h_r/R_1^k)=R_1^k/R_4^k=0.25^k$

We assume that common path loss model used in wireless networks is the open space path loss which has k equal to 2. Therefore, α=0.25, β=0.11, Ɣ=0.06 and

$$I(u) = n1 + 0.25n2 + 0.11n3 + 0.06n4 \quad (3)$$

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:

$$I(e)=(I(u)+I(v))/2 \quad (4)$$

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

$$I(P)=I(e_1) + I(e_2) + ... + I(e_n)$$

D. IA-OLSR protocol design

1) Specifying n1, n2, n3, and n4

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According to the formula (3), the interference of a node u in MANET is
I (u) = n1+ 0.25n2 + 0.11n3 + 0.06n4
Each node of MANET has a co-ordinate (x,y). Supposed that the co-ordinate of u, v is (x1,y1), (x2,y2), respectively. The distance between u and v is

$$\sqrt{(x_1-x_2)^2+(y_1-y_2)^2} \quad (5)$$

The formula (5) is used to calculate the distances between u and all other nodes in MANET. The number of nodes in zone1, zone2, zone3, and zone4 of node u is specified by comparing distances between nodes and u to R_1, R_2, R_3, and R_4.
In IA-OLSR, topology information of MANET is maintained and updated by each node. Information and position of a node are updated when any node changes its status. The distances between it and other nodes are recalculated. Therefore, interference of nodes and links is recomputed too.

2)Modelling MANET as a weighted graph

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 any two neighbor nodes. The weight of each edge is the interference level of the corresponding link.
This graph is dynamic. The edges and the weight of them are changed when any node changes its status.

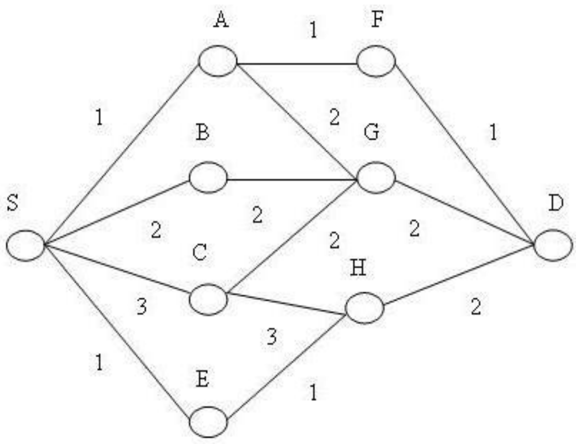

Fig 2. IA-OLSR

3)Using Dijsktra's algorithm

The minimum interference path from a source to a destination is found by applying Dijsktra's algorithm to the weighted graph above.

In the Figure 2, we illustrate an example for MANET that is considered as a weighted graph. The weight of each edge is set on the edge.

Applying Dijsktra's algorithm for this weighted graph with the source S and the destination D we have the minimum interference path S-A-F-D that has the value as 3.

III.PERFORMANCE EVALUATION

A. Simulation environment

We implement protocol in NS-2 with 11Mbps 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 Random Waypoint and Two-Ray Ground models have been used as propagation model and mobility model, respectively. 40 nodes is used and they move within an area of 550m x550m.

B. Simulation results

In the simulations, we compare the performance between IA-OLSR and OLSR when RTS/CTS is enabled and disabled for:

1-Packet delivery fraction (PDF)
2-Delay
3- Routing overhead

In the first simulation, the nodes move randomly within the area of 550m x 550m, Constant Bit Rate (CBR) changes from 80 Kbps to 120Kbps and turning on RTS/CTS.

The PDF of IA-OLSR can outperforms that of the OLSR 29% as shown in Figure 3. The PDF of IA-OLSR is higher than the OLSR because IA-OLSR avoids high interference area.

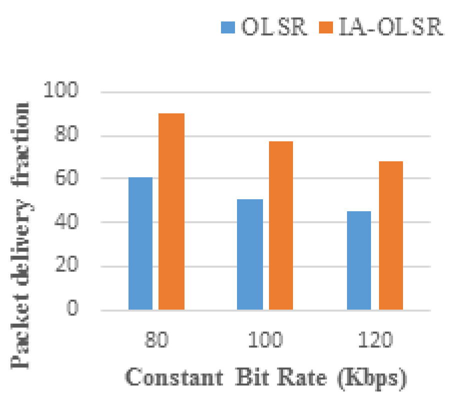

Figure 3. Packet delivery fraction with RTS/CTS

In Figure 4, the delay of IA-OLSR has the ability to reduces significantly compared to that of the OLSR. It is about 3 times. That is because IA-OLSR is interfered less than OLSR

We can see in Figure 5 that Routing overhead of IA-OLSR is about 9% less than that of the OLSR. For the reason that the number of the lost packets of the OLSR is higher than those of IA-OLSR therefore retransmissions of the OLSR increases.

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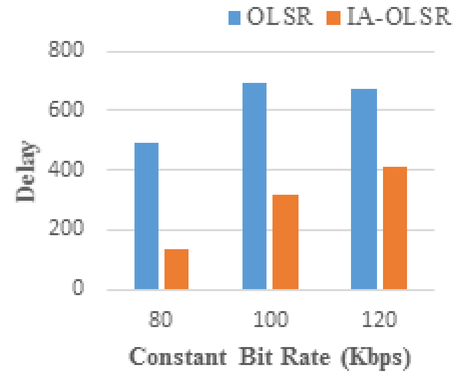

Figure 4. Delay with RTS/CTS

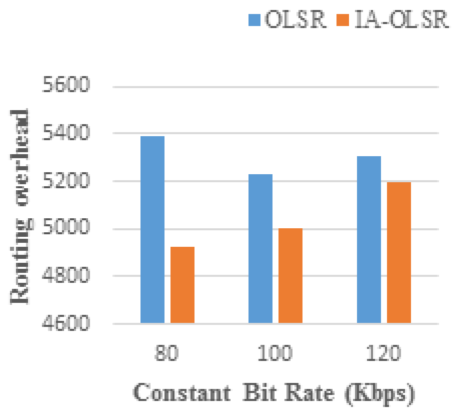

Figure 5. Routing overhead with RTS/CTS

In the second simulation, the nodes move within the area of 550m x550m, Constant Bit Rate (CBR) changes from 80 Kbps to 120Kbps and turning off RTS/CTS.

We can see in Figure 6 at CBR of 80Kbps, the PDF of IA-OLSR can be about 30% higher than that of the OLSR. It is because IA-OLSR always finds the low interference area.

In Figure 7, the delay of IA-OLSR is 8.5 times lower than that of the OLSR. In this case, interference affected OLSR more than IA-OLSR. Two protocols, especially IA-OLSR have less delay when RTS/CTS is disabled.

In Figure 8, Routing overhead of IA-OLSR is about 5% lower than that of the OLSR. It is because the number of the lost packets of the OLSR outperforms those of IA-OLSR. Therefore, OLSR must retransmit packets more than IA-OLSR.

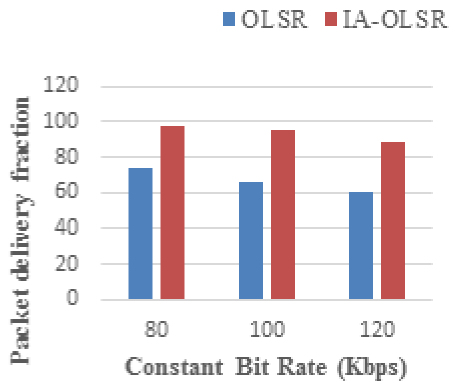

Figure 6. Packet delivery fraction without RTS/CTS

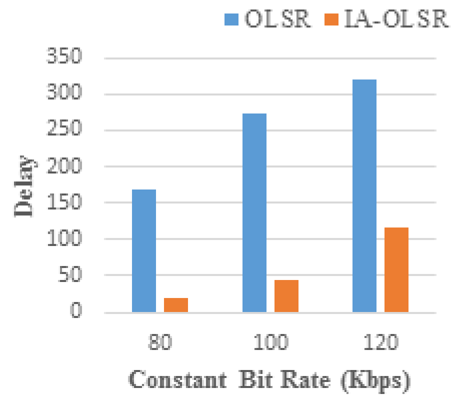

Figure 7. Delay without RTS/CTS

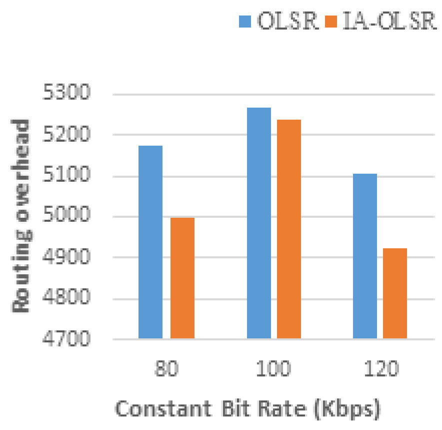

Figure 8. Routing overhead without RTS/CTS

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IV. CONCLUSION

Interference is a key factor reducing the network performance. In this paper, we compare our Interference-Aware Routing protocol(IA-OLSR) to the prminient protocol OLSR in important terms as packet delivery fraction, delay and routing overhead when RTS/CTS is enable or disabled. IA-OLSR is significantly better than OLSR for the packet delivery fraction and is lower than OLSR in term of delay and routing overhead.

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BIOGRAPHY

Phu Hung Le is now with Banking Academy of Vietnam. He received the Ph.D degree in Computer Science from Pierre and Marie Curie University (Paris 6 University), France. Phu Hung Le is the author of many articles and is a reviewer for many international conferences and journals. His research interests are Mobile Ad hoc Networks and Sensor Networks.