An Interference-aware routing protocol for Mobile Ad hoc Network

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Abstract—In Mobile Ad hoc NETwork (MANET), interference reduces significantly the network performance such as data loss, conflict, retransmission and so on. Therefore, interference is one of the important problems in research. Many protocols to find the road in MANET have been proposed but there are not many routing protocols about interference and they are only the hop-by-hop protocols. In this paper, we propose a formula to calculate the interference of a node, a link, a path and a novel Interference-Aware OLSR routing protocol (IA-OLSR) based on the Optimized Link State Routing protocol (OLSR) for mobile ad hoc network. IA-OLSR has the minimal interference from a source node to a destination node. The more difference between IA-OLSR and other protocols is that our protocol looks for the next hop based on calculating the interference between the current node and its neighbor nodes by taking into account of the geographic distance instead of hop-by-hop. Simulation results show that the IA-OLSR' packet delivery fraction in our study is significantly higher than the one of the original OLSR and OLSR-feedback. Our results also show that IA-OLSR' normalized routing load and routing overhead are lower than the corresponding results from the original OLSR and OLSR-feedback.

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

I. Introduction

A mobile ad hoc network (MANET) is the network without any pre-existing communication infrastructure. Wireless mobile nodes can freely and dynamically self-organize into arbitrary and temporary network topologies, allowing people and devices to seamlessly internetwork in areas.

MANET has many potential 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:

Proactive (table-driven): Each node maintains the necessary routing information and topology of network. The advantage of these protocols is that a path to the destination is immediately available, so no delay is experienced when an application needs to send packets. Some proactive protocols are OLSR [1], Destination-Sequenced Distance-Vector (DSDV) [3] .

Contrary to proactive protocols, on-demand routing protocols only calculate a path before data transmission. Some on-demand protocols are AODV [4], DSR [5], TORA [8]. And the third category is hybrid protocols that use both periodic and on-demand routing, for example, the Zone Routing Protocol (ZRP) [12] .

Data transmission in MANET cannot avoid influence of interference. Interference causes data loss, conflict, retransmission and so on. Therefore, interference is one of the factors that has the greatest impact on network performance. Reducing interference on the path is a critical problem in order to increase the network performance. Currently, there are not many routing protocols about interference for MANET and they are only the hop-by-hop protocols. In this paper, we propose a formula of interference of a node, a link, a path and a novel interference-aware routing protocol based on the geographic distance between nodes in order to minimize the interference impact to the data transmission.

This paper is organized as follows. Section II introduces the detail structure of IA-OLSR. Section III we compare the IA-OLSR to the original OLSR [1], OLSR-feedback(OLSR-FB) [7] 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.

We proposed an interference-aware routing protocol (IA-OLSR) which inherits all above characteristics. Moreover, IA-OLSR also 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, one is the transmission range (R_t) and the other is 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 the range that a node can receive signals but cannot 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.

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 know 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 four 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 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).

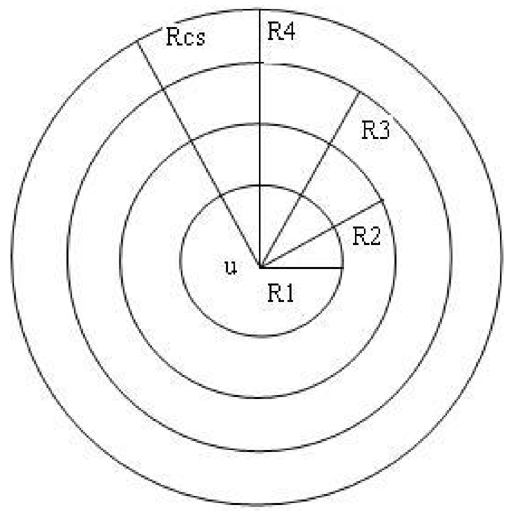

Figure 1. Illustration of radii of interference

zone1: $0<d<=R_1$, $R_1=1/4Rcs$
zone2: $R_1<d<=R_2$, $R_2=2/4Rcs$
zone3: $R_2 <d <= R_3$, $R_3=3/4Rcs$
zone4: $R_3<d <= R_4$, $R_4=Rcs$

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 zone2, zone3 and zone4 are α, β, γ respectively ($\gamma<\beta<\alpha<1$). 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 γ are determined as follows. According to [10], 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, γ=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

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

$$\sqrt{(x1-x2)^2 + (y1-y2)^2} \quad (5)$$

The formula (5) is used to calculate the distances between u and all other nodes in MANET. After comparing those distances to R_1, R_2, R_3, and R_4 we will have the number of nodes in zone1, zone2, zone3, and zone4 of node u.

In IA-OLSR, topology information of MANET is maintained and updated by each node. When any node changes its status, its information and position are updated. 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.

3)Using Dijsktra's algorithm

Applying Dijsktra's algorithm to the weighted graph above we will have the minimum interference path from a source to a destination.

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.

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

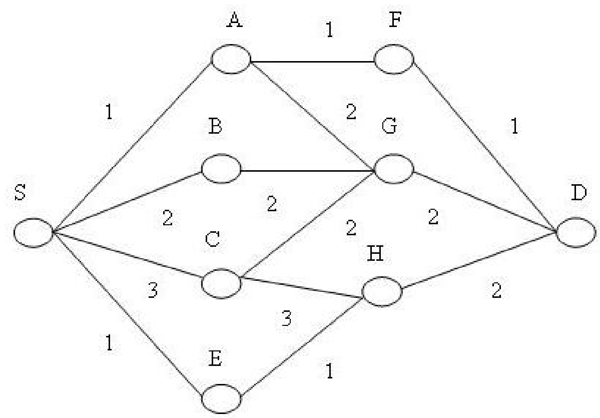

Figure 2. IA-OLSR example

III. PERFORMANCE EVALUATION

A. Simulation environment

The protocol is implemented in NS-2 with 10Mbps 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-OLSR, the original OLSR and OLSR-feedback (OLSR-FB) for:

1-Packet delivery fraction (PDF)
2-Routing overhead
3-Normalized routing load(NRL)

In the first simulation, the nodes move randomly within the area of 600m x700m, the speed of the nodes is from 4m/s to 10m/s, the packet size of 512 bytes and Constant Bit Rate (CBR) changes from 320Kbps to 1024Kbps.

As shown in Figure 3, the PDF of IA-OLSR can be about 34% higher than that of the original OLSR and that of OLSR-FB. The PDF of IA-OLSR is higher than the original OLSR and OLSR-FB because IA-OLSR has lower interference.

Routing overhead of IA-OLSR is about 8% lower than that of the original OLSR and that of OLSR-FB as shown in Figure 4. For the reason that the number of the lost packets of the original OLSR and OLSR-FB is higher than those of IA-OLSR therefore retransmissions of the original OLSR and OLSR-FB increase.

Figure 5 shows that the NRL of IA-OLSR has the ability to decrease about 43% compared to that of the original OLSR and to that of OLSR-FB. That is because routing overhead of IA-OLSR is lower and the number of packets of IA-OLSR is lost less than those of the original OLSR and OLSR-FB.

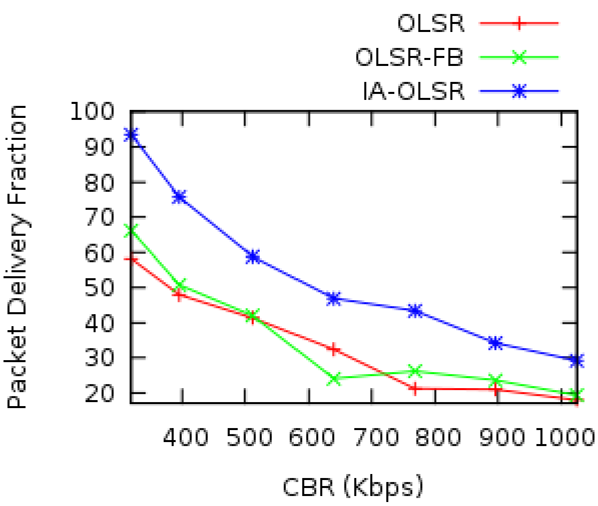

Figure 3. Packet delivery fraction

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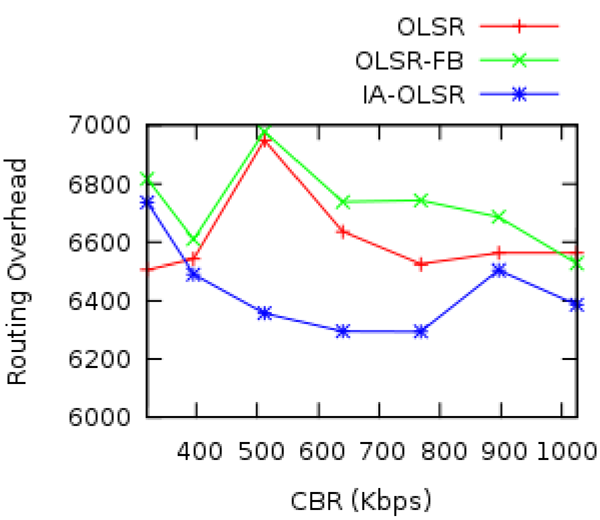

Figure 4. Routing overhead

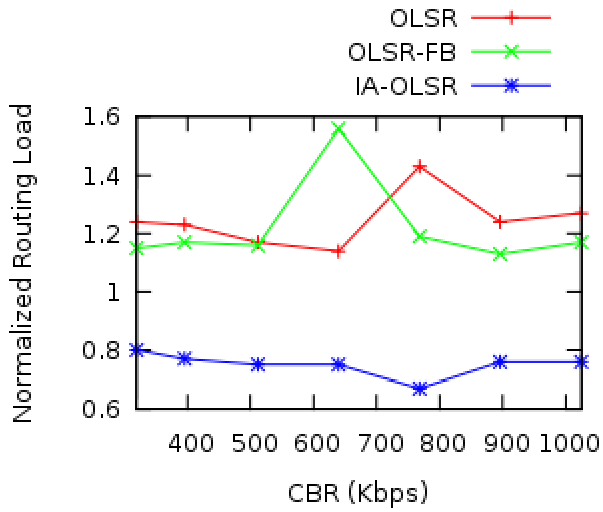

Figure 5. Normalized routing load

In the second simulation, the nodes move with the same speed from 1m/s to 10m/s within the area of 600m x700m, the packet size is 512 bytes and CBR value of 396Kbps.

As shown in figure 6, the PDF of IA-OLSR can be about 37% higher than that of the original OLSR and OLSR-FB. It is because IA-OLSR always avoids the high interference area.

Figure 7 shows that Routing overhead of IA-OLSR is about 8% lower than that of the original OLSR and OLSR-FB. Due to the fact that the number of the lost packets of the original OLSR and OLSR-FB is higher than those of IA-OLSR. Therefore, the packet retransmissions of the original OLSR and OLSR-FB are more than those of IA-OLSR.

The NRL of IA-OLSR decreases about 49 % compared to that of the original OLSR and OLSR-FB as shown in Figure 8. For the reason that the lost packets and routing overhead of IA-OLSR are lower than those of the original OLSR and OLSR-FB.

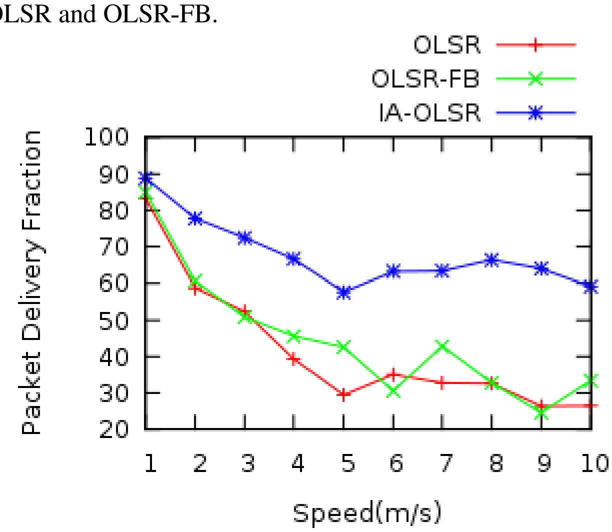

Figure 6. Packet delivery fraction

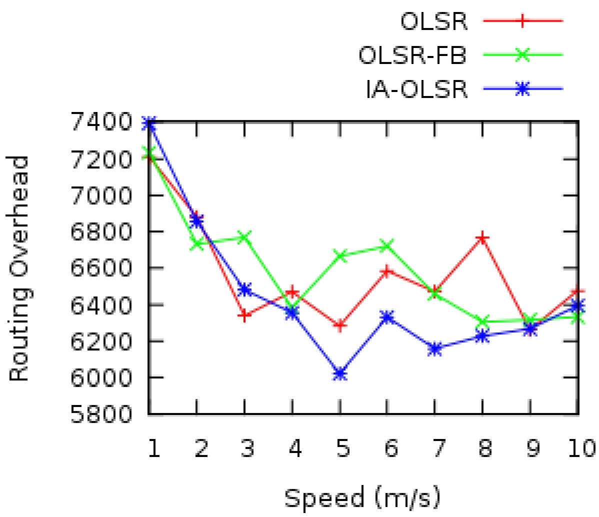

Figure 7. Routing overhead

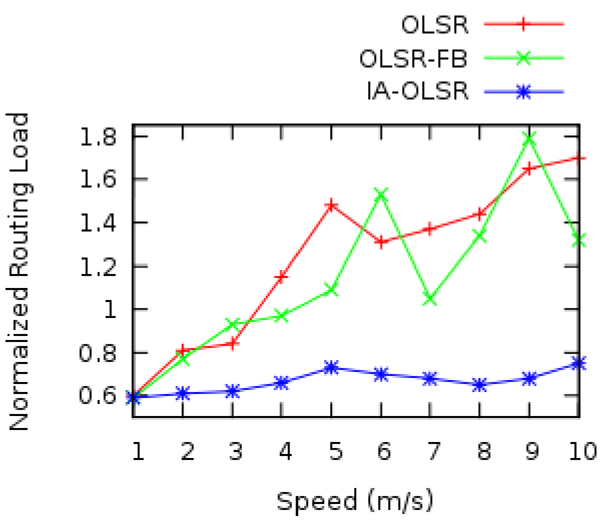

Figure 8. Normalized routing load

IV. CONCLUSION

Interference is one of the most important factors affecting the network performance. In this paper, we proposed a formula of interference and a novel Interference-Aware Routing protocol(IA-OLSR) for MANET. IA-OLSR calculates interference between nodes by the geographic distance and it is significantly better than the original OLSR and OLSR-feedback for the packet delivery fraction, routing overhead and normalized routing load. In the next work, we will do more research in interference and build a multi-path routing protocol.

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