Proposal of interference reduction routing for ad-hoc networks

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***Abstract*— In this paper, we propose an interference reduction routing protocol for ad-hoc networks. The interference is one of the degradation factors in wireless communications. In the ad-hoc network, some nodes communicate simultaneously. Therefore, these communications cause interference each other, and some packets are corrupted due to interference from another node. In the proposed protocol, each node estimates required transmission power according to hello messages. Therefore, the node can transmit a data packet with minimum required transmission power. Consequently, the interference against neighbor nodes can be reduced. From simulation results, we can find that the proposed protocol can reduce the number of control messages and can improve the throughput performance.**

***Keywords*— Ad-hoc networks, Interference reduction, Routing protocol**

I. Introduction

In the wireless ad-hoc networks, all nodes share the same frequency band for communication. Therefore, almost all wireless devices support carrier sense multiple access (CSMA). If the node employs the CSMA, the node senses the wireless channel first. Then the node transmits a data packet when the wireless channel is not used.

Each node tries to transmit a data packet autonomously in the ad-hoc networks. Then, neighbor nodes cannot transmit a data packet when one node is transmitting a data packet. Moreover, the transmission power is assumed to be always constant in the almost all wireless devices for the ad-hoc networks. Therefore, many nodes in the large area cannot transmit a data packet even if distance between two communication nodes is short. Consequently, the throughput performance is also saturated due to the lack of the wireless channel resource.

On the contrary, some nodes can transmit a data packet simultaneously when the distance between nodes is long. This means that any transmission between each node will add to interference level. The interference is the one of the degradation factors in wireless communication. Therefore, it is important to reduce the interference level in the ad-hoc networks to improve transmission performance[1], [2].

Transmission power control is one of the effective mechanisms for reducing the interference level. Researches about the transmission power control are classified broadly into media access control (MAC) mechanisms[3], [4], [5] and routing mechanisms[6], [7], [8].

In the papers of MAC mechanisms, some authors have proposed MAC protocols to exchange control information for controlling the transmission power due to the channel status. However, almost all protocols require modifications of frame structure. As a result, these protocols are not compatible with standard protocol such as IEEE 802.11.

In the papers of routing mechanisms, some authors have proposed routing protocols to find routes with minimum consumed energy. However, a lot of information should be exchanged between nodes to find an optimum route. Moreover, load of routing information processing is also high. Finally, almost all papers about the transmission power control are aimed for reducing the consumed energy.

In this paper, we propose an interference reduction routing protocol for ad-hoc networks. Our protocol is designed based on optimized link state routing (OLSR)[9]. A first feature of this protocol is to control the transmission power for neighbor nodes according to the hello messages. Therefore, the interference level can be reduced by transmitting a data packet with minimum required transmission power.

A second feature is to select a faraway node as a multi point relay (MPR) node by considering a received signal strength (RSS) value. Consequently, the selected MPR node is effective for multi-hop communications. In numerical results, we can find that the throughput performance can be improved with fewer control messages.

II. Interference reduction routing

The proposed routing protocol is designed based on the OLSR protocol. OLSR is one of the proactive routing protocols for ad-hoc networks. Each node transmits a hello message periodically, and detects neighbor nodes and two-hop neighbor nodes. Then, each node finds the shortest path to all nodes.

Figure 1 shows example communications with OLSR. In this example, three communications are performed between node A and B, node C and D, and node E and F. Additionally, an interference area of each node is drawn as a circle. In general, the transmission power control is not performed in OLSR. Therefore, all node transmits a packet with maximum transmission power. As a result, the transmitted signal interferes neighbor communications. If the RSS is larger than the carrier sensing threshold, a node does not transmit any packets. On the contrary, if the RSS is less than the carrier sensing threshold, the node transmits packets. This transmitted packets may be corrupted due to the interference. In the ad-hoc network, some communications are generally performed

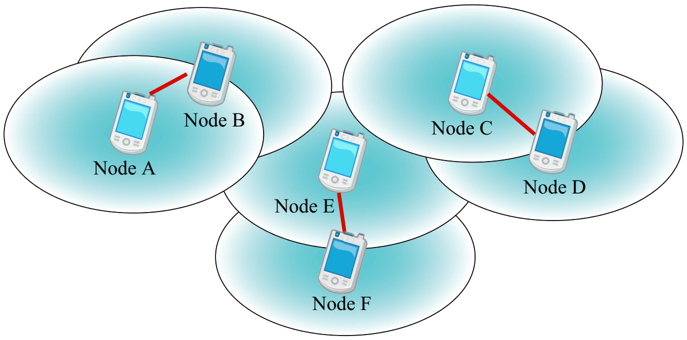

Fig. 1. Example communications with OLSR.

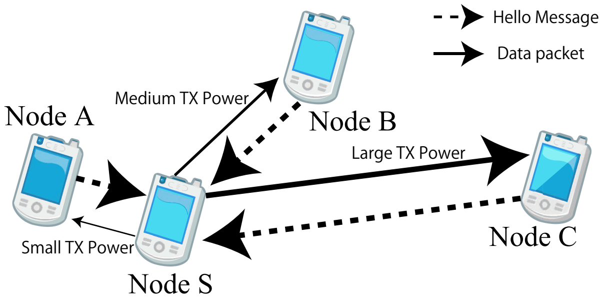

Fig. 2. Brief overview of proposed communications.

simultaneously. Therefore, the throughput performance is effected by the interference from neighbor nodes.

The proposed protocol has two big features that are different in OLSR. First one is to estimate the minimum transmission power for required transmission quality by using hello messages. Then, the node can control the transmission power for each neighbor node appropriately. Figure 2 shows a brief overview of communications in the proposed routing protocol. In this example, the node S communicates with node A, B and C. Node A exists near the node S, and node B is some distance from the node S. Node C exists faraway from the node S. In the proposed protocol, the node S transmits a packet to node A with smaller transmission power because the small transmission power is enough to communicate with node A. On the contrary, the node S transmits a packet to node C with larger transmission power because the distance between the node A and the node S is long and the larger transmission power is needed to communicate.

Figure 3 shows example communications with proposed protocol. In the example, the transmission power control is performed with proposed protocol. Therefore, the interference of each node becomes smaller than that in the conventional protocol. As a result, the transmission error due to the interference from the neighbor node may be improved. Moreover, the reduction of the transmission power causes the improvement of the interference effect to the whole network.

The second feature of the proposed protocol is to find the MPR node, which can communicate with many nodes. Figure 4 shows the example of MPR selection. MPR node is selected

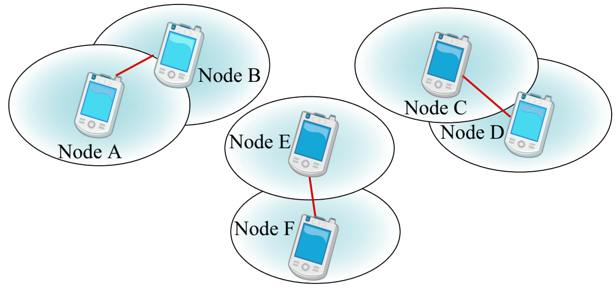

Fig. 3. Example communications with proposed protocol.

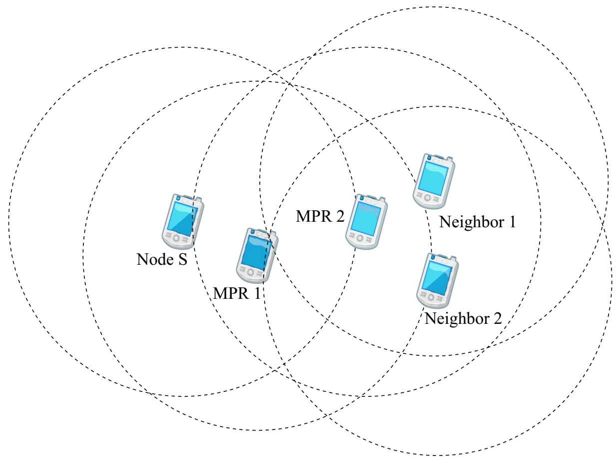

Fig. 4. Example MPR selection in proposed protocol.

based on the number of neighbor nodes in general OLSR. Therefore, the adequate MPR node may not be selected if the number of neighbor nodes is the same. In this figure, MPR 1 and MPR 2 are candidate nodes of MPR for the node S. MPR 1 and 2 have two neighbor nodes. A hop count may be reduced when the distance between the node S and a MPR node becomes longer. Therefore, the MPR 2 is selected as the MPR node in the proposed protocol.

A. Overview of proposed procedures

Figure 5 shows the procedures of the proposed protocol for receiving a hello message and transmission of data packet. Following procedures are performed when the node receives the hello message from neighbor nodes.

- Estimation of SINR
  In the proposed protocol, the node estimates the SINR of the hello message. SINR is the one of the evaluation factor for wireless link quality. Therefore, we can obtain the information about the wireless link.
- Estimation of RSS
  In the proposed protocol, the node can control the transmission power. Therefore, the node has to calculate the marginal power to satisfy the determined wireless link quality. In IEEE 802.11 systems, the wireless resource is shared by all nodes. Consequently, we can assume that the channel status from the node to the neighbor node is

almost same as the channel status from the neighbor node to the node. As a result, we can employ the estimated RSS and SINR values of the hello message to estimate the channel status from the own node to the neighbor node.

If the node has a data packet to transmit, following procedures are performed.

- Calculation of marginal SINR
  The marginal SINR to satisfy the wireless link quality is different when the packet length is different. Therefore, the node calculates the marginal SINR with SINR of the hello messages and packet length. In this paper, we employ the packet error rate (PER) as the indication of wireless link quality.
- Calculation of marginal RSS
  The node calculates the marginal RSS to satisfy the marginal SINR. It can reduce the transmission power if the RSS of the hello message is larger than the marginal RSS.
- Calculation of transmission power
  The node calculates the reduction value of the transmission power based on the RSS of the hello messages and the marginal RSS. Then it transmits a data packet with the marginal transmission power.

B. Measurement of wireless link status

In this paper, we employ IEEE 802.11 as a wireless communication device for ad-hoc networks. Therefore, all nodes share the same frequency channel band for communication. This means that the channel response of wireless link between two nodes is almost same. Consequently, the node can estimate the channel status for the neighbor node by receiving the packet from this neighbor node.

The proposed protocol utilizes the hello message in OLSR protocol. The hello message is exchanged periodically by broadcasting mode. Therefore, a node can listen the hello messages from neighbor nodes. In the proposed protocol, all nodes transmit the hello message with default transmission power. This is because, the hello message is an important message to recognize the neighbor nodes. Moreover, the default transmission power of each node is the same in this paper.

C. Transmission power control

Some transmission power control methods are proposed to determine the lowest transmission power for stable communications. In this paper, we employ a received signal strength (RSS) to measure a link quality. In generally, the link quality is determined by a signal to interference and noise ratio (SINR). Additionally, the interference should be small because CSMA is employed in IEEE 802.11 system. As a result, SINR is determined mainly by the RSS.

IEEE 802.11 systems employ some modulation schemes for each transmission rate. The relation between bit error rate (BER) and SINR is analyzed in the conventional research. Therefore, we can estimate the BER performance by SINR as follows.

$$p_b = Func(SINR) \tag{1}$$

If a node try to transmit a data packet. It can estimate a packet error rate (PER) p_p by the bit error rate p_b and packet length l. The packet error rate is obtained as follows.

$$p_p = 1 - (1 - p_b)^l \tag{2}$$

In this paper, we assume that a target packet error rate p_t is determined beforehand. Therefore, we can obtain a target signal to interference and noise ratio $SINR_t$ according to the target PER p_t. Then, the node estimates a required received signal strength RSS_r that satisfies the packet error rate p_t. Finally, it can obtain the adequate transmission power from a maximum transmission power P_{max}, RSS and RSS_r as follows.

$$P_{TX} = \begin{cases} P_{max} \times \frac{RSS_r}{RSS}, & RSS_r \leq RSS \\ P_{max}, & RSS_r > RSS \end{cases} \tag{3}$$

In the proposed protocol, each node can control the transmission power according to the RSS, packet length, and target PER. Therefore, the proposed protocol can reduce the redundant transmission power. Moreover, total transmission power transmitted to the network is also reduced. As a result, the performance deterioration due to the interference is also improved.

D. MPR selection based transmission power

MPR is one of the important functions in OLSR protocol. A MPR node has a responsibility to forward the control messages and to construct the route to all nodes. Therefore, the MPR node selection is also important. The node with maximum neighbor nodes is selected as the MPR node in OLSR. In the proposed protocol, the faraway node is selected as the MPR node if the number of maximum neighbor nodes is same. This is because, the faraway node can reduce the hop count for the destination node.

III. Numerical results

In this section, we compare the performance for the proposed protocol with that for the conventional OLSR protocol. The simulations are performed by the network simulator QualNet[10]. In the simulations, we assume the IEEE 802.11g as the wireless communication device, and the transmission rate is fixed at 18M [bps]. 100 nodes are placed uniformly in 1000 x 1000 [m] area. The source and the destination node are selected randomly. The application is File Transfer Protocol (FTP) and data packets with the length of 1 [KB] are transferred for 60 [s]. We consider the additive white gaussian noise (AWGN) environment and the free space propagation model. A Target PER in the proposed protocol is set to 0.001

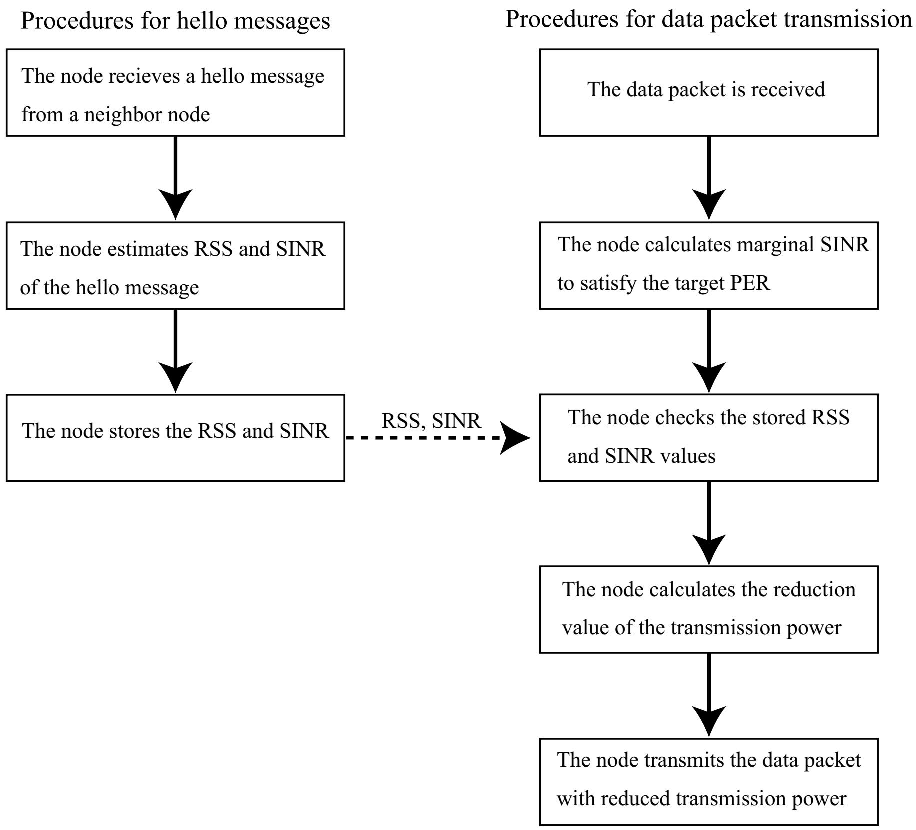

Fig. 5. Procedures in the proposed protocol.

TABLE I
SIMULATION PARAMETERS

Simulator	QualNet
Communication period	60 [s]
Simulation trials	100 times
Number of nodes	100
Simulation area	1000 x 1000 [m]
Node placement	Uniform
Node mobility	None
Communication system	IEEE 802.11g
Transmission rates	18[Mbps]
Propagation pathloss model	Free space
Wireless environment	AWGN
Routing protocol	OLSR, Proposed protocol
Application	FTP
Data packet size	1 [KB]
Number of connections	1 - 25
Target PER	0.001

for TCP communications[11], [12]. The simulation results are an average of 100 simulation trials. Detail simulation parameters are shown in Table I.

Figure 6 shows the total TCP throughput versus the number of connections. From the results, we can find that our proposed protocol can improve the throughput performance. This is because, the proposed protocol can select the effective MPR node for reducing the hop count, and each node can control the adequate transmission power for each data packet to each neighbor node. If the transmission rate is fixed, it is not easy to improve the wireless resource efficiency. However, our protocol can achieve a large improvement of wireless resource efficiency more than 10%. Consequently, the interference reduction scheme will be one of the important functions in ad-hoc networks.

Figure 7 shows the retransmission rate of RTS versus the number of connections. The retransmission rate of RTS means that the node has to retransmit the RTS due to the lack of CTS reception. The results show that our proposed protocol can improve the retransmission rate of RTS, because our protocol can control the transmission power according to the SINR at the receiver node. Then, the probability that the communication interferes the neighbor communication can be reduced. Moreover, the continuous transmission can be achieved by improving the retransmission rate of RTS. This is because communications are interrupted temporary due to the retransmission of RTS.

Figure 8 shows the number of received broadcast packets per transmitted broadcast packet. By this value, we can evaluate how many broadcast packets are received correctly. From the results, the number of received broadcast packets in OLSR becomes smaller according to increasing of connections. This is because, the increasing of connections causes the increasing

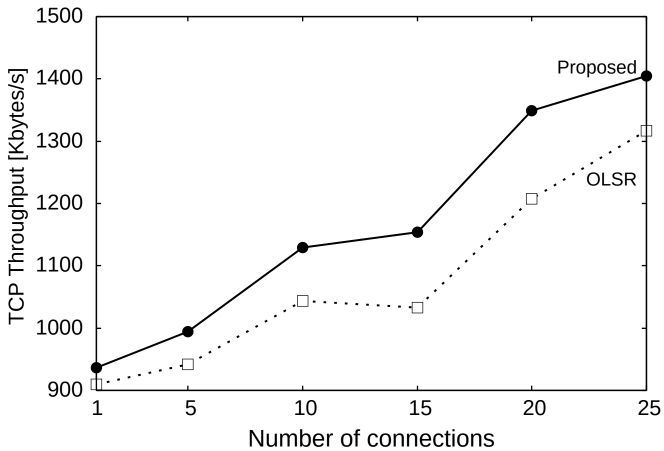

Fig. 6. Total TCP throughput.

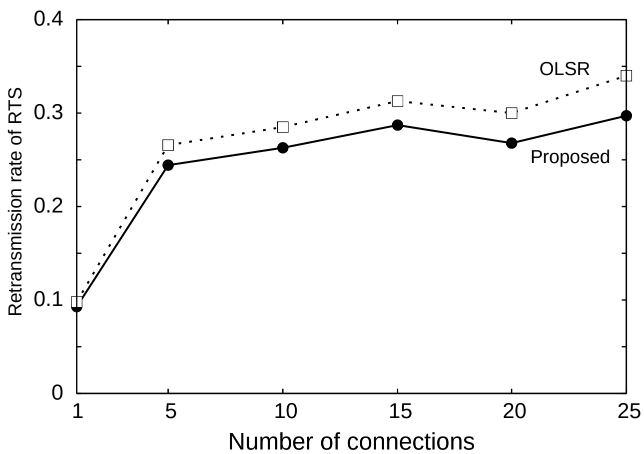

Fig. 7. Retransmission rate of RTS.

of interference. Therefore, communications are affected by each other. Finally, some broadcast packets may be corrupted due to the interference. Meanwhile, the number of receiver broadcast packets in the proposed protocol can keep a larger value than that in OLSR. Because the node can control the transmission power and reduce the interference power in the proposed protocol. Then, the corruption due to the interference can be reduced.

Figure 9 shows the number of received hello messages per transmitted hello message. This value means that how many nodes can receives the transmitted hello message. The hello message in OLSR is used to recognize neighbor nodes. Therefore, more adequate route can be found if the number of received hello messages increases. In Fig. 9, we can find that the proposed protocol can improve the number of received hello messages. This is because, the redundant transmission power can be reduced in the proposed protocol. Then, the total interference can be also reduced. As a result, more far away node can receive the hello message.

Figure 10 shows the number of received topology control

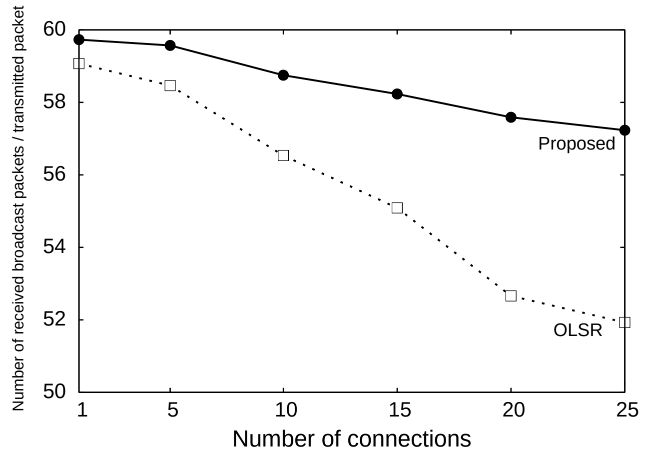

Fig. 8. Number of received broadcast packets per transmitted broadcast packet.

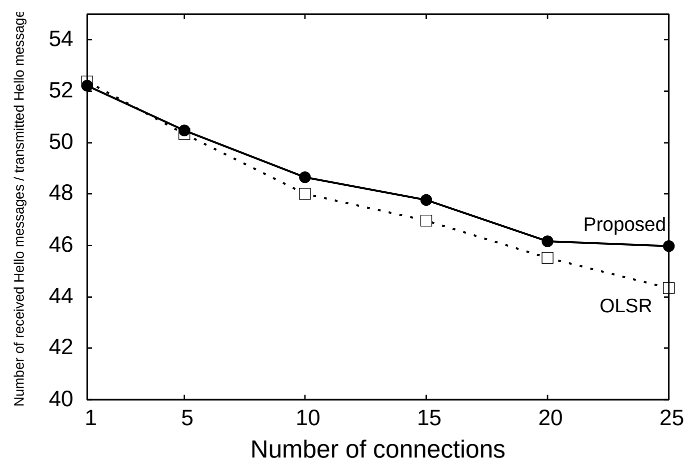

Fig. 9. Number of received Hello messages per transmitted Hello message.

(TC) messages per transmitted TC message. This value means that how many nodes can receives the transmitted TC message. From the results, the performance of OLSR deteriorates according to the increasing of the connections because the increasing of the connection causes the larger interference in OLSR. Therefore, it may be difficult to find faraway neighbor nodes when the interference becomes larger. On the contrary, the performance of the proposed protocol can keep the higher value even if the number of connections is increased. This is because, the increase of the interference can be reduced by controlling the transmission power. As a result, the node can receive the more TC messages from faraway nodes.

Figure 11 shows the number of relayed TC messages per generated TC message. The results show that the proposed protocol exchanges the fewer numbers of TC messages than that in OLSR. Because the faraway node is selected as the MPR in the proposed protocol if the number of neighbor nodes is same. As a result, the proposed protocol can extend the communication distance for TC messages, and improve the

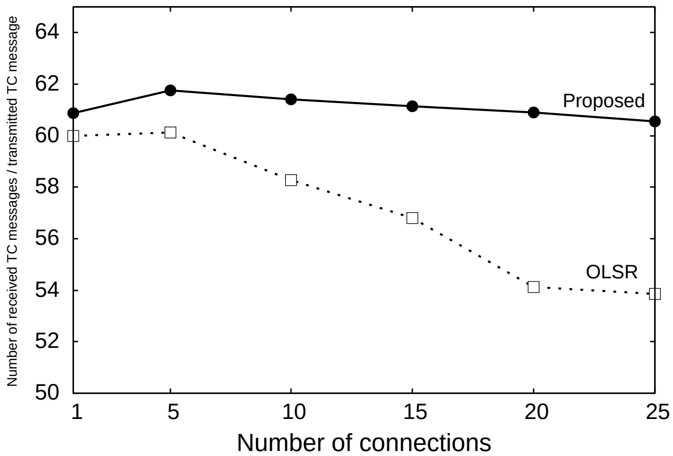

Fig. 10. Number of received TC messages per transmitted TC message.

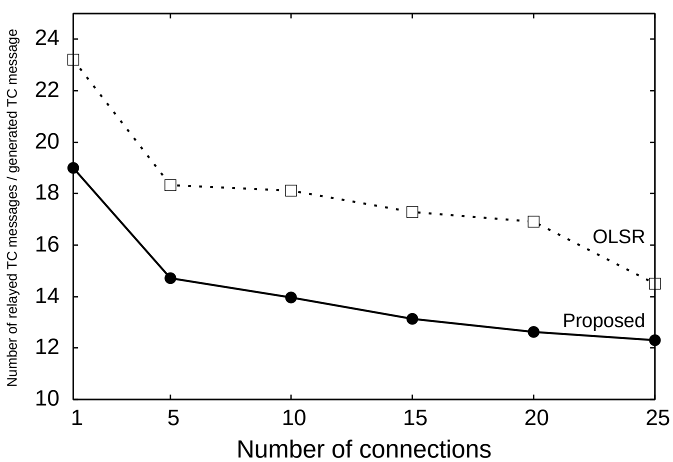

Fig. 11. Number of relayed TC messages per generated TC message.

utilization ratio of wireless resource.

IV. CONCLUSIONS

The interference is one of the big degradation factors in wireless communication. Especially, communications in ad-hoc networks come under the influence of interference from neighbor communications. This paper proposed the interference reduction routing protocol for ad-hoc networks. Our protocol is based on the OLSR protocol, which is a popular proactive routing protocol in ad-hoc networks. The proposed protocol has two big features that are different in OLSR. First one is to estimate the minimum transmission power for required transmission quality by using the hello messages. Then, the node can control the transmission power for each neighbor node appropriately. Second one is to find the MPR node, which can communicate with many nodes and exists at far from the node. From the simulation results, we confirmed that the interference is the one of the degradation factors for ad-hoc networks, and our protocol can improve the throughput performance with fewer control messages.

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