Proposal of traffic aware routing based on neighborhood communication for ad-hoc networks

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Abstract— **In this paper, we propose a traffic aware routing protocol for ad-hoc networks. In the proposed protocol, nodes estimate the utilizable wireless resource for constructing routes. Moreover, they consider the neighbor traffic according to the route requested connection. In order to achieve the above objects, nodes always sense a wireless channel to confirm the channel condition. Then, they remove the traffic of route requested connection from measured data to estimate the utilizable wireless resource without own connection traffic. To construct routes based on the measured traffics, nodes select forwarding delay period according to the utilizable wireless resource. From simulation results, we can find that the proposed protocol can improve the packet delivery ratio according to dispersed traffic.**

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

I. Introduction

In wireless ad-hoc networks, same frequency band is shared by all wireless nodes. Therefore, sharing mechanisms of wireless resource are important factors to achieve ad-hoc networks. Carrier sense multiple access (CSMA) is the most well-known mechanisms for media access control. If nodes employ the CSMA, they sense a wireless channel first when they try to transmit a data packet. Then, they transmit the data packet when the wireless channel is not used.

In the ad-hoc networks, some nodes may try to communicate simultaneously. Meanwhile, nodes cannot transmit a data packet due to CSMA mechanisms when neighbor nodes are transmitting data packets. Therefore, traffic distribution is an important factor to realize simultaneous communication in ad-hoc networks.

The conventional routing protocols for ad-hoc networks are classified into three categories: minimum hop count protocols, consumed power aware protocols, and traffic aware protocols [1]. Ad Hoc On-demand Distance Vector Routing (AODV) [2] and Dynamic Source Routing (DSR) [3], [4] are well-known protocols in the minimum hop count category. The minimum hop count routing protocols can construct minimum distance routes. Meanwhile, the performance degrades due to traffic concentration. Consumed power aware routing protocols can construct routes with minimum consumed power for communication [5], [6], [7]. Therefore, it is useful to extend lifetime of wireless nodes. Traffic aware routing protocols can construct routes with low traffic [8]. Hence traffic distribution can be achieved, and throughput is also improved.

In this paper, we focus on the traffic aware routing protocols to achieve reliable simultaneous communication in ad-hoc networks. In the conventional traffic aware routings, some factors such as number of transfered data packets [9], number of links to neighbor nodes [10], [11], busy ratio of physical wireless channel [12], [13], etc. are considered as an indicator of traffic.

Moreover, collecting schemes of traffic information are classified into two categories. First one is to collect all traffic information in whole networks [9], [10], [11], [12], [13]. In this category, nodes can find an optimum route to detour heavy traffic area. On the contrary, an overhead for collection of traffic information becomes especially large. Second one is to collect partial traffic information in whole networks [14], [15], [16], [17], [18]. In this category, nodes can find a sub optimum route. But, an overhead will be smaller than that of first category.

In CSMA mechanisms, nodes transmit data packets when they confirm that wireless channel is not used by neighbor nodes. Moreover, wireless signals spread in a circular pattern at the center of a transmitting node. Therefore, to detour heavy traffic area, nodes should confirm the wireless channel status.

In multi-hop communication, neighbor traffic of own connection affect to own communication, because some data packets are forwarded hop by hop over the route [19], [20]. Additionally, routes may be reconstructed due to link losses, movement of nodes, etc. in ad-hoc networks. Therefore, routing protocols should consider the traffic of own connection not to detour own traffic.

In this paper, we propose a new traffic aware routing protocol for ad-hoc networks. The proposed protocol employs the channel busy ratio, which is a utilizable ratio of wireless

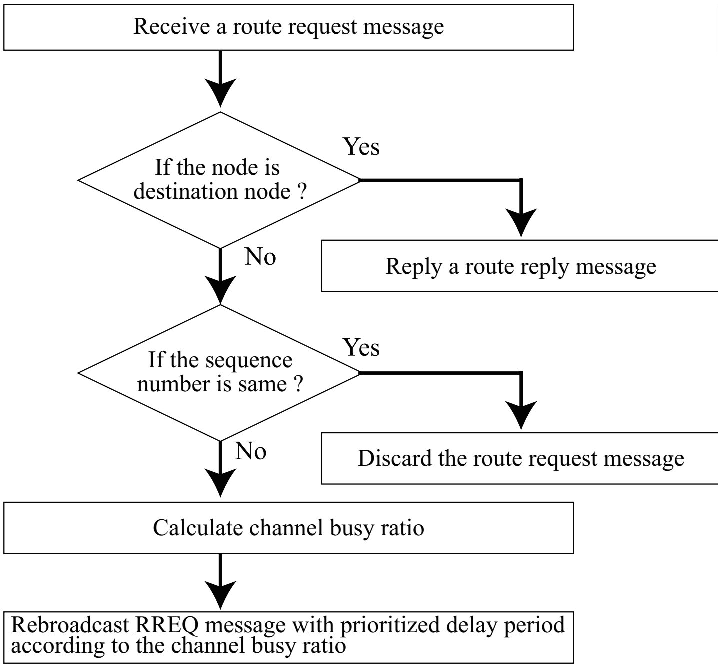

Fig. 1. Flowchart for route request messages.

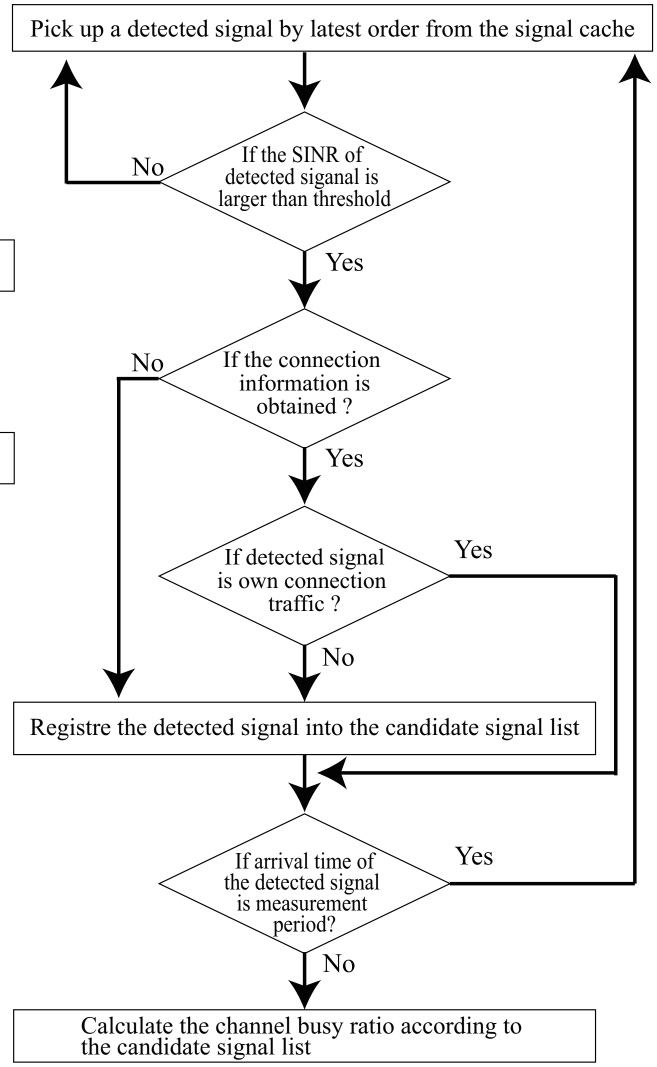

Fig. 2. Flowchart for calculation of channel busy ratio.

channel, as an indicator of traffic. Then, nodes consider the own connection traffic to calculate the channel busy ratio. Meanwhile, the proposed protocol employs AODV as the base routing protocol. Therefore, nodes achieve prioritized route construction by changing forwarding delay period according to the channel busy ratio. From numerical results, we can find that the throughput performance can be improved when simultaneous communication is performed.

II. Proposed traffic aware routing

A. Prioritized route construction

The proposed routing protocol is designed based on the AODV protocol. AODV is one of the reactive routing protocols for ad-hoc networks. Nodes transmit a route request (RREQ) message to whole networks when the nodes try to transmit data packets. Neighbor nodes rebroadcast the received RREQ message to achieve flooding. A destination node replies a route reply (RREP) message to the source node when it receives the RREQ message to own node.

Figure 1 shows the flowchart for route request messages. When nodes receive a route request message, they check the destination address in the route request message. If the destination address matches own address, nodes reply a route reply message to the host of the source address in the route request message. If not, nodes check the sequence number in the route request message. If the sequence number is updated, nodes start to calculate the channel busy ratio. In the route construction of AODV, destination nodes select a route, which conveys the first arrival route request message. Therefore, the proposed protocol controls the forwarding delay period of the route request messages. Hence, nodes set the forwarding delay period of the route request message according to the calculated channel busy ratio. In the procedure of prioritization, long delay period is set for high channel busy ratio not to be selected as a route.

B. Calculation algorithms for channel busy ratio

The feature of the proposed scheme is to consider the own connection traffic to calculate channel busy ratio(CBR). Figure 2 shows the flowchart for calculation of channel busy ratio. In the proposed protocol, nodes are always sensing a wireless channel to collect traffic information. The collected traffic information is registered into the signal cache. When nodes start to calculate a channel busy ratio, nodes pick up detected signals by latest order from the signal cache for

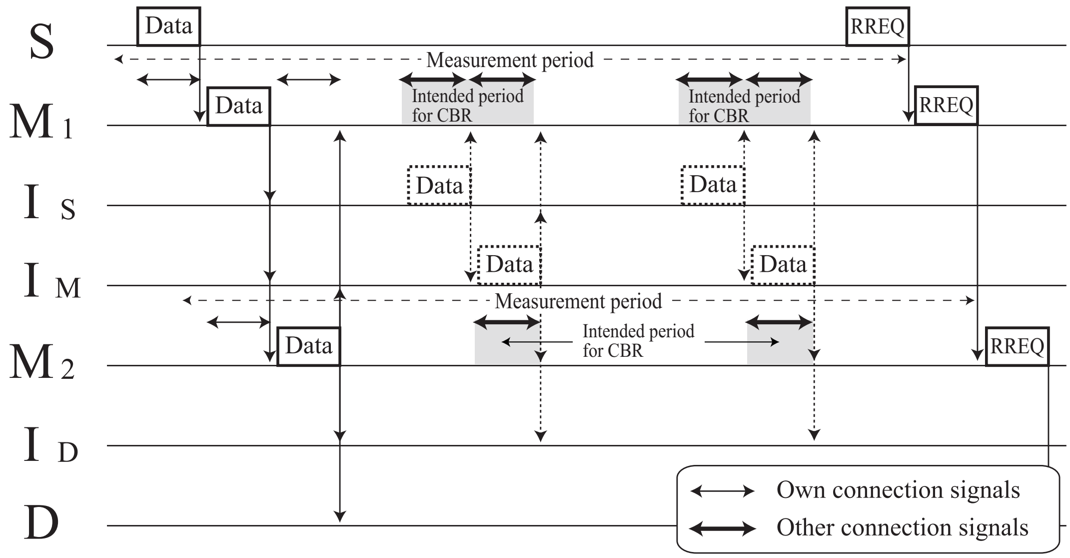

Fig. 4. Example calculation of channel busy ratio in packet flow.

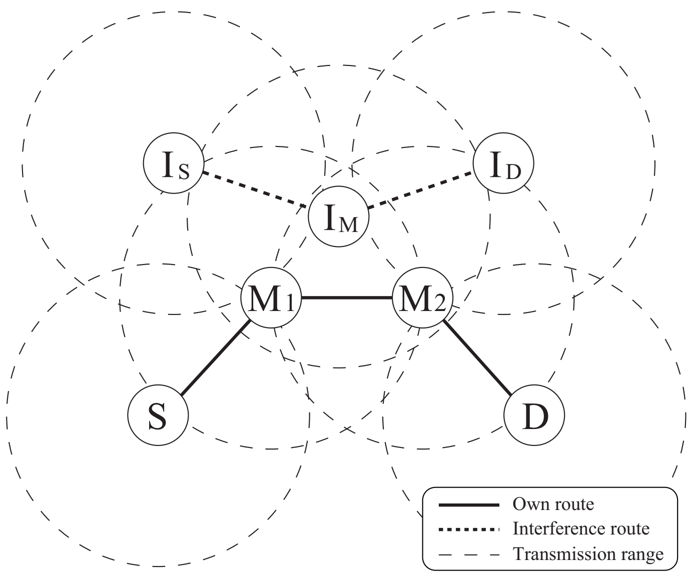

Fig. 3. Example network for calculation of channel busy ratio.

certain period. If the SINR of the detected signal is larger than the sensing threshold in IEEE 802.11 systems, nodes try to check the connection information such as a source address and a destination address in the packet. When the connection information is obtained, nodes checks the detected signal is a part of connection, which is requested in the received route request message, through the own node. If the detected signal is other traffic, nodes register the detected signal into the candidate signal list. Above-described processes are repeated for certain measurement period. Finally, nodes calculate the channel busy ratio from the candidate signal list.

C. Example calculation of channel busy ratio

Figure 3 shows the example network for channel busy ratio, and Fig. 4 shows the example calculation of channel busy ratio. In the example network, node I_S communicates with node I_D through node I_M. Node S has communicated with node D through node M_1 and M_2, and it tries to find a new route to node D due to a route failure. Node M_1 exists in the transmission ranges of node I_S and node I_M, and node M_2 exists in the transmission ranges of node I_M and node I_D.

In Fig. 4, node S transmits the data packet to node D through node M_1 and node M_2. Therefore, node M_1 and node M_2 receive the data packets. Then, node I_S transmits the two data packets to node I_D. Since node M_1 and node M_2 exist in the transmission regions, they receive the data packets of the communication between node I_S and node I_D.

When node M_1 receives the RREQ message from node S, it starts to calculate the channel busy ratio for the certain measurement period. In the example, first data packet is ignored for the channel busy ratio because it is the data packet of own connection from node S. On the contrary, successive four data packets are targeted for the channel busy ratio because they are the data packets of other connection. By the same token, node M_2 can calculate the channel busy ration for the the certain measurement period.

III. EXAMPLE OPERATIONS

Figure 5 shows the example route construction procedures, and Fig. 6 shows the packet flow of routing control messages. In the example, constant bit rate with 128 [Kbps] is performed between node I_S and I_D as the interference connection. Additionally, bandwidth is assumed to 2 [Mbps]. When node

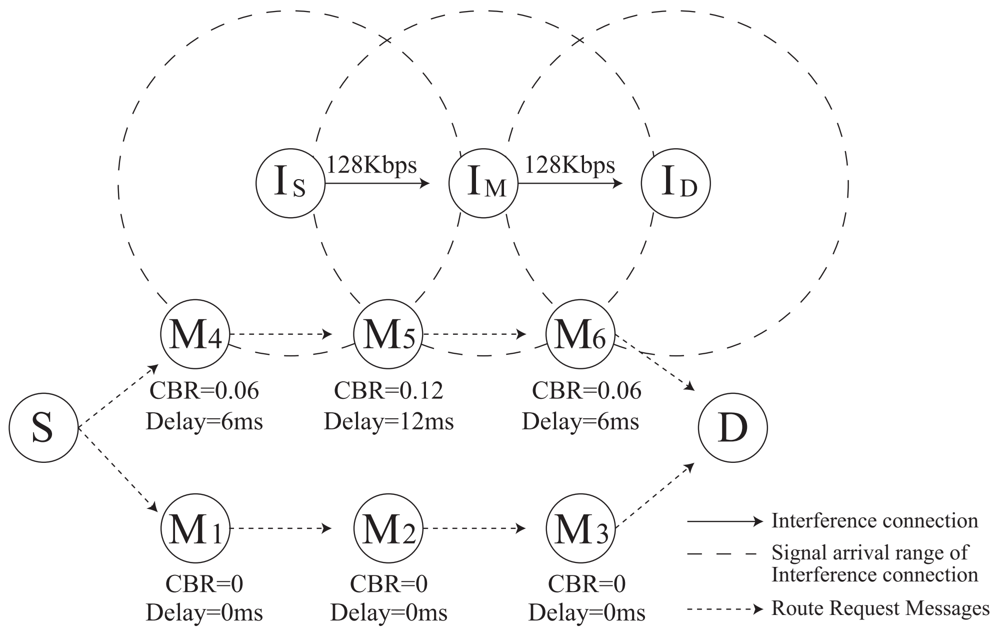

Fig. 5. Example route construction procedures.

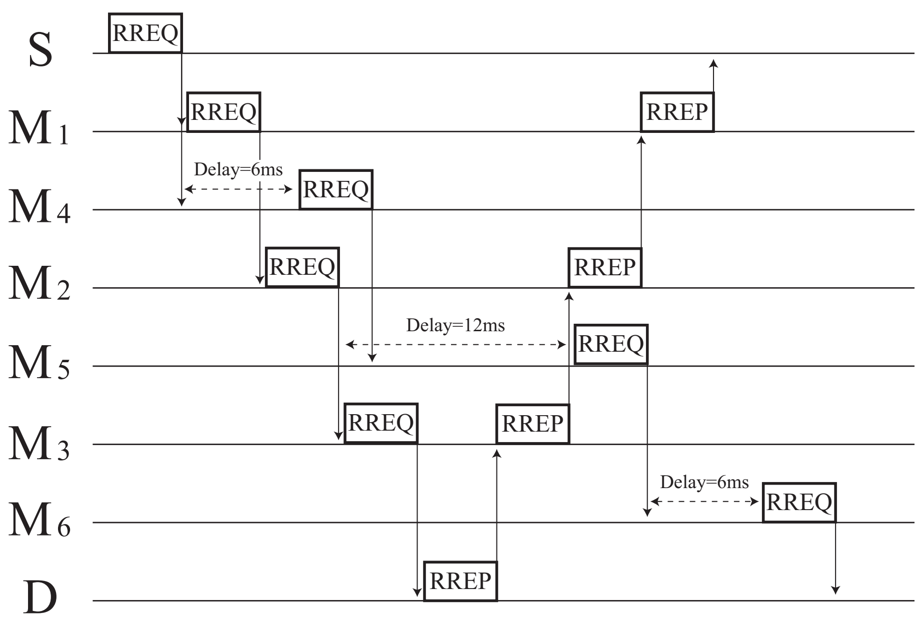

Fig. 6. Example flow of control messages.

S tries to construct a route to node D, the following procedures are performed.

- Node S broadcasts the RREQ message to whole network in order to find routes to node D.
- Node M_1 and node M_4 receive the broadcasted RREQ message from node S. They calculate the channel busy ratio, and pick up detected signals by latest order from the signal cache for certain period. Node M_1 does not receive any signals from neighbor nodes. Therefore, the channel busy ratio (CBR) of node M_1 is 0. On the contrary, node M_4 receives signals from node I_S. Since node I_S transmits data with 128 [Kbps] and the bandwidth is 2 [Mbps], the CBR of node M_4 is 0.06. Then, they set the forwarding delay according to the CBR. Therefore, the forwarding delay of node M_1 is set to 0 [ms], and the forwarding delay of node M_4 is set to 6 [ms]. As the results, node M_1 forwards the RREQ message without the forwarding delay. Meanwhile, node M_4 forwards the

TABLE I

FORWARDING DELAY PERIOD.

Channel busy ratio(CBR)	Delay [ms]
0 - 0.2	0 - 20
0.21 -	600

TABLE II

SIMULATION PARAMETERS.

Simulator	QualNet
Simulation time	500 [s]
Simulation trials	50 times
Number of nodes	200
Simulation area	11000 × 11000 [m]
Node placement	Uniform
Node mobility	None
Communication system	IEEE 802.11g
Transmission rates	6[Mbps]
Propagation pathloss model	Free space
Wireless environment	AWGN
Routing protocol	AODV, Proposed protocol
Application	CBR 64 [Kbps]
Data packet size	1 [KB]
Call arrival rate,	1/20 - 1
Average call-holding time,	exponential with 20 [s]
Measurement period,	3 [s]

RREQ message with the 6 [ms] forwarding delay.

- Node M_2 receives the RREQ message from node M_1, and node M_5 receives the RREQ message from node M_4. Node M_2 does not receive any signals from neighbor nodes. Therefore, the channel busy ratio (CBR) of node M_2 is 0. On the contrary, node M_5 receives signals from node I_S and node I_M. Therefore, the CBR of node M_5 is 0.12. As the results, the forwarding delay of node M_2 is set to 0 [ms], and the forwarding delay of node M_5 is set to 12 [ms].
- Node M_3 receives the RREQ message from node M_2, and node M_6 receives the RREQ message from node M_5. By the same token, they set the forwarding delay according to the CBR. Therefore, the forwarding delay of node M_3 is set to 0 [ms], and the forwarding delay of node M_5 is set to 6 [ms].
- Node D receives the RREQ message from node M_3 earlier than the RREQ message from node M_6. Therefore, it replies the RREP message to node S through node M_3, M_2, and M_1. Finally, the route without neighbor traffic can be constructed without exchange of traffic information between nodes.

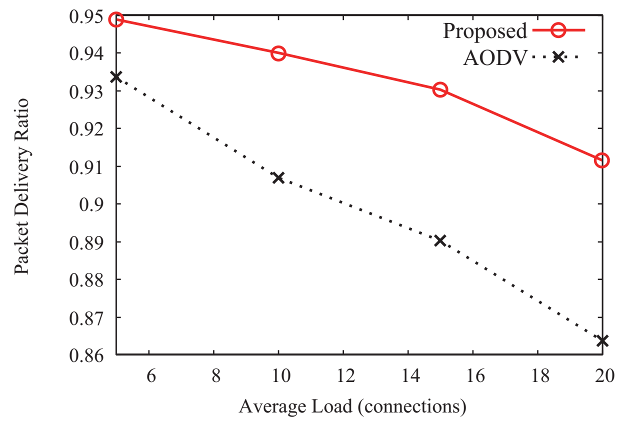

Fig. 7. Packet delivery ratio.

IV. NUMERICAL RESULTS

In this section, we compare the performance for the proposed protocol with that for the conventional AODV protocol. The simulations are performed by the network simulator QualNet[21]. In the simulations, we assume IEEE 802.11g as the wireless communication device, and the transmission rate is fixed at 6 [Mbps]. 200 nodes are placed uniformly in 11000 × 11000 [m] area. The source and the destination node are selected randomly. The application is constant bit rate with 64 [Kbps] and data packets with the length of 1 [KB]. We consider the additive white gaussian noise (AWGN) environment and the free space propagation model. The simulation results are an average of 50 simulation trials. Detail simulation parameters are shown in Table II.

Figure 7 shows the delivery ratio of data packets. From the results, we can find that the proposed protocol can keep the higher delivery ratio even if the number of connection increases. The reason is that the proposed protocol can select routes in unoccupied area by prioritized route construction according to the channel busy ratio. On the contrary, the performance of AODV degrades with increasing in the number of connections. This is because, nodes construct a minimum hop route in AODV, and some constructed route may be overlapped. Therefore, neighbor connections affect each other.

Figure 8 shows the normalized link failures per data packets. The results show that the proposed protocol can reduce the link failures. When nodes employ the IEEE 802.11 systems, route failures are usually detected by transmission failure in datalink layer. Therefore, interference between neighbor traffics causes the increasing of link failures.

Figure 9 shows the normalized number of route request messages per data packets. From the results, we can find that the proposed protocol can reduce the number of route request messages. This is because, our protocol can reduce the number

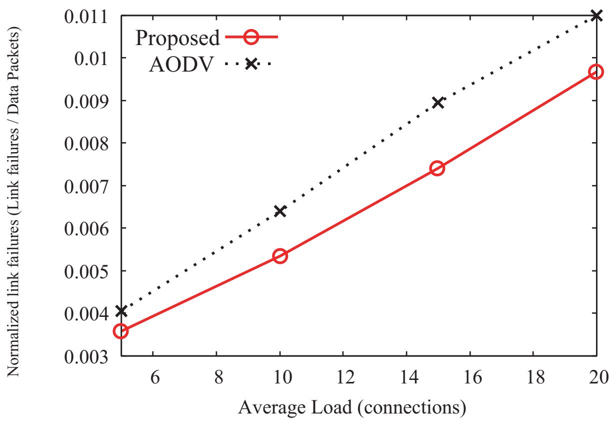

Fig. 8. Normalized link failures per data packets.

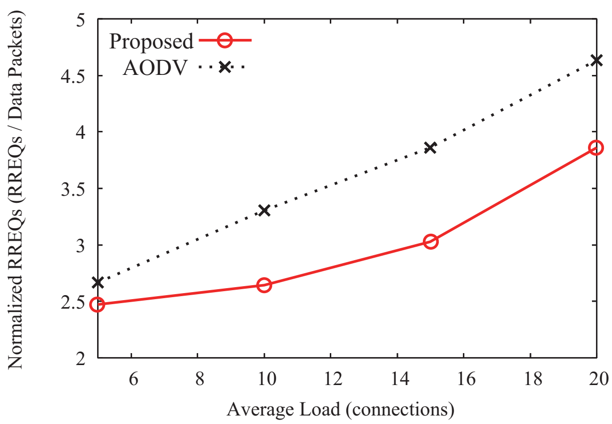

Fig. 9. Normalized number of route request messages per data packets.

of link failures by detouring heavy traffic area. Therefore, route reconstruction is also reduced in the proposed protocol. On the contrary, nodes try to reconstruct routes in AODV, and the number of route request messages also increases.

V. Conclusions

The traffic aware routing is one of the performance improvement schemes for ad-hoc networks. Especially, communication in ad-hoc networks performs simultaneously. Moreover, same connection traffic affects each other in ad-hoc networks. In this paper, we proposed the traffic aware routing, which focus on the unused wireless channel resource and traffic of own connection. From the simulation results, we confirmed that the interference between connections is the one of the degradation factors for ad-hoc networks, and our protocol can improve the throughput performance with a few control messages.

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