A Belt-Zone Method for Decreasing Control Messages in Ad Hoc Networks

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Abstract. MANET(Mobile Ad Hoc Network) is the composite technology of mutual wireless connections of nodes in mobile networks. In AODV(Ad hoc On-demand Distance Vector) Routing, all the nodes have to receive route request messages, and rebroadcast the route request messages for others. It causes a lot of network traffic overheads. In this study, we propose a belt-zone selection method for decreasing the number of RREQ messages. All nodes that receive the RREQ message don't rebroadcast, but only the nodes within a selected zone rebroadcast it for setting a routing path. The belt-zone a logical concentric area is decided by the signal strength from RREQ sender. We also provide an efficient belt-zone selecting sequence by simulations. In high density networks, an intermediate area within several logical concentric areas from the sender must be selected as the primary area. But, in low density networks, the far area from the sender is better to be selected as the primary belt-zone area. By applying the proposed belt-zone mechanism to AODV networks, a lot of control messages can be decreased on various load situations.

1 Introduction

MANET is a network with no fixed infrastructure, such as underground cabling or base stations, where all nodes are capable of moving and can be connected dynamically in an arbitrary manner. Nodes, in MANET, work as routers to discover and maintain routes to other nodes[1]. An important challenge in the design of ad hoc networks is the development of a dynamic routing protocol that can efficiently find a routing path between two communicating nodes. MANET routing protocol consists of table-driven protocol and on-demand protocol[2-5]. In table-driven protocol, each mobile node maintains routes to all nodes in the network. It requires periodic routing advertisements to be broadcasted by each node. In a dynamic mobile network, the topology information is soon out of date, and the propagation of routing information is too slow to be accurate. But the other hand, an on-demand routing protocol creates routes only when the source node has data to transmit to destination. In AODV, which is a representative on-demand routing protocol, a source node broadcasts a route

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request control message(RREQ) to discover a routing path to a destination node. Neighbors of the sender node receive it. Each node that has received the RREQ message rebroadcasts it to its own neighbors. This process continues until the RREQ reaches to the destination node. All message which is received is rebroadcasted even they do not participate in route setting. It brings bandwidth waste and traffic overhead. In this paper, we propose a belt-zone concept and a selection sequence method for decreasing the number of unnecessary control messages and increasing network efficiency.

2 AODV Routing

AODV routing protocol supports the multi-hop routing among mobile nodes for establishing and maintaining an ad hoc network. In AODV, a node requests a route only when it is needed, and the other case of nodes do not need to maintain routing table. To send a message from the source to the destination, the source node initiates a route discovery procedure. A RREQ message is flooded through the network until it reaches to the destination or it reaches to a node that knows the route to the destination.

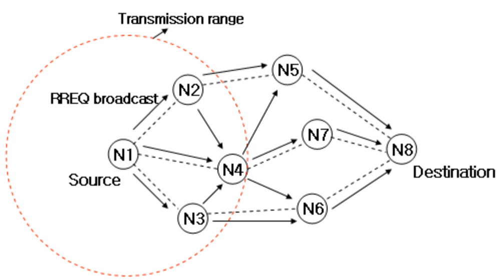

Fig. 1. AODV Routing Protocol Route Request

Fig. 1. shows RREQ messages flooding. Nodes received. RREQ messages check if node itself is a destination node. If the node is not the destination node, increases RREQ messages hop count by 1 and broadcasts RREQ messages to neighbor nodes. While transmitting RREQ messages, intermediate nodes save RREQ packets broadcasted node's address in routing table and use in reverse path. A duplicated RREQ message is dropped.

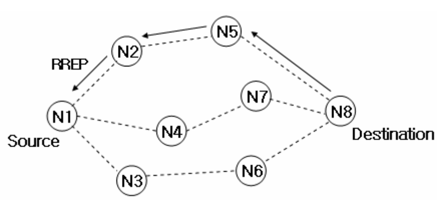

Fig. 2. AODV Routing Protocol Route Reply

A route reply (RREP) control message from the destination is unicast back to the source along the reverse path. Fig. 2 shows a transmission process of a RREP message from destination to source node. When the RREP is routed back along the reverse path, all nodes on this route set up a forward path by pointing the node that transmit the RREP. These forward route entries indicate the route to the destination node. Through this procedure, the route is made. In AODV, by flooding the RREQ message, a lot of RREQ messages have to be transmitted. This derives large overhead and fast power consumption.

3 A Belt-Zone Selection Method

The purpose of belt-zone method is to decrease the number of unnecessary RREQ messages. All nodes that receive the RREQ control message need not rebroadcast the message, but only the nodes within a selected zone rebroadcast it and set the routing path. When each node receives the RREQ, the node checks the signal strength if it is within in-bound and out-bound signal strength threshold. When the state is true, then it is in selected zone and rebroadcasts the message. This can decrease the number of the RREQ control messages. The node that rebroadcasts the RREQ message and establishes a stable routing path is considered a member node of selected belt-zone.

3.1 The Concept of Belt-Zone

A belt-zone(BZ) is a scope of area. The nodes in the selected area rebroadcast the RREQ message received from a sender. It is included in belt-zones which is a logical concentric area within transmission range from the sender. In fig. 3, between $SSTR_{in}$(in-bound Signal Strength Transmission range) and $SSTR_{out}$(out-bound Signal Strength Transmission range) is set as a selected BZ. Nodes inside the BZ rebroadcast a RREQ message that is received from A(Sender) and nodes outside of the BZ abandon it. In fig. 3, node A broadcasts a RREQ, then node B in the selected belt-zone rebroadcast the RREQ and nodes C, D, E, F abandon it. The signal strength of node B detects is weaker than $SSTR_{in}$ and stronger than $SSTR_{out}$, therefore node B is included in the belt-zone and rebroadcasts RREQ message to neighbor nodes as a new sender. Detected signal strength by node C is stronger than $SSTR_{in}$ and it can decide itself as out of belt-zone, therefore node C abandons the message. BZ can be decided as follow (1).

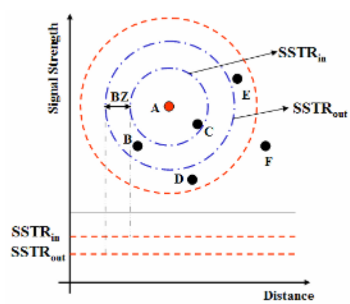

Fig. 3. The measurement of signal strength

$$\mathrm{SSTR_{in}} \geq \text{received SS} \geq \mathrm{SSTR_{out}}\ . \tag{1}$$

In fig. 4, when the source node A sends RREQ messages to find the destination node N. Node B, C, D, E, F are in the transmission area of node A depend on measured signal strength. If a node is aware that it is between $SSTR_{in}$ and $SSTR_{out}$, the rebroadcasts the RREQ message. In fig. 4 node B and E are decided and rebroadcast the message, but node D, C, F abandon the message. The rebroadcasted RREQ message sent from node E is received by nodes C, D, F, I, J, and K. Only node J and K belongs to the BZ for the message, therefore these nodes rebroadcast it.

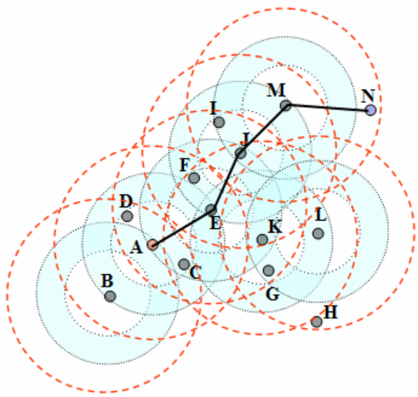

Fig. 4. A route discovery procedure using the belt-zones

By the similar sequence, node J, M relay the message to destination node N.

3.2 Belt-Zone Extension

Nodes broadcast RREQ control messages only when the node belongs to the selected BZ. If a route discovery procedure is failed, the source node extends BZ scope and re-start a new route discovery procedure to find the destination. Function (2) is the first belt-zone extension case.

$$\mathrm{SSTR_{out(N)}} = \mathrm{SSTR_{out(P)}} - \mathrm{BZ_{width}}\ . \tag{2}$$

Where $SSTR_{out(P)}$ is previous signal strength, $SSTR_{out(N)}$ is the new signal strength threshold, and BZ_{width} is extension parameter. In the first expansion, the area is extended to the direction of the outside.

After first time belt-zone expansion, the route discovery procedure is repeated. If finding the destination is again fail, then BZ scope area is re-extended. Function (3) shows the case of second extension of BZ area. In this case, the broadcast area is extended to in-bound direction.

$$\mathrm{SSTR_{in(N)}} = \mathrm{SSTR_{in(P)}} + \mathrm{BZ_{width}}\ . \tag{3}$$

As the expansion result, the BZ scope includes whole transmission area from the sender as shown in fig. 3.

4 Performance Evaluation

4.1 The Belt-Zone Model

To select efficient belt-zone, we use two models. One is divided as three zones and the other is divided as four zones.

In first model, we simply divide whole transmission area as three logical concentric BZ areas. BZ_1 is the area in which the signal strength is from $SSTR_0$ to $SSTR_1$. BZ_2 is the area in which the signal strength is from $SSTR_1$ to $SSTR_2$. BZ_3 is the area in which the signal strength is from $SSTR_2$ to $SSTR_3$.

In second model, we select the big inner area from the sender as BZ_0 and remained outside transmission are a will be divided for three BZ areas. BZ_0 is the area in which the signal strength is below $SSTR_0$. BZ_1 is the area in which the signal strength is from $SSTR_0$ to $SSTR_1$. BZ_2 is the area in which the signal strength is from $SSTR_1$ to $SSTR_2$. BZ_3 is the area in which the signal strength is from $SSTR_2$ to $SSTR_3$.

By simulation results, we find that BZ_1 of fig. 5 and BZ_0 of fig. 6 are seldom selected as selected BZ. Therefore for effective analysis, we do not select those two area as selected BZ in the future experiments.

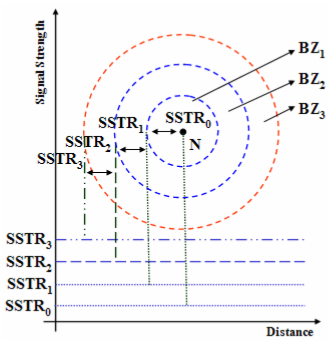

Fig. 5. First belt-zone model for simulation

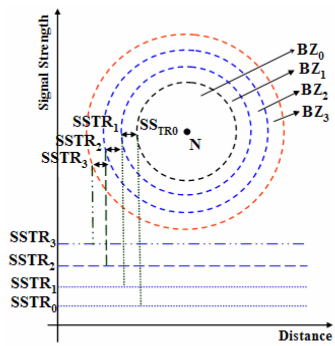

Fig. 6. Second belt-zone model for simulation

4.2 Simulation Environment

Simulation environment consists of the number of nodes = 5, 13, 25, 50 per unit area, and use the area of 2000 x 2000. Each node is distributed randomly. For each parameter, 100 simulations are done. To find out the most effective first selection belt-zone area, by the number of RREQ messages, the success rate of transmission is monitored depending on the changing of node density.

Simulation result of first model shows that only BZ_3 has possibility to be selected as belt-zone as shown in fig. 7-8. We can realize that BZ_3 has 100% success rate of transmission and the number of RREQ messages are far fewer than AODV as shown in fig. 9-10.

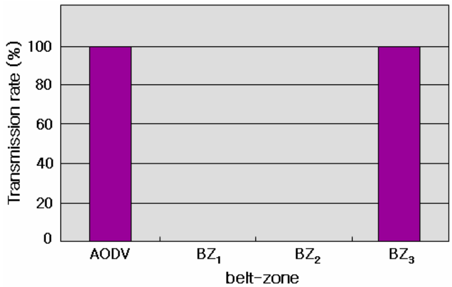

Fig. 7. The Success rate of transmission in first model when nd=5 (low density)

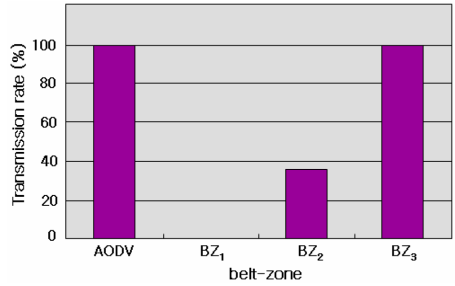

Fig. 8. The Success rate of transmission in first model when nd=25 (high density)

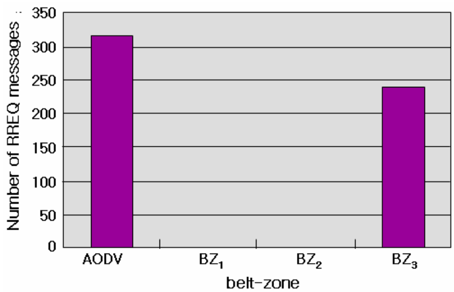

Fig. 9. The Number of RREQ message in first model when nd=5 (low densiy)

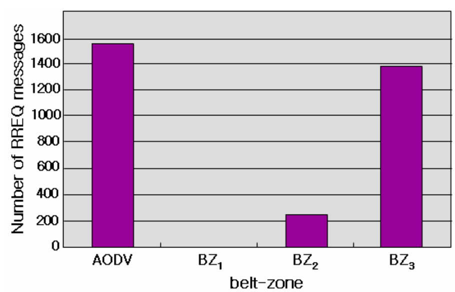

Fig. 10. The Number of RREQ message in first model when nd=25 (high density)

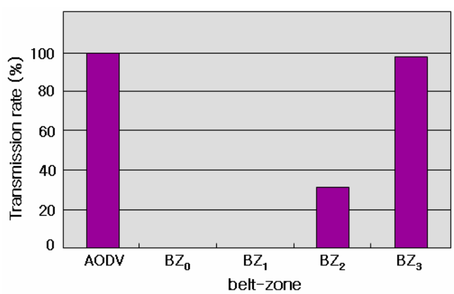

Fig. 11. The Success rate of transmission in second model when nd=5 (low density)

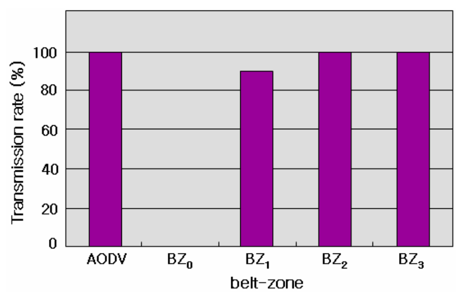

Fig. 12. The Success rate of transmission in second model when nd=25 (high density)

The simulation result of [Fig. 11-12] shows that the success rate of transmission in low node density and high node density case. Regardless of node density, success transmission rate of BZ_0 is 0%.

Fig. 13-14 Show the number of RREQ control messages with traditional AODV and proposed belt-zone method in low density case and high density case. As we can see BZ_3 is found as the most efficient area for the condition of low density. For high-density condition, BZ_2 is found as the most efficient area. We can say that first selected BZ must be different depend on the node density of BZ.

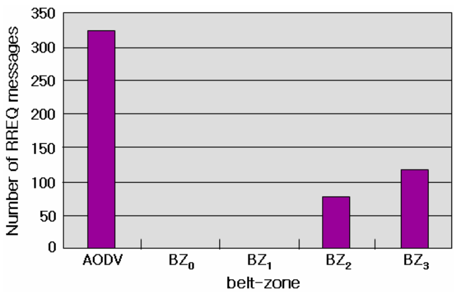

Fig. 13. The Number of RREQ message in second model when nd=5 (low density)

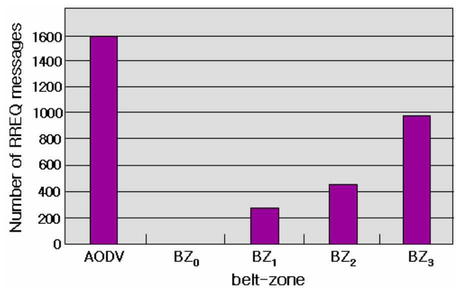

Fig. 14. The Number of RREQ message in second model when nd=25 (high density)

Density decision function of the initial belt-zone selection is as follows:

$$\begin{aligned} BZ &= f(N), \\ &\text{if } (N \leq 10) \text{ then BZ3 }, \\ &\text{if } (N > 10) \text{ then BZ2 }, \\ &\text{where N is the number of nodes in a unit area.} \end{aligned} \quad (4)$$

According to above density decision function, first BZ selection will be set up and RREQ message will be broadcasted. As expansion of belt-zone selection method, first the most suitable belt-zone must be selected. If route-establishment fails, then the belt-zone area must be extended.

In low density case, BZ_2 is added as extension to BZ_3. Fig. 15 shows despite belt-zone is extended, total number of RREQ message is fewer than that of AODV. Fig. 16 shows transmission success rate of both are 100%.

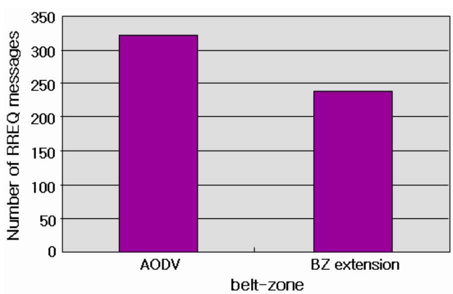

Fig. 15. The number of RREQ message of AODV and that of extended BZ in low density

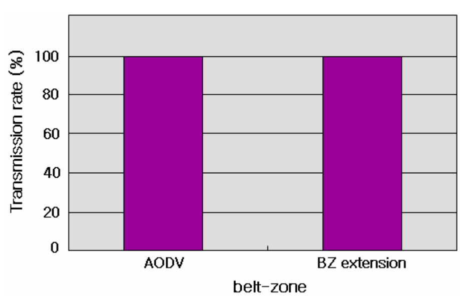

Fig. 16. Transmission success rate of AODV a nd that of extended BZ in low density

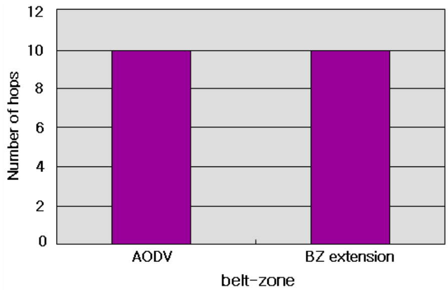

Fig. 17. The number of AODV hop and that of extended BZ hop in low density

Fig. 17 shows that hop counts are the some even though the methods are different.

As the results of simulation, we confirm that the proposed BZ method can give apparent improvement of performance.

5 Conclusions

We proposed a belt-zone model to select the most suitable subset of communication area for decreasing RREQ messages. The proposed BZ model divides the whole transmission range from the send as subsets of concentric areas. The key idea is that a belt-zone is selected as a rebroadcast area, for control message then only the nodes in the zone attend to establish route. If the route searching process fails, then the belt-zone area is extended. The primary selection of a belt-zone depends on node density. In the case of low-density, selecting out-bound area is prior. Extension of the area is done to in-bound areas. In the case of high-density, selecting intermediate area is prior. Extension of the belt-zone is done first to out-bound, then next to in-bound.

By applying our proposed belt-zone method to AODV networks, we can observe that a lot of control messages are decreased on various load situations.

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