A Routing Protocol with Directional Antennas for improving robustness in Mobile Ad Hoc Networks

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Abstract

Using directional antennas in ad hoc networks have many potential advantages. Especially, the higher gain of directional antennas affects connectivity and robustness of wireless ad hoc networks. Therefore, in this paper, we propose a new routing algorithm which enables fully utilizing the higher gain property of directional antennas. We believe the proposal has some novelty in the negotiation of transmission range by directional antennas is decided in the receiver instead of in the sender. Proposed scheme can significantly reduce the number of hops in route. Our preliminary simulation results show that our scheme is more efficient than the existing on-demand routing protocol.

1. Introduction

Wireless ad hoc networks are typically assumed that all nodes are equipped with omnidirectional antennas. But using directional antennas in ad hoc networks is an attractive issue due to its potential advantages such as spatial reuse, lower power consumption, lower chance of interference and higher gain compared with using omnidirectional antennas.

Previous researches have been more concentrated on MAC layer. However, using directional antennas can affect the routing layer. In [1], authors decreased routing overhead by selectively choosing suitable directional antenna in route discovery phase. In case of [2], authors proposed MAC and routing protocols well suited for ESPAR antenna which allows an arbitrary radiating structure.

Actually, previous researches didn't investigate deeply the advantage of increased transmission range due to higher gain of main lobe, in the aspect of receiver side. We propose a new routing scheme which utilizes this characteristic.

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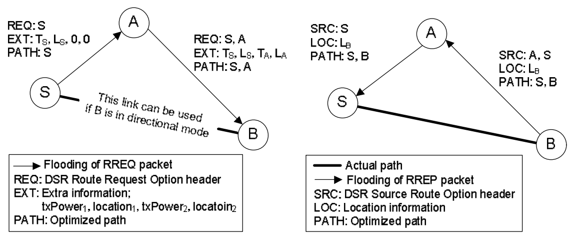
2. Advanced Routing Protocol Using Directional Antennas

This section describes our proposed scheme. We assume that each node is able to know its own location information by location detection device like GPS and equips one directional antenna. Directional antenna has two modes, omni mode and directional mode. In directional mode, the antenna gain in preferred direction is higher than in omni mode which the gain is all equal in the view of top, so a node can transmit the signal more strongly with the same transmission power and can receive the signal more clearly.

A node stays in omni mode while it is idle in order to receive the signal from any direction, so all nodes receive RREQ in omni mode if it isn't busy. Therefore, the path included in RREP is comprised of nodes which were in omni mode in the route discovery phase. However, if a node participated in the routing path is in directional mode, it is possible that the node receives the signal from not the previous hop or the next hop but the node which is far away because receive gain in directional mode is higher than in omni mode, as mentioned before. But previous routing protocols don't support this characteristic.

In our scheme, an intermediate node Y which received RREQ including path $\{\ldots,X,X+1,\ldots,Y-1\}$ determines that it can receive the signal from the node X which is more than one-hop away if Y is in directional mode. Determination is done by utilizing wireless channel propagation model such as two-ray ground path loss model [3]. If it is possible, path is shortened by removing the node id $\{X+1,\ldots,Y-1\}$ from the path.

Some extra information must be offered to enable the determination, so we modified the packet structure



(a) Flooding of RREQ (b) Return of RREP

Figure 1. Procedure of our scheme.

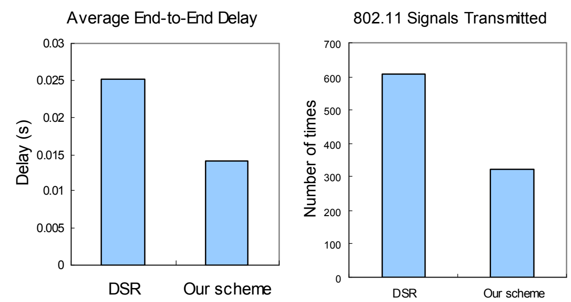


Figure 2. Simulation results

of Dynamic Source Routing protocol [4]. However our main ideas can be easily adapted to other on-demand routing protocols with small modifications.

● **Flooding of RREQ**: Two pieces of set comprised of transmit power information and location information are attached to RREQ packet of DSR. We will refer them as $txPower_1$, $location_1$, $txPower_2$, $location_2$. Optimized path, short path acquired by our scheme, is also attached to RREQ.

Fig 1-(a). shows a procedure of RREQ flooding. Initially, source node S puts its own transmit power T_s and location information L_s into $txPower_1$ and $location_1$. $txPower_2$ and $location_2$ are set to zero.

When node A receives RREQ from S, node A sets $txPower_2$ and $location_2$ with its own information T_A and L_A because A is a neighbor node of source node. Then id "A" is attached to the end of optimized path.

After this RREQ is relayed to node B, B determines whether it can receive the signal from S in directional mode. Determination is possible by estimating power P_r of the signal from S with two-ray ground path loss model. Distance can be calculated from L_S and L_B. Transmitted signal power is T_S and receiver antenna gain G_B is the gain of node B in directional mode (G_B^d). In Fig 1-(a), node B can receive the signal from S because G_B^d is sufficient for receiving the signal from node S. Therefore node B replaces the last id "A" of optimized path with "B". $txPower_2$ and $location_2$ also replaced by T_B and L_B.

● **Return of RREP**: A destination node initiates RREP packet which is expanded to store optimized path and location information. Location information exists for previous node in optimized path to know the location for next hop.

In Fig 1-(b), node S can't receive RREP packet from B directly because S can't know which direction RREP comes from. Therefore, RREP is sent back by {…,B,A,S}. Node B must be in directional mode to receive the data packet from S directly, so it adjusts antenna's pattern toward the sender side S. B can know S's location by relayed RREQ. Finally, source node S acquires optimized path {…,B,S} instead of {…, B,A,S} which is a path acquired by the existing DSR.

3. Conclusion

We have presented a new routing scheme with directional antennas. Our scheme reduces delay and increases the network capacity by shortening the length of routing path. We validate the performance of our scheme by simulating with QualNet [5] simulator which supports the realistic directional antenna. As seen Fig 2, our preliminary simulation results show that our scheme has better performance than previous routing protocol, DSR. As a future work, we will consider how to use acquired path more intelligently. More complicated scenarios such as heterogeneous environment with mobility will also be considered for a performance evaluation.

4. References

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