An improvement of Ad hoc On-demand Vector Routing Protocol with buffer queue metric

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Abstract. The ad hoc on-demand distance vector (AODV) is a routing protocol that is usually used in the mobile ad hoc networks (MANETs) and other wireless ad hoc networks. The AODV is a reactive protocol, so a source node will use control messages to find routes to a destination node whenever there are data packets that are needed to transmit. If there is more than one route to the destination node, the source node chooses the shortest route (the route has the fewest number of hops). However, this selection is not ideal in some cases. Considering there is a defected node or unavailable node in the shortest route, the path from the source node to the destination node becomes unstable. To avoid this problem, an enhancement of the AODV is proposed. The proposed solution uses another metric besides the number of hops to find the best route. The new metric is the degree of the queue in the buffers of involved nodes. The nodes that have the queued buffers are relatively busier than other nodes, so they should not be considered in the procedure of the new path establishment. In this paper, the performance of the proposed solution is evaluated using the NS-3 simulator, and the performance results show that the solution improves the performance of the network more than the AODV.

Keywords: AODV, MANET, Routing, Protocol, Simulation.

1 Introduction

The mobile ad hoc networks (MANETs) are wireless networks that have many autonomous mobile nodes (devices) and "ad hoc" means "for this special purpose" in Latin. The nodes get together to make a self-configured network without any fixed infrastructure. The nodes in ad hoc networks can forward packets without the presence of a base station because each node can work as a router. Fig. 1 depicts a wireless network with a base station and an ad hoc network.

There are some advantages of MANETs. First, it can be deployed in different environments and scenarios. Second, the process of deployment is rapid because the networks do not need pre-configured infrastructure. Moreover, the network topology can change and the number of nodes can be decreased or increased.

The ad hoc on-demand distance vector (AODV) is a routing protocol that is widely used in MANETs [1][2]. However, it still has some drawbacks. Therefore, we proposed an improvement of the AODV. In this manuscript, Section 2 gives information about

A. Putro Suryotomo and H. Cahya Rustamaji (eds.), *Proceedings of the 2023 1st International Conference on Advanced Informatics and Intelligent Information Systems (ICAI3S 2023)*,
Advances in Intelligent Systems Research 181,
https://doi.org/10.2991/978-94-6463-366-5_14

MANET routing protocols and the AODV protocol. Then, we review some related works in Section 3. The proposed solution is described in the next section and the simulation results are presented in Section 5.

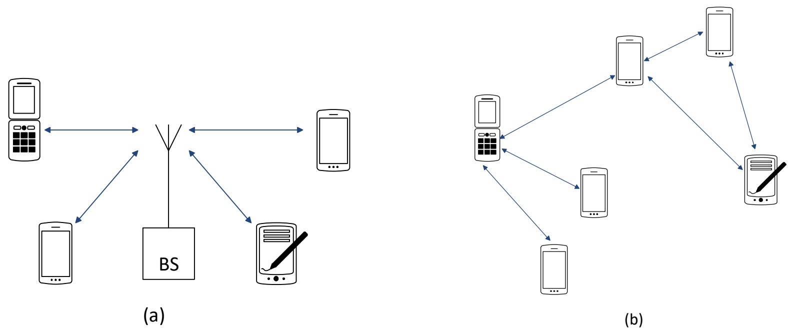

Fig. 1. (a) Wireless network with a base station; (b) Ad hoc network.

2 MANETs Routing Protocols and Ad hoc On-Demand Distance Vector Protocol

2.1 MANETs Routing Protocols

The MANET routing protocols are classified into three categories: reactive, proactive, and hybrid.

- *Reactive protocols*: The reactive protocols do not maintain the network topology information and the route will be obtained whenever there is a request for communication. These protocols do not need to update the network topology periodically but it takes time to establish a route.
- *Proactive protocols*: These protocols always have up-to-date information of routes from each node to other nodes in the network. The network topology is updated periodically, so if there is no communication, a huge amount of control messages is redundant.
- *Hybrid protocols*: The hybrid protocols try to use the advantages of both reactive protocols and proactive protocols. They provide different ways of routing for each level of network.

Some examples of MANET routing protocols are AODV (reactive), DSDV (proactive), and ZPR (hybrid) [3][4].

2.2 Ad hoc On-demand Distance Vector Protocol

The AODV is a reactive protocol, so whenever a source node needs to transmit data packets to a destination node, the source node commences a procedure to find a route to the destination node. This procedure is the route discovery process with some control packets, namely route request (RREQ), route reply (RREP), and route error (RERR). The headers of the RREQ and RREP are shown in Table. 1 and Table. 2. The RREQ packet contains the following information: message type, source address, destination address, broadcast ID, hop count, source sequence number, and destination sequence number. The RREP packet contains the following information: message type, source address, destination address, hop count, destination sequence number, and life time. The broadcast ID is used to differentiate each route discovery process, so each time a node commences a route discovery process, it will use a unique broadcast ID. Sequence number describes if the information in a node is old or not. The node will update its routing table if it receives a message that has higher sequence number than the number of it. The life time describes how will the established route should exist, afterwards the source node needs to start another route discovery process. The route discovery process is described as follows.

First, the source node broadcasts the RREQs to all of its neighbor nodes. After that, the neighbor nodes continue to broadcast the RREQs to other nodes. This process ensures there is no loop because the RREQs are discarded if the intermediate nodes receive the duplicated RREQs. When an RREQ reaches the destination node, the destination node replies with an RREP. This RREP will travel backward to the source node. After receiving the RREP, the source node starts to send data packets to the destination node because the source node now knows the path to the destination node.

Moreover, if an intermedia node also knows the path to the destination node, it can reply with an RREP to the source node. With this RREP, the source node can establish a path to the destination node. When the source node receives more than one RREP, it decides to choose the path with has the fewest number of hops.

Fig. 2 illustrates a route discovery process. The source node (node 1) wants to send data packets to the destination node (node 4). First, node 1 broadcasts RREPs to all of its neighbor nodes. Then the intermediate nodes continue to broadcast RREPs if they do not know the route to the destination node. When node 4 receives an RREQ, it replies with an RREP. Node 1 transmits the data packets as soon as it receives the RREP.

Table 1. RREQ packet format.

Type	Reserved	Hop Count
Broadcast ID		
Destination IP Address		
Destination Sequence Number		
Source IP Address		
Source Sequence number		

Table 2. RREP packet format.

Type	Reserved	Hop Count
Destination IP Address		
Destination Sequence Number		
Source IP Address		
Life time		

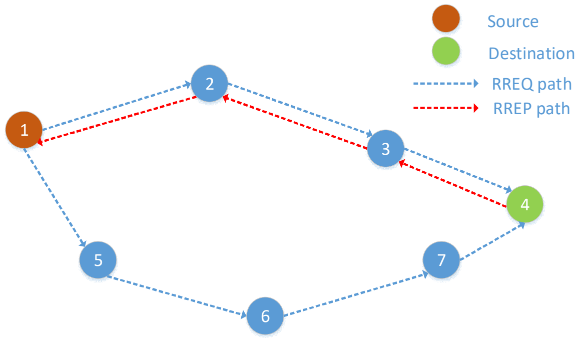

Fig. 2. Route discovery process.

3 Related Works

There are some works that improve the efficiency of AODV. In R-AODV, the reverse route request (R-RREQ) is used [5]. After the destination node receives an RREQ, it floods R-RREQ to find the source node. R-AODV increases the number of control messages in the network, so it is the main drawback of this protocol. Instead of flooding R-RREQ, the destination node can reply with more than one RREP, then the overhead (the number of control messages) is not modified much.

EDA-AODV and ENH-AODV concerned about the energy of nodes in the network [6][7]. Our proposed protocol also helps to share the energy consumption between nodes in the network. Instead of busy nodes, the free nodes are likely to get involved in transmissions, so a node can avoid the shortage of energy because it does not need to forward packets continuously.

4 Proposed Solution

In AODV, the source node chooses the path with the sole metric which is the number of hops. If the source node receives multiple RREPs, it will update its routing table to the destination node with the RREP that has the smallest value in the header "Hop Count". This leads to the issue that some nodes are involved inequitably in communications. For example, the nodes which locate in the center of the network topology are likely involved in the transmission path between the source node and the destination node. Moreover, the nodes which are transmitting data packets should not be considered in the route discovery process. Therefore, we proposed that the queue length in the buffer of nodes can be considered as another metric. The RREP has some reserved bits and these bits can be used to store the information of queue length in the buffer. The new metric is calculated as follows:

$$NewMetric = \alpha * HopCount + \beta * QueueLevel \quad (1)$$

α and β are the weight factors. They are used to determine which parameter is more important in the calculation. We can change α and β depending on each type of network. For example, in the networks that have data packets transmitted continuously, β should be outweighed by α.

HopCount is the value in the header "Hop Count" of RREPs. QueueLevel is the threshold of the queue length in the buffer of each intermediate node. The value of QueueLevel can be preconfigured as follows:

Table 3. The configuration for QueueLevel

Buffer size	Value
0	0
Threshold A	1
Threshold B	2
…	…

The thresholds A and B are set depending on each network and we can decide if more thresholds are needed. It is obvious that the route that has the smallest hops count and its queue level is 0 will be chosen by the source node.

The new metric can help to share the load between nodes of the network. The nodes that have buffer queues will be often ignored in establishing of new route and the free nodes have higher chances of getting involved in the communications. The load mitigation also reduces the chance in that the nodes are out of commission.

Besides new metric calculation, another technique is also implemented in the protocol. Normally, the destination node only replies with one RREP. However, in the proposed solution, the destination node replies with multiple RREPs. Every time the destination node receives an RREQ, it replies with an RREP. The more RREPs return to the source node, the more options the source node has to choose a suitable route to the destination node. This technique was often used by other researchers in their works.

5 Simulation Results

The simulations are implemented using Network Simulator 3 (NS-3) [8]. We conduct 2 simulation cases, and α and β are set to 1. Both cases have 2 UDP links: the main link is the link that we used to assess the performance of the routing protocol, and the subordinate link is used to make some nodes have queued messages in their buffers. The subordinate link in the two cases has different packet sizes. The simulation parameters are as follows:

Table 4. Simulation parameters

Parameters	
Number of nodes	30 nodes
Traffic load	UDP, CBR traffic generator
Application	2 UDP links

Parameters	
Routing protocol	AODV and Improved AODV
Main UDP link	Transmission time: from second 10 to second 30 Packet size: 1024 bytes Packet rate: 20 packets/second
Subordinate UDP link	Transmission time: from second 2 to second 30 Packet size: 3024 bytes (case 1) and 4024 bytes (case 2) Packet rate: 100 packets/second

To evaluate the performance of AODV and improved AODV, we use three metrics:

- **Throughput**: The data rate of the transmission from the source node to the destination node.
- **Packet Delivery Ratio (PDR)**: The ratio of packets sent from the source node and the packets received at the destination node.
- **Average End-to-End Delay**: The time interval between transmitting time by the source node and arrival time at the destination node (including the processing time and queueing time).

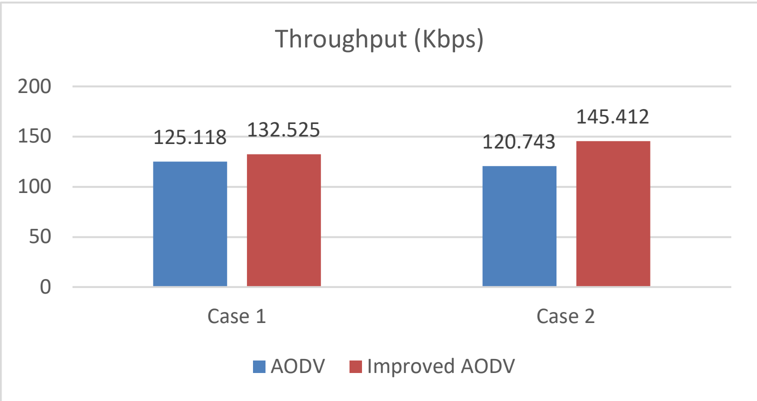

Fig. 3. Comparison of throughput.

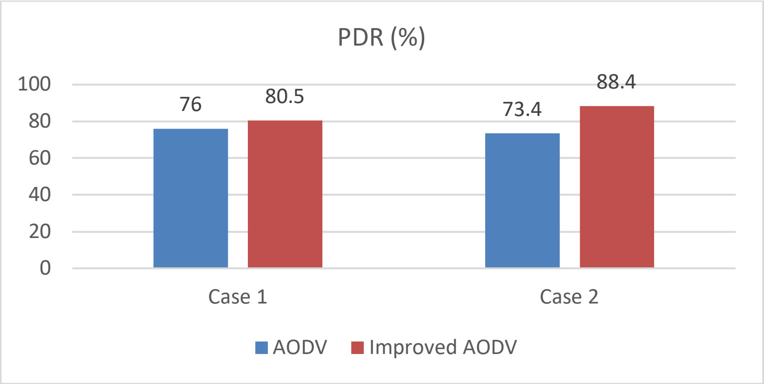

Fig. 4. Comparison of packet delivery ratio.

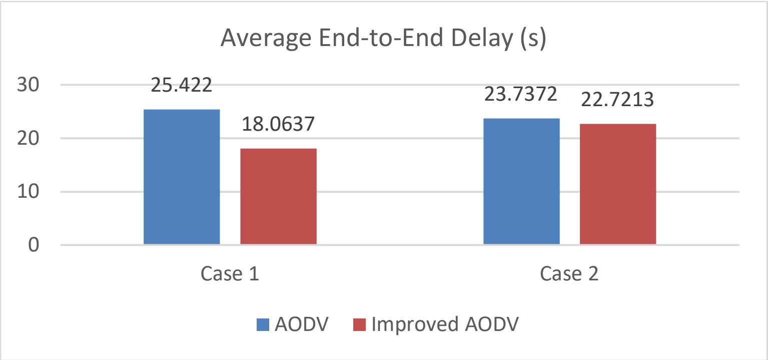

Fig. 5. Comparison of average end-to-end delay.

As can be seen in Fig. 3, Fig. 4, and Fig. 5, the improved protocol outperformed the AODV. The throughput and PDR of the improved protocol are higher than that of the AODV, while the AODV has a higher Average End-to-End Delay.

6 Conclusion

We proposed the idea of using a new metric in the route discovery process of the AODV and this metric is the level of buffer queue in a node. The nodes that have messages queued in their transmission buffer are less likely to get involved in the new path from the source node to the destination node. This solution helps to share the load equitably between nodes in the networks. We conducted some simulations to evaluate the performance of the proposed idea. The results show that the improved protocol outperformed the AODV.

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