Stable AODV Routing Protocol with Energy-aware in Mobile Ad Hoc Network

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Abstract—In Mobile Ad Hoc Network (MANET), due to the mobility of the nodes it is difficult to find the route which can maintain the whole process of data transmission. Therefore, it is very critical to balance, maintain and repair the route within the mobility of nodes and the limited battery energy. Currently there are many protocols from different aspects to solve this problem. This paper proposes a new improved routing protocol, which is based on delayed replay program, and its main objective is to create the stable routing protocol based on hop AODV, node mobility speed and node communication state. The discovery process of improved routing protocols only let the low-speed node forwards the RREQ package, and re-routing request packet delay broadcast according to node's degree of busy. NS2 simulator is adopted to assess the performance of using the program. Simulation results show that the proposed method has better performance than conventional methods, which mainly shows in better performance on the aspects on packet transmission rate of improved protocol, control overhead and end to end delay.

Index Terms—Mobile Ad Hoc Network; Route Maintenance; Energy-aware Routing; Replay Program; Stable Routing

I. INTRODUCTION

Mobile Ad Hoc Network (MANET) [1] is the network without infrastructure and consists of many dynamic mobile nodes; nodes as a terminal or routing communicate with other nodes in network. Routing protocol in MANET is based on the routing information maintenance and stored, which can be classified as the first type, table-driven and reactive and on-demand hiring agreement. In proactive routing protocol, each node maintains all information on all nodes in the network, and there is a global view of the network topology. The main advantage of proactive routing is that it determines a route only need shortest time, but since the control packets and routing are not utilized, there is a waste of network resources. Due to the limited resources of nodes in the network, the dynamic characteristics and unstable wireless connection, routing process is the most important challenge of MANET. In Mobile Ad hoc Network (MANET) [2], there is no need of the support for wireless devices, because the mobile nodes can connects, distributes and exchanges the date with the adjacent nodes during the movement. Via any specific routing protocols, the source node can receive and re-broadcast a series of data to the intermediate node, and they are transferred the data to any destination node with MANET protocol. Popular self-organizing routing protocols, such as on-demand distance vector routing protocol [3] and dynamic source routing protocol [4], it is assumed between any source and destination node exists a complete end to end path, first using AODV and DSR determine a the complete routing and forwarding data. However, this assumption is vulnerable when in the absence of delay-tolerant network (DTN) [6] in the immediate end to end path. The evident transmission delay and interrupt in DTN will cause the damage of network topology, including the reasons like the terrain around the obstacle, exhaustion of battery, the limited transmission distance, unreliable wireless connection and the mobile terminal [5]. Therefore, in the DTN, It is unwise of using the traditional store and forward routing protocol, even though it is commonly used in traditional computer networks and in MANET.

In reactive routing protocols, only when a node in the network need to transmit data to other nodes in network, a route is created, and there is no predefined route. The Destination-Sequenced Distance Vector Routing (DSDV) [6] is the representative of this type of routing. The main advantage is that it reduces the network cost, because there is no exchange of network topology information. On the other hand, when the old route fails, the source node must send a request for starting a new routes, which increases time to find the route. Auto-organizing demand distance vector (AODV) [7] and Dynamic Source Routing DSR [8] are examples of reactive protocols. AODV is a reactive protocol which mainly consists of three phases: route discovery, routing answering and routing maintained. When a node needs to send a message to another node, it broadcasts request packets to all adjacent nodes to initialize the discovery process of route. And then each adjacent node rebroadcasts the RREQ to its neighboring points; this process continues until the packet reaches the destination point or the intermediate nodes containing the destination points. Many copies of the same RREQ flood into the network and cause the broadcast storm. This problem waste the network resources, such as bandwidth and node battery power. Since many redundant request packets are broadcasted by the neighboring nodes, and a node may
receive the packet more than once. If all the intermediate node receives the RREQ and replay it at the same time, there will be competition and collision.

In the reaction formula network, many proposals have been proposed to solve the problem of the broadcast storm. Researchers use different mechanisms to control the broadcast process, and they allow the one certain group of adjacent nodes (not all nodes) to replay it, in which the group is chosen based on different characteristics. Many programs based on counts, distance and probabilistic [9] replay the time. Node uses a threshold to determine whether replay or not, and these programs reduce the delay time and the number of RREQ packets. On the other hand, there are several disadvantages, such as using the loss probability of the fixed threshold value and destination nodes. Currently the new solutions have been proposed, such as the use of other features like the mobile of node and the communication load. Some new programs will be introduced in the next sections. The purpose of these programs is to reduce the end to end average delay and routing load and maximize the network throughput.

Literature [10] defines the stability of the link as the degree of stability of link and a measure of duration of the communication. Signal strength is a parameter used to assess the stability of the link. Literature [11] proposes the SSA, and the route discovery is based on the stability of average signal strength and the position of the node. Literature [12] proposes the RABR; the routing selection of this method is based on the intelligent routing remaining life assessment of candidate routes. The main difficulty of this protocol is how to choose the optimal protocol threshold. In literature [13] N. Sharma based on the received signal strength calculates the and stability of the link and routing stability and puts forward the RSQR, which is based on the threshold and the link is divided into stable and unstable link. Literature [14] proposes the EBL, and the author considers the link stability and remaining battery capacity are important. EBL not only improves the energy efficiency but also reduces the network segmentation. Literature [15] proposes the LAER, link stability and energy wastage rate are jointed in route discovery to reduce the control overhead and balance the traffic load. Literature [16] proposes the PERRA; it is a kind of reactive routing protocol, which takes into account the links stability and energy efficiency. Due to constraints of congestion and maintenance of alternative paths, the control overhead is greatly reduced. According to the battery power and link stability of the parameter node [17] the expected route lifetime is roughly predicted, and more appropriate stable link is choose. With backup route, when AODV-BR [18] is interrupted in the unpredictable link, the rapid recovery of route is achieved, which is updated by monitoring data packets and RREP packets. In this highly dense network high control information overhead and collisions will be caused. Literature [19] improves the route discovery process of AODV, which is based on the remaining energy of nodes, communication state and the quality of the wireless connection; the intermediate node delays the time of RREQ. This technology prevents the death of nodes with a small amount of residual energy. Furthermore, the high load nodes are avoided to add to the route, which reduces the end-to-end average delay [20].

AODV protocol is the most popular reactive protocol, whose main objective is finding the shortest path between the source node and the destination node in the discovery process. Route discovery process of this protocol broadcasts the route request packet (RREQ) in the network, which will lead to a sharp degradation of network performance, especially when mobility of node is higher. By removing the high-speed mobile nodes to solve the problems, some routings are congested and other routes are not used, which can lead to poor network performance. So the route discovery process should be changed to look for a stable routing and load of balancing different nodes. To solve this problem, this thesis proposes a solution using the node mobility of the intermediate node and communication load to determine the best reliable routing. The improved route discovery process only let the low-speed node forwards RREQ packet and according to the busy degree of nodes (such as the number of cache packets) to delay the broadcast of request packet. Through using NS2 simulation platform the improvements are evaluated. The results show that the proposed program is better than the original AODV on the end to end average delay and routing load.

II. PROBLEM MODEL

Quality of the link will affect the performance of the network, improved version of AODV based on link quality has been proposed. It determines the optimal steady route based SNR values [21]. This method modifies the route discovery process of AODV, and route selection process based on the number of hops and SNR is feed backed. In the routing process, by measuring the obtained data packets of intermediate adjacent nodes and the SNR of control packets the link quality is monitored and maintained [22].

The program will get rid of the link in which the value is less than the preset threshold value, but if there is no available route stable, the weak link will be repeatedly added to the network to keep the network connection. Furthermore, a signal switching mechanism has been proposed to maintain the route and the link quality feedback on the link layer is used to monitor the connection of the nodes. The technology promotes the early discovery of non-connectivity, so the early warning of routing errors will be sent to the upstream node; in the current destruction of the route, the source node will be allowed to find a new route.

Topology of MANET is represented as the undirected graph \( G = (V, E) \), wherein \( V \) is the collection of node; \( E \) is the set of edges of the node connection. Let \( P(u, v) = \{P_1, P_2, ..., P_n\} \), wherein each \( P_i \) is a feasible path between \( u \) and \( v \). Considering the route stability and remaining energy, the problem of selecting the optimum path from the source to the destination node can be described as:
\[ f_1 = \prod_{e \in P_i} LS(e) \]  

\[ f_2 = \prod_{e \in P_i} Ce(t) \]  

\[ \text{where in,} \]

\[ Ce(t) = \begin{bmatrix} R_i \\ F_i \end{bmatrix} \]  

and \( R_i > EThr1 \), \( q_i < QThreshold \).

\[ \text{where in} \quad R_i \text{ and } F_i \text{ are respectively the remaining energy and full capacity of the nodes} \]

For each indicator of the objectives important factors \( w_1 \) and \( w_2 \) are provided; the above optimization can be transferred into a single objective problem expressed as follows:

\[ RFact(P_i) = w_1 \cdot f_1 + w_2 \cdot f_2 \]

\[ = w_1 \cdot \prod_{e \in P_i} LS(e) + w_2 \prod_{e \in P_i} Ce(t) \]  

\[ \text{where in} \quad p_1 + p_2 = 1 \]

Maximizing the sum of the objectives expressed as follows:

\[ RFact(P_i) = \max \{RFact(P_1), RFact(P_2), ..., RFact(P_n)\} \]  

III. PROPOSED SCHEME

A. Route Discovery

The proposed scheme improves the route request phase of AODV, and depending on the speed of the node (VON program) \[8\] and the communication load which nodes will be replayed is determined to create a stable route. VON scheme divide the nodes into high-speed and low-speed node. Since the high speed generates instable routes, they do not participate in the route discovery phase. Because there are more information is broadcasted caused by instable routes, the delay time of load and the destination point will be increased.

In VON, the speed of node is calculated based on the control packet of data transmission and the required time of the date. Because routing may be destroyed, any communication between two nodes at least requires one RREQ, one RREP, and a data transformation shown in Figure 1. Assumption \( T \) the required time of source point transferring one packet to the destination point, then a successful communication will take \( 3T \).

Based on the discussion above, the speed \( V_i \) of the node \( i \) do not needs to satisfy the condition:

\[ V_i \leq R/3T \]

where in \( R \) is the transmission range of node \( i \). Threshold parameter \( V_{th} \) is the low-speed node based on rate. When an intermediate node \( B \) receive the DRREQ packet, it is not the destination node, and the operations on the node are as follows:

If \( V_i < V_{th} \), then

Replay RREQ packet;

Otherwise,

Discarding RREQ packets.

Figure 2 describes the AODV routing discovery phase based on VON program

Node S broadcasts a RREQ to the node 1, node 2 and node 3. Node 2 and node 3 forwards the route request packet and 3 to their neighboring points except node 1. Node 1 compares its speed and threshold parameter \( V_{th} \) and then discarded because it is a high-speed node. When node D receives the RREQ packet, it sends a RREP and then back to the source node S; its routing recovery phase is the same with AODV.

B. Routing Selection

When the destination node receives the first RREQ, it will start the timer \( \Delta t \) t seconds. According to the objective function (Formula 5) value, route request received APST and AEC to calculate the reliability of the path. It stores all the RREQ of reliability values contained in the routing cache. After the timer expires, it finds the path with the minimum target value, and then it will send RREP. After the completion of the timer \( \Delta t \), the arrived route request will be discarded.

Algorithm 1: Target node performs

Input: Packets of neighbor node
if ( P is a RREQ packet) then
if (SS 1 < SThr2) then
Discard the packet P
return
end if
if (SS 1 > SThr1) then
LS = 1
DSS = SS2 - SS1
if (SS1 < SThr1) and (SS 1 > SThr2) then
if (DSS < ul) then
LS=1
else
LS = (u2 - DSS)/ (u2 - ul)
end if
end if
end if

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is a measured communication status of the node $i$, which is the ratio of the number of queued packets $N_{q}(i)$ and the buffer size $N_B$.

$$F_i = N_{q}(i) / N_B$$

$T_0$ is the standardized delay time based on network density, and the delay time of dense network is greater.

When the intermediate node receives the route request packet, the operation is shown in Figure 3.

![Figure 3. Operation on intermediate nodes after received the RREQ](image)

In network with larger load, the low-speed node is busy and the busy node increases the end delay. To achieve load balancing, this thesis delays the replay of busy node and give the opportunity to non-busy node. Delay time $D_j$ is given by the following formula:

$$D_j = F_j * T_0$$

where in $F_j$ is a measured communication status of the node $j$, which is the ratio of the number of queued packets $N_{q}(j)$ and the buffer size $N_B$.

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Figure 4 shows the improved routing protocol how to select a stable route “S-2-4-7-D”; the source node $S$ replays RREQ to the neighboring nodes: node 1, 2 and 3. Node 1 will discard the RREQ packet, because it is a high speed node; the delay time of node 3 is greater than node 2, because node 3 is busier. Node 2 has less delay time, which illustrates that RREQ has earlier replay on the node, because it may be early arrived the destination node compared with node 3. So, Node 2 will forward the RREQ packet to its neighboring nodes before the node 3. When the route request packet arrived the destination point D, D and traditional AODV will send a RREP packet to the source node $S$ at the same time.

Figure 4 shows that a few of the control message needs to reach the destination node. Similarly, since the RREQ packets will early reach the destination node through the non-busy peak, which reduces the latency.

Within the Frame time slot is consisted of unreserved, successful, and failed. Unreserved time slot means that there is no node currently occupied at this slot. Successful time slot refers to the time slot data successfully transmitted from the destination node to the source node. Failed time slot is all timeslots except for UTS and STS.

The ability dealing with channel errors is used to evaluate the performance of MANET protocol. In the AODV based on MANET, the number of STS owned by each frame is the parameters to measure their capability. If under the relatively poor channel conditions and MANET protocol data packets can still valid, it indicates that it can get a lot of STS. $p_s$ is the probability of successfully transmitting packets in UTS.

$$p_s = (1 - p_c) p$$

where in, $p_c$ represents the transmission probability of collision.

According to the literature[8], the desired number of STS can be expressed as $E[X]$:

$$E[X] = p_s \sum_{j=1}^{F} (F-j) \left(2pr \right)^{F-j} e^{-2pr} \left( F-j \right)!$$

$$+ p_c \sum_{j=1}^{F} \left(2pr \right)^{j} e^{-2pr} \left( j \right)!$$

Throughput is defined as the ratio of the number of success slots STS in each frame $F$ and the overall slots. $\sigma$ and $\sigma_{cop}$ are respectively the throughput of AODV shown in formula (7).

$$\sigma = \frac{E[X]}{F}$$

$$\sigma_{cop} = \frac{E[X]}{F}$$

Normalized throughput gain is shown in formula (8) as follows:

$$\sigma_{gain} = \frac{\sigma_{cop} - \sigma}{\sigma}$$
path as the mobile model. Constant bit rate (CBR) is used as the packets of 512 bits. Source-destination combination is randomly spread in the network. Packet rate is set as 10, 15 and 20 packets / second. The channel capacity on MAC layer protocol is 2Mb / s and the 802.11 protocol with the transmission range as 200m. These nodes select a random speeds between the minimum speed value 0 m / s and a maximum speed of 30 m / s. Queue Interface on MAC layer can maintain 512 packets (256kB) [25,26].

B. Experiments and Analysis

Figure 5 shows the end to end delay. As expected, the proposed method can reduce the end-to-end delay, especially in high-speed networks. When the rate is growth, there are more control messages need for discovering the route. These messages cause the competition and collision problems. Through allowing non-busy nodes broadcast early than the busy node, improved methods can alleviate this problem. These non-busy nodes may faster find a route. So, end-to-end delay will be reduced, and unnecessary control messages from busy nodes will be deleted. Figure 5 depicts the average end-to-end delay result obtained by these three solutions. The obtained results show that in the all speeds conditions improved method is better than the traditional AODV, which under the low speed conditions achieves a competitive performance and in high-speed conditions it is better than AODV based on VON.

![Figure 5. End-to-end delay when the packet rate is 4](image)

![Figure 6. Routing load](image)

Since the low and non-busy nodes perform the retransmission, which reduce the load and cost of routing; there nodes also reduce the number of nodes required for the control message; the structure is shown in Figure 6.

Figure 7 shows that when the packet rate is high, the performance of the proposed method is improved relative to the traditional AODV and AODV based on VON. When the packet rate is low (less than 10) the AODV based on VON is better AODV; when the packet rate is low, most of the nodes will be idle, so there is no need to delay the broadcast and these measured delay time of the nodes will be the same, which also cause the collisions and competition issues, so the end-to-end delay time will be longer. However, to the busy nodes with a high packet rate will be avoided to broadcast at once, which will become apparent.

The routing load of the improved method with different packet rates is better than the traditional AODV and AODV based on VON; the experimental results are shown in Figure 8, which minimize the number of packets.

![Figure 7. End-to-end delay when the speed is 20m / s](image)

![Figure 8. Standardized routing load when the speed is 20m / s](image)

For a number of different mobile speeds 0, 5, 10, 15 and 20, an extensive set of simulation is carried out. 10 runs of simulations are conducted, and the mean value of the obtained results is given as the performance indicators.

In Figure 9 it can be seen that since the link interrupted and the route repaired the NCO is increase with the increase of the mobility. When the mobility is low, the NCO of the proposed method, RSEA and LAER are 5.1%, 5.4% and 6.3%. When the mobility high, the NCO of the proposed method, RSEA and LAER are 22.8%, 26.2% and 31.3%. At high dynamic environment RSEA shows better performance. Because the “the first connect, the last break” and the local route repair mechanism, there is less control overhead compared with other two protocol. Link break is earlier forecasted, and the data transmission can be switched to the alternative route before it is interrupted.

From Figure 10 it can be observed that in the three protocols, PDR is reduced with the increase of speed. The reason of decreasing is that when the speed is increased, the link will be interrupted and the route will be searched again. When the mobility is high, the PDR of the
the proposed method, RSEA and LAER are respectively as 94.7%, 93.8% and 91.3%. The PDA of the proposed method is increased by 1% relative to RSEA, and this is because it combines the “first connect, the last interrupt” route maintenance mechanism, which significantly reduces the number of the packet loss caused by unpredictable link interruption.

The variance of the remaining nodes energy is shown in Figure 11. This parameter shows the load balancing capabilities of the agreements. With the increase of mobility due to frequent routing switch, the variance of the residual energy decreases. When the Mobility is Low, the energy variance percentages of the proposed method, RSEA and LAER are 18.8%, 19.2% and 21.54%. When the mobility is high, the energy variance percentages of the proposed method, RSEA and LAER are 7.8%, 8.3% and 11.3%.

As shown in Figure 12, the end-to-end delays of three protocols increase with the increase of the mobility due to the frequent interruption. When the mobility is high, the average end-to-end delays of the proposed method, RSEA and the LAER are 0.18 seconds, 0.21 seconds and 0.32 seconds. The reason why the delay of the proposed method is the lowest is that it avoids the link interruption caused by node mobility and battery energy loss. RSEA agreement combines “the first connect the last break” route maintenance mechanism, which can quickly adapt to the changes in the network. When the mobility is high, the performance of the proposed method is higher than the RSEA by 14%. 

When RSEA is in the high dynamic environment, it shows a better performance. Because of the repair mechanism of “first connect, and then break” and the local route, this leads to less control overhead compared with the other two protocols, in which it forecasts the

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Link outage earlier, so the data transmission can be switched to an alternative route before the original route link interrupted. As can be seen from the experiment, when the mobility is low, the NCO of proposed method, RSEA and LAER are 5.1%, 5.4% and 6.3%. In high mobility, the NCO of proposed method, RSEA and LAER are 22.8%, 26.2% and 31.3%, which can be specifically seen in Figure 13. With the increasing of mobility, due to frequent routing switch, the variance of the residual energy decreases. When the mobility is Low, the energy variance percentages of proposed method, RSEA and LAER are 18.8%, 19.2% and 21.54%. When in high mobility, the energy variance percentages of proposed method, RSEA and LAER are 7.8%, 8.3% and 11.3%. The variance of the energy remaining nodes is shown in Figure 14. This parameter characterizes the load balancing capabilities of the agreements. From the experimental analysis, the end to end delay of three protocols increases with the increasing of mobility, because the path is frequently interrupted. When with high mobility, the average end-to-end delay of the proposed method, RSEA and LAER are 0.18 seconds, 0.21 seconds and 0.32 seconds. The reason of the lowest delay of the proposed method is that the link interruption caused by node mobility and battery energy loss is avoided. In the RSEA agreement, the maintenance mechanism of “first connect, and then break” is combined, which can quickly adapt to the changes in the network. When with high mobility, the performance of proposed method is higher than the RSEA at 14%. It can be specifically seen in Figure 15.

V. CONCLUSION

This thesis introduces an improved AODV to establish a stable routing, which is based on hop AODV, node mobile speed and node communication status. The results show that the proposed program through pre-arming significantly improves the transmission rate of data packet and reduces the control overhead and delay caused by unpredictably link interruption. Compared with LAER, it also reduces the variance of the node energy and increases the time of network partition. In the high-speed dynamic network, it exhibits superior performance. When the mobility is low, compared with the method LAER, the delay of the proposed method is slightly high. The proposed AODV is superior to the traditional AODV and AODV based on VON on the aspects of end-to-end delay, routing load and spend. In order to avoid passing the congestion and fast nodes, the number of the control packets in the routing discovery process is minimized. In the future, in a different node density, traffic and mobility model, the proposed protocol will be the important part of research.

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