A Novel Link Stability and Energy Aware Routing with Tradeoff Strategy in Mobile Ad Hoc Networks

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Abstract **—**Mobile ad hoc networks (MANETs) are self-organizing, rapidly deployable networks without any fixed infrastructure. In MANETs, mobile terminals can move freely, which cause frequent link breakage. Due to the dynamic nature of the network, finding a stable route for transmitting data is a challenging task. In order to adapt to the topological changes and provide some quality of service (QoS), this paper propose a novel link stability and energy aware routing algorithm with tradeoff strategy, and implement it on Ad Hoc On-demand Distance Vector Routing Protocol (AODV), namely NLSEA-AODV. The new protocol sets up routes with high stability in route discovery based on link stability and node energy information, and predict the breaking link in route maintenance. Besides, the routing takes a route stability-hop count tradeoff strategy to select routes with high stability and low hop count. Simulation results show that the new protocol has a better overall performance than original AODV protocol, which improved the network utilization greatly.

Index Terms **—**MANETs, quality of service, link stability, energy aware, AODV

I. Introduction

A Mobile Ad hoc Network (MANET) is a dynamically changing network of arbitrarily moving wireless nodes that operate with a limited battery charge and transmission range where no fixed infrastructure or access point exists. Nodes in MANET usually move freely and communicate with other nodes by the help of intermediate nodes. Hence, routing is a critical issue and hot topic in mobile ad hoc networks (MANETs). However, routing is also especially difficult since node mobility may cause radio links to be broken frequently. Some conventional routing protocols in wired networks are not suitable for ad hoc networks. In this background, a large number of researchers pay their attention to this field and propose many efficient routing protocols for MANETs. These routing protocols generally can be categorized as proactive or reactive in nature [1]. Proactive routing protocols discover routes between every pair of nodes, irrespective of their requirement, through network-wide table updates or link-state updates. However, in a dynamically changing environment, typical of MANETs, the proactive routing protocols are not of high effectiveness and route maintenance get expensive. Hence, more and more researchers have focused on reactive protocols (or on-demand routing protocols), such as Ad Hoc On-demand Distance Vector Routing Protocol (AODV) [2], Dynamic Source Routing (DSR) [3] etc. Reactive routing protocols are proofed to be more effective and have better performance in MANETs. However, most of reactive routing protocols usually take the shortest path as a route, without considering link stability and energy elements, as a result, may cause radio links to be broken frequently and short network lifetime, which make source node to rediscover a new path for transmitting data. Such rerouting operation waste the scarce radio resource and battery power, besides, rerouting delay will also affect the quality of service (QoS) and degrade network performance. In many circumstances, shortest path (minimum hop count or least delay) is not always the best choice for network performance, such as high density network and high mobility network. Many researches proved that link stability and energy factor have great impact on overall performance in MANETs. In this case, an algorithm about how to evaluate link stability and energy efficiency and get the optimal route is a critical and hot issue in ad hoc networks.

With the popularity and improving accuracy of Global Position System (GPS) in MANETs, more and more mobile terminals become easy to chive with GPS. This paper, combined with GPS technology, proposes a novel link stability and energy aware routing algorithm with tradeoff strategy. In the algorithm, a link stability parameter is defined to express the value of link stability. Besides, via the information coming from MAC layer, we get the node power information and take a probability broadcast method to balance traffic and improve network lifetime. Different energy ratio has different probability to response the route request packet (RREQ). In route discovery, a node which located in stable zone of the upstream node responds to the RREQ and attach the calculated the link stability with tradeoff to the RREQ, in addition, forwarding the RREQ according to the energy information of the node. Destination node selects a route with the lowest route stability with tradeoff, which means the route has low hop count and high stability value. Besides, in route maintenance process, the routing algorithm adopts link breakage prediction, by early

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predicting the breakage of a link and searching for a new available route to replace the old one, reducing the delay in rerouting efficiently.

The remainder of the paper is organized as follows. Section II simply summarizes the related work in this filed. Section III gives a detailed introduction to the novel routing algorithm and section IV describes the implementation of NLSNA-AODV based on AODV. The simulation results and analysis are given in Section V. Conclusions are drawn in Section VI.

II. Related Work

Given the growing importance of link stability and energy aware in mobile ad hoc networks over the last few years, a number of works have proposed to improve the performance for MANET. Some of these methods rely on the received signal's strength, while others make use of the location information of the nodes composing the link to predict the link expiration time. In addition, many routing algorithms use the link lifetime as well as the nodes' energy factors as routing metrics to select more stable and energy efficient routes for data transmission.

Reference [4] proposes ABR, in which associativity is defined to reflect the degree of the stability of association between two nodes. As taking link stability into consideration, ABR improves the average route survival time. In SSA [5], the average signal strength and location stability of the nodes are used for route selection such that the chosen route lasts longer. Reference [6] proposes a method based on the received signal strength difference to judge the relative movement of a pair of nodes, which further improve the performance of the network. A method with GPS to predict the link and the route lifetime based on the nodes' location and movement information has been proposed in [7]. The method predicts the Link Expiration Time (LET) at each hop of the route, which allows the prediction of the Route Expiration Time (RET). RET is defined with the minimum LET of the links composing the route. However, this method whether is of high efficiency remains to be further proofed.

In [8], predicted battery lifetime has been used as the routing metric that extends the lifetime of the network by reducing the energy variance of the nodes. In [9], authors use remaining battery level of the intermediate nodes in the route as the metric for route selection which results in increased operational lifetime by routing around the nodes that are low in power.

As link lifetime and energy information all have an impact on the lifetime of the selected route. Some routing algorithms begin to consider the two metrics simultaneously. In [10], the link availability prediction is adopted in AODV. According to the energy value and link available time recorded in the received packets, the routing protocol chooses stable routes and pre-repairs the route before it gets broken, but the algorithm doesn't consider the radio propagation environment sufficiently. Reference [11] proposes a protocol named with REAQ-AODV, in which the reliability factor is based on the route stability and the residual energy of the intermediate nodes. The route with the highest reliability factor is selected for data transfer. While the link stability-hop count tradeoff is not considered in the algorithm. Reference [12] uses the predicted link expiration time as part of the link weights via GPS, the weight of each link takes the hop count into consideration, and the destination chooses the route with the lowest sum of the link weight. While this method overlooks the relationship between algorithm complexity and network performance, and node energy is also not referred to.

Our proposal applies the link stability and energy aware metrics in routing design. Since in most kinds of mobile networks, e.g. vehicular network, mobility is not strictly random, and some prediction of node mobility is possible [13]. Hence, we propose a method to predict the lifetime of a link through observing the relative movement during a time interval. The novel algorithm that we developed is based on the location and velocity vector information of nodes in the network, selects a route with route stability-hop count tradeoff by using probability broadcast, which improve the overall performance obviously.

III. The Design of the Algorithm

In this section, we will give a detailed introduction about the novel link stability and energy aware algorithm. At the same time, the link breakage prediction will also be referred to in the section.

A. *Link Stability Prediction*

Reference [6] analyzes the edge effect in mobile ad hoc networks for most of existing routing protocols. With the increase of node density, most on-demanding routing protocols in route selection with the shortest path criteria usually set up unstable routes. Because the shortest path means the furthest neighbor node, and small movement of the node may lead to route breakage, resulting in the increase of data packet loss and control overhead. Thus the shortest path is not always the best one. We hope a new route can maintain as much time as possible, in this sight, link stability maybe more important than other metrics. We utilize the position information of nodes in the network to get optimal routes for data transmission. Here, we give the network with the following conditions: mobile nodes are equipped with an omni-directional antenna, with same parameters and radio transmission range, and nodes can learn their real-time two-dimensional coordinates and velocity vectors via GPS. In the network, nodes can exchange Hello packets with neighbor nodes and gets the location information of neighbor nodes through Hello packets.

In MANETs, due to the limited resources of energy, radio transmission range of nodes is also limited. As shown in Fig. 1, we divide the radio transmission range of nodes into three areas, namely Stable Zone (SZ), Buffer Zone (BZ) and Warning Zone (WZ). In order to establish stable routes, we select intermediate nodes which located in the Stable Zone of corresponding upstream nodes to respond RREQs. Herein we create a Buffer Zone between Stable Zone and Warning Zone, the aim is to ensure the newly established route not to occur prematurely failure. Warning Zone is to predict the link which is breaking in advance in route maintenance process and inform upstream node or the source node to set up a new available route early, which ensure continuous data forwarding and reduce rerouting delay.

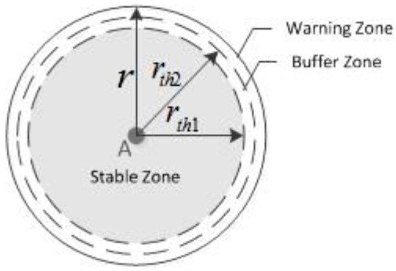

Fig. 1. Radio transmission range of mobile nodes

We let r is the radio transmission range of node A and node B, node A is adjacent to node B, and A is a precursor of B. Here r_{th1} , r_{th2} is the threshold value of Stable Zone and Warning Zone respectively. Define $d_{A,B}$ is the distance between node A and node B. Reference [14] analyzes the mathematical relationship between the distance and the link availability. When the distance is less than or equal to 0.9 r, the availability is almost equal to 1, which means the link is available. As the distance gradually increase to r, the link availability deteriorates quickly. This shows that when the distance is greater than 0.9 r (nearly leaving the wireless transmission range of nodes), the link is of low availability or nearly unavailable, so it should be repaired in time. Thus we let r_{th2} equal to 0.9 r. In order to prevent the newly established route to move into Warning Zone and re-discover a route early, we design a Buffer Zone in this paper. The Buffer Zone should be appropriate to get ideal results. We let r_{th1} equal to 0.8 r. It can ensure both adequate enough Buffer Zone and large enough Stable Zone.

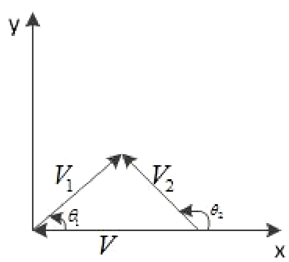

Fig. 2. Relative velocity

At a given time t_0, we take a close look at node A and node B. Here we assume at certain time t_0 their velocity vectors are V_1 and V_2 respectively, and we regard node A as a stationary node and node B as a moving node, then we can calculate the relative velocity vector of node B to node A according to the Fig. 2

$$V = V_2 - V_1 \tag{1}$$

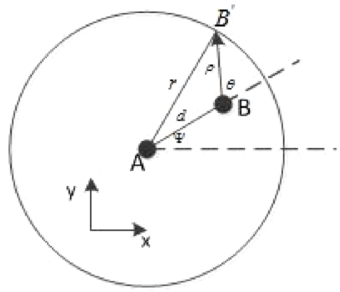

Fig. 3. Link stability estimation

Fig. 3 gives a case of link stability estimation. We will firstly consider the one-hop link between A and B. In our analysis, we take A as the reference node, from the view of node A, node B moves at a relative velocity V as described in Fig. 2, and after a period time t, node B will travel out of the transmission range of node A, the relative movement track is $B \to B'$. And the distance during this period time t is ρ, then we can get the expression according to the law of cosine.

$$\begin{aligned} r^2 &= \rho^2 + d^2 - 2\rho d\cos(\pi - \theta) \\ &= \rho^2 + d^2 + 2\rho d\cos\theta \\ &= \rho^2 + d^2\sin^2\theta + d^2\cos^2\theta + 2\rho d\cos\theta \\ &= (\rho + d\cos\theta)^2 + d^2\sin^2\theta \end{aligned} \tag{2}$$

We continue to transform the form and get the expression of $\rho(d,\theta)$:

$$\rho(d,\theta) = \sqrt{r^2 - d^2\sin^2\theta} - d\cos\theta \tag{3}$$

The coordinate of node A at time t_0 is $(x_A(t_0), y_A(t_0))$, the coordinate of node B at time t_0 is $(x_B(t_0), y_B(t_0))$, then the distance between A and B at time t_0 is:

$$d(t_0) = \sqrt{(x_A(t_0) - x_B(t_0))^2 + (y_A(t_0) - y_B(t_0))^2} \tag{4}$$

Besides, we can also get the angle expression of ψ

$$\psi(t_0) = \arctan\frac{y_B(t_0) - y_A(t_0)}{x_B(t_0) - x_A(t_0)} \tag{5}$$

The relative velocity vector of node B to node A is also expressed by another format:

$$V = V_2 - V_1 = |V|\angle\phi \tag{6}$$

where the $|V|$ represents the magnitude of relative velocity vector V and $\angle\phi$ represents the angle of relative velocity vector V. According to the analysis above, we get the angle θ

$$\theta = \phi - \psi \tag{7}$$

By the value of distance and relative velocity at time t_0, we can calculate the link residual time estimation

$$t_r = \frac{\rho(d,\theta)}{|V|} \tag{8}$$

Let $LS_{A,B} = t_r$ expresses the link stability between node A and node B. In most of stability routing protocols, the destination selects a route with the highest stability from several different paths. But the route with the highest stability may be not the best choice in some sense. Because the higher stability usually means the greater hop count in ad hoc networks, which also means greater delay. In this paper, we introduce a tradeoff strategy to solve this issue. The tradeoff function assigns each link with '1' which represents its hop count plus the inverse of LS. Here we use $LSWT$ express the link stability with tradeoff. Take the link between A and B as a example, the $LSWT$ of the link is:

$$LSWT_{A,B} = 1 + \frac{1}{LS_{A,B}} \tag{9}$$

As for the destination node, it will calculate the route stability with tradeoff (RSWT) by following expression:

$$RSWT = m(1 + \frac{1}{LS_{\min}}) \tag{10}$$

where m is the hop count of the corresponding path. When selecting the optimal route from several different paths, the destination node will choose the route with lowest RSWT value. If the destination receives k RREQs coming from different paths, the expression of the optimal route is as below:

$$RSWT_{opt} = \min\{RSWT_1, RSWT_2, \cdots, RSWT_k\} \tag{11}$$

By using the tradeoff strategy, the algorithm can select a route with high stability and low hop count, which is better choice for data transmission.

B. Energy Method

As it is known, MAC layer contains a wealth of useful information. With the popularity of cross-layer design, more and more researches begin to add some MAC information to their routing algorithms, especially the energy information. Because energy level is also a critical factor that affecting the traffic balance and network lifetime. For example, if a node's energy is used up, the route containing the node will get broken. Besides, in some circumstances, some nodes are usually chosen as intermediate nodes by several routes simultaneously, which leads to premature depletion of battery energy. Hence we propose our own energy aware method to improve the average network lifetime and balance network traffic.

In the algorithm, we take a probabilistic scheme utilizing the energy information in the nodes. In MANETs, the broadcast storm during the route discovery phase is a well-known problem, which occurs when uncontrolled broadcast mechanism is used to disseminate RREQs. One of the most efficient suggested solutions is the probabilistic scheme which demonstrates better performance than other existing solutions [15]. Besides, probabilistic scheme is appropriate for energy aware. As for high energy level, we will give a large probability for forwarding in intermediate nodes, which can ensure the RREQ can be delivered to next hop. Otherwise, a low probability is assigned to the RREQ, which can balance the network traffic efficiently and relieve the congestion.

When receiving a RREQ, a node sends a query to MAC layer for its own energy information. Here we define E_i to represent the initial energy taken by the node, and E_{res} to represent the residual energy in the node. The node broadcasts the RREQ according to the ratio of E_{res} to E_i. When the ratio is greater than 0.3,which means the node has relatively enough power to transmit data, the node will broadcast the received RREQ in the probability 1. Otherwise the node will broadcast the RREQ with the probability $P(E_{res}/E_i)$.

Here, we propose a probability broadcast function with exponential distribution using the energy information of nodes, the broadcast function is:

$$P(E_{res}/E_i) = e^{-\left(1-\frac{E_{res}}{E_i}\right)} \tag{12}$$

The probability broadcast function graph is described in Fig.4. Where the x-coordinate expresses the value of E_{res}/E_i, and the y-coordinate expresses the value of broadcast probability of the corresponding E_{res}/E_i in the node.

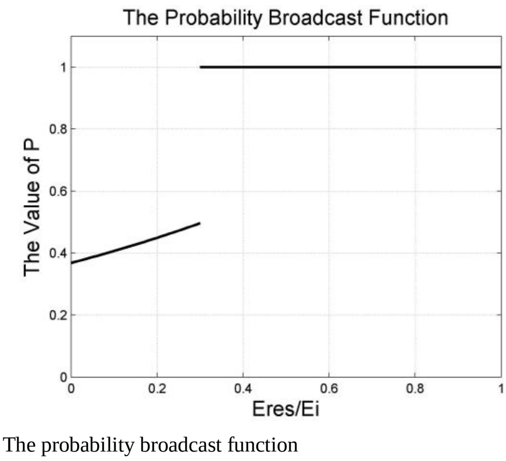

Fig. 4. The probability broadcast function

IV. The Implementation of NLSEA-AODV

This section will give a detailed introduction to the implementation of the novel algorithm. AODV is a standardized on-demand routing protocol, and has better performance in wireless ad hoc network. However, AODV takes the shortest path as a route for data transmission, without considering the route stability and energy element, thus it is unable to provide a certain QoS guarantee. We would like to implement our novel algorithm on AODV which is named with NLSEA-AODV and make the novel protocol refer to route stability and energy aware.

A. Route Discovery

In order to build a route to the destination, each node needs to broadcast periodic hello message to check the connectivity. Unlike the hello message format in the original AODV, we add x, y two new fields in hello message, which represent the x, y coordinate information of the node. The new hello message format is shown as below:

<dest_addr, dest_sequence, hop_cnt, lifetime, x, y>

As link stability is considered in the new protocol, several new fields (x, y, velocity_amplitude, velocity_angle, stability_indicator) needs to be added to RREQ packet for recording the coordinate information and velocity vector of upstream node as well as the link stability with tradeoff function. Thus the new RREQ has following fields:

<source_addr, source_sequence, broadcast_id, dest_addr, dest_sequence, x, y, velocity_amplitude, velocity_angle, stability_indicator(SI), hop_cnt>

Besides, we will also update the format of Neighbor Table. The Neighbor Table adds distance and status two fields. Distance represents the distance value corresponding to the neighboring node, while status reflects the relative movement of two neighboring nodes, and the value is initialized to -1, when using with 1 and 0, where 1 indicates that the two nodes are approaching and 0 means they are moving away. The format of Neighbor Table is shown as follows:

<Neighbor ID, Expire, Distance, Status>

The NLSNA-AODV is implemented on the basis of AODV, thus it has many same characteristics with original AODV.NLSNA-AODV is also an reactive routing protocol, when the source has some data to transmit, the source would firstly check the routing information to the destination in the Route Table, if the source node has the routing information to the destination, then the source would follow the next hop in the Route Table. Otherwise, the source initiates a route discovery process and broadcasts a RREQ pack to its neighbors.

On receiving RREQ packets, intermediate nodes which located in the Stable Zone of upstream nodes respond to the RREQs that are not duplicates, otherwise the RREQs will be dropped by intermediate nodes. When intermediate nodes determine to hand the receiving RREQs, according to the link stability and energy aware algorithm introduce in last section, firstly calculate the link stability with tradeoff based on the information in RREQ and attach it to the SI field if the new estimation value is greater than the value in the SI field, then send a query to MAC layer for energy information and get the ratio of residual energy to initial energy, lastly intermediate nodes forward the RREQs with the probability according to the probability broadcast method. Table I gives the pseudo code of operation in intermediate nodes.

TABLE I: OPERATIONS IN INTERMEDIATE NODES

Input: A RREQ packet P from a neighbor node; Threshold value r_{th1}, r_{th2}

```
if( P is a RREQ packet)
  if( P is a duplicate or P is not in the Stable Zone)
    Drop packet P
    Return
  end if
  if( P is not received before and P is in the Stable Zone)
    then
      LSWT← Get_LSWT()
      p←Get _Broadcast_Probability()
      RN←RandomNumber(0,1)
      if ( LSWT ≤ RREQ.SI)
        If( RN <p)
          Broadcast packet p
        else
          Drop packet p
        end if
      end if
      if (LSWT >RREQ.SI)
        if( RN <p)
          RREQ.SI =LSWT
          Broadcast packet p
        else
          Drop packet p
        end if
      end if
  end if
end if
```

TABLE II: OPERATIONS IN THE DESTINATION NODE

Input: A RREQ packet P from a neighbor node; Threshold value r_{th1}, r_{th2}, Delay_Timer

```
if ( P is a RREQ packet)
  if ( P is a duplicate or P is not in the Stable Zone)
    Drop packet P
    Return
  end if
  if( P is not a duplicate or P is in the Stable Zone)
    LSWT← Get_LSWT()
    RSWT← Get_RSWT()
    RREQ.SI= RSWT
    Arrange Delay_Timer
    if( Number of RREQ =1)
      Send a RREP packet to the source
    else
      Handle_otherRREQs();
      Select the route with minimum RSWT value
      Send a RREP packet to the source
    end if
  end if
end if
```

When the destination receives the first qualified RREQ from the source, the destination will delay a short timer. The timer aims to make the destination receive several RREQs coming from different paths, then the destination can select an optimal route from these paths. On receiving RREQs, the destination will calculate the

RSWT for each RREQ and select the minimum RSWT value, which means the route has lower hop count and higher route stability. Then the destination sends a RREP on the reverse path to the source. If the route discovery time expires, the source will use the method of classical flooding to restart a route discovery. The Table II describes the operations in the destination node in pseudo code.

B. Route Maintenance

After the destination selects the best route base on route stability with tradeoff function, the source uses it to transmit data packets through selected path. When a link break occurs in active route during the transmission, route maintenance is called for setting up a new route. In this paper, the link breakage prediction mechanism is adopted in the route maintenance process, which can pre-repair the route which is going down. It is executed once every hello timer, to monitor the status of the route. If an intermediate node is located in the Warning Zone of the upstream node and the status is ‘0’ which represents the two neighboring nodes are moving away, then the intermediate node sends a RERR packet to the upstream node. Otherwise, the intermediate node continues to monitor the link. The upstream node receives the RERR packet and repairs the route in local node. If the upstream node of the breaking link can’t repair the route successfully, it would send a RERR packet to the source for rerouting.

V. Simulation and Performance Evaluation

In this section, we analyses the performance of our proposed protocol and it is compared with the protocols AODV, SSA, REAQ-AODV.

A. Performance Metrics

Number of Routing Failure: It refers to the number of routing changes during simulation, reflecting the stability of the routing protocol.

Packet Delivery Ratio: It is the ratio of number of packets received at the destination and the number of data packets sent by the source, reflecting the reliability of the network.

Average End-to-End Delay: It is the average time of a data packet has taken to reach its destination.

Normalized Control Overhead: It is the ratio of the number of control packets sent and the number of packets delivered at the destination.

B. Simulation Parameters

We simulate the performance of four protocols in NS-2.35. And the simulation parameters are listed in the Table III.

C. Simulation Results and Analysis

In this subsection, we will give the simulation results and some technical analysis. In order to reduce the random error, the results are the average value of 10 tests.

TABLE III: SIMULATION PARAMETERS

Topology	1000m×1000m	Transmission Range(m)	250
Channel Capacity	2M/s	Pause time(s)	2
Routing Protocols	NLSEA-AODV, REAQ-AODV, SSA, AODV	Wireless Transmission Model	TwoRayGround
Channel Type	Wireless channel	The Speed of Nodes	5~30m/s
The Number of Nodes	60	Mac Layer Protocol	802.11DCF
The Number of Links	20	Mobile Model	Random Way Point
Traffic Type	CBR	Queue Type	PriQueue
Packet Rate	4 packets/s	Packet Size(B)	512
Queue Size	100	Simulation Time	500s

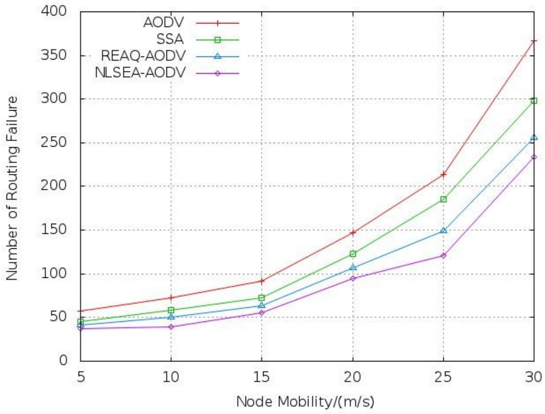

Fig. 5. Number of routing failure versus node mobility

From Fig. 5, we can observe that the number of routing failure increases as the node mobility increases in all four protocols. The reason is that, as the increase of mobility, the network topology changes rapidly, which accelerates the frequency of link breakages and route discoveries. At high mobility, SSA shows 18.8% decreases in number of routing failure compared to AODV, REAQ-AODV shows 30.2% decreases compared to AODV, while NLSEA-AODV is 36.2% less than AODV in number of routing failure. It is because that SSA, REAQ-AODV and NLSEA-AODV all take link stability into consideration, thus the protocols establish routes with high stability and long lifetime, which can ensure better data transmission. As NLSEA-AODV selects an optimal route by predicting the residual lifetime of each link via relative movement instead of only estimating the link strong or weak with the defined threshold, the protocol behaves better than other two protocols.

From Fig. 6, we observe that the Packet Delivery Ratio (PDR) decreases gradually with the increase of node mobility. The reason for that is frequent link breaks and rerouting operations. However, NLSEA-AODV is of the best performance, and REAQ-AODV is the next, followed by SSA and AODV. At high mobility, NLSEA-AODV shows 1.5% increase in PDR compared to AODV, 0.9% increase compared to SSA, and 0.6% increase compared to REAQ-AODV. It is maybe complained by that due to link stability and link breakage prediction incorporated in it, which greatly improve lifetime of routes and reduces the number of packets dropped.

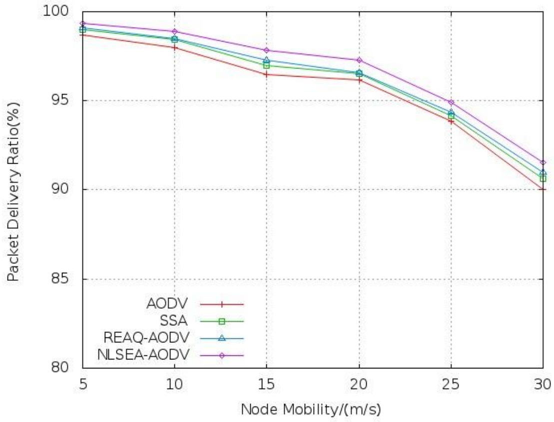

Fig. 6. Packet delivery ratio versus node mobility

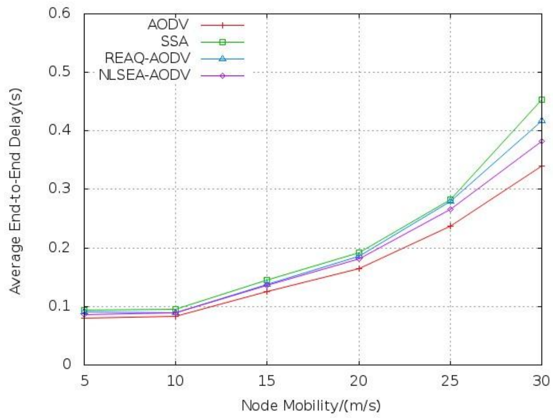

Fig. 7. Average end-to-end delay versus node mobility

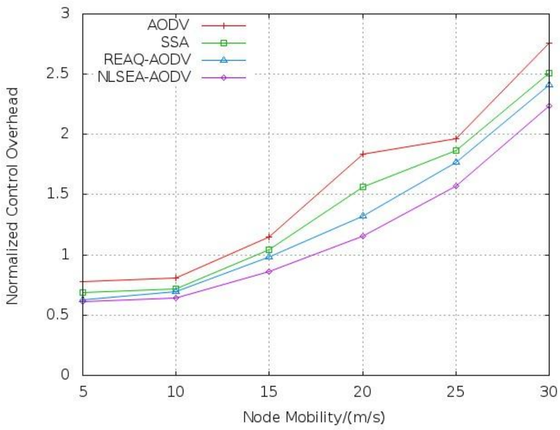

Fig. 8. Normalized control overhead versus node mobility

Fig. 7 describes the end-to-end delay of the four protocols, which increases with the increase of node mobility. With the increase of mobility, routes in the network get broken frequently, which improves the latency of data transmission. It is obvious that the delay of SSA, REAQ-AODV and NLSEA-AODV is high compared to conventional AODV, while NLSEA-AODV is lower than SSA and REAQ-AODV. It is because these three protocols establish more stable routes, which usually means high hop count and processing latency. But NLSEA-AODV takes a route stability-hop count tradeoff strategy, which make the routes established with relative low hop count and high stability.

Fig. 8 shows the Normalized Control Overhead (NCO) performance of the four protocols. We can find NCO increases with the increase of node mobility. AODV has the highest NCO, SSA is the next, and followed by REAQ-AODV and NLSEA-AODV. As SSA, REAQ-AODV and NLSEA-AODV all refers to link stability, thus they have longer route lifetime than AODV, which means less rerouting operations. Besides, due to the link breakage prediction, NLSEA-AODV can re-discover an alternate route in advance before the link breaks.

From the simulation results, we can learn that the performance of NLSEA-AODV is obviously better than conventional AODV except the average end-to-end delay. And the increase of the delay is still in an acceptable margin. We have reason to believe that the novel routing can provide better network performance.

VI. Conclusion

As the link stability and energy aware draws more and more interests from researchers, it has been a hot topic in MANETs. This paper proposes a link stability estimation method with tradeoff strategy and a probability broadcast thought to balance node energy and network traffic. Simulation results showed that the novel proposed scheme significantly increases the packet delivery ratio and reduces the number of routing failure and normalized control overhead. Although the delay is lightly increased, it is still in a good condition. Besides, the proposed scheme behaves better even in high mobility condition. In future, more factors affecting link stability estimation will be researched.

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