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Topology Change Aware on Demand Routing Protocol for Improving Reliability and Stability of MANET

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Abstract: In mobile adhoc networks (MANETs), the most essential problem is to ensure the quality-of-service (QoS) during data transmission via multiple paths from a source to the destination node. To tackle this problem, a topological change adaptive adhoc on-demand multipath distance vector (TA-AOMDV) routing protocol was developed, which ensures QoS according to the different parameters for high-speed node mobility. But, it did not consider the path stability related to the node density, which also affects the routing efficiency. Hence, this paper develops a reliable and stable TA-AOMDV (RSTA-AOMDV) routing protocol that applies a new forwarding strategy to enhance the path reliability and stability for data transmission. In this protocol, every origin node relays data packets to the target in a hop-by-hop manner depending on local information gathered from its one-hop adjacent during the forwarding phase. Also, two different metrics are considered: (i) destination region selection (DRS) and (ii) weighted closeness and connectivity (WCC) to find the stable path from the source to the destination node. During the adjacent finding phase, a forwarding node self-selection mechanism is introduced to reduce the communication overhead due to the high node density and severe congestion. Finally, this protocol is simulated for 2 different cases: (1) a varying node mobility and (2) varying number of nodes. In the case of high-speed node mobility, i.e. 50m/s, the RSTA-AOMDV protocol achieves a 50.7 % packet delivery ratio (PDR), 109.4ms end-to-end delay (E2E-D), 158.51Kbps throughput, 73.4 % normalized routing overhead (NRO) and 11J mean energy consumption (MEC) compared to other existing protocols. Similarly, in the case of high node densities, i.e. when the number of nodes is 100, the RSTA-AOMDV protocol achieves a 66.5 % PDR, 1485.74ms mean E2E-D, 639.7Kbps throughput, 15 % NRO and 22.7J MEC compared to the existing protocols.

Keywords: MANET, Multipath routing, QoS, Link stability, TA-AOMDV, Node density, Destination region selection, Weighted closeness, Forwarding node selection.

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1. Introduction

MANETs are often deployed in a range of domains, such as disaster rescue, graphics and healthcare and defensive systems [1]. A maximum QoS is required for MANETs because they endure external and internal problems such as connection failure, topology changes and energy depletion [2-7]. So, it is critical to explore and develop unique routing protocols for MANETs.

Standard single-path routing protocols such as AODV and DSR find the shortest path from an origin node to the target nodes [8]. If a node has insufficient resources or a high volume of data, QoS efficiency will suffer as a result of traffic congestion at that node. Some routing protocols include extra node parameters such as available bandwidth and link reliability [9-11]. Alternated paths provide more reliable connectivity in MANETs with dynamic topology changes [12]. By considering the backup path, many paths can quickly switch paths to reinitiate the data transfer after node or link failure. It will ensure better load-balancing, fault tolerance and throughput [13-15] by considering the accessible resources of nodes on the route.

Nonetheless, in the case of high-speed mobility of resource-constrained nodes, the routing protocol of dynamic link-state altering quickly to maintain QoS has still not been investigated. In addition, it is highly difficult to obtain proper criteria for route stability. To combat these difficulties, Chen et al. [16] developed the TA-AOMDV routing protocol to guarantee QoS by adapting high-speed node mobility. In this TA-AOMDV, a robust route election scheme was developed to lessen the route switching latency according to the remaining power, throughput, queue size and the possibility of path reliability amid nodes. Besides, a link failure estimation strategy was employed to modify the routing policy depending on periodic probabilistic measures of link stability. It can be deployed as a successful solution for high-speed MANET with QoS and resource restraints including vehicle-to-vehicle multimedia broadcasting, etc. But, the route stability related to the node density was not considered for high-speed MANETs, since the route stability was highly related to the node density.

Therefore, an RSTA-AOMDV routing protocol is proposed in this article to discover highly reliable paths for data forwarding. In this newly designed protocol, the source node forwards packets to the destination based on a hop-by-hop manner using local information accumulated from its single-hop nearby nodes during the data transmission stage. After that, 2 distinct metrics, namely DRS and WCC are determined to choose the successive forwarding nodes. The DRS is used to explore the target area whereas the WCC is calculated based on the distance, relative velocity and the number of adjacent between the source and target nodes in one hop. But, the network performance is affected in the adjacent finding stage because of high node density and congestion. This is resolved by proposing a forwarding node self-selection mechanism that reduces the communication overhead during the adjacent node finding phase. So, the control overhead is reduced to select the forwarding nodes.

The rest of the portions are prepared as follows: The recent work linked with the different multipath routing protocols in MANET based on various criteria is presented in section 2. Section 3 describes the RSTA-AOMDV routing protocol and section 4 depicts its efficacy. Section 5 summarizes this paper and suggests its possible improvement.

2. Literature survey

A well stable and reliable multipath QoS multicast routing (SR-MQMR) protocol [17] has been developed to enhance the utilization of the requested bandwidth. A velocity-aware and stability-estimation-based multipath routing protocol (VaSe-MRP) has been developed [18] to choose the reliable forwarding nodes using the velocity vector data.

An AOMDV [19] was developed with a novel fitness function (AOMDV-FFn) of the genetic algorithm to find the optimized path from those paths provided by the AOMDV routing protocol. A stable and bandwidth-aware dynamic routing protocol [20] was designed to achieve an efficient, stable route with adequate bandwidth and energy hold nodes for every kind of QoS data transfer.

AOMDV using multi-criteria analysis (MCA) scheme [21] was presented. In this protocol, multiple available routes were sorted based on the different criteria to create effective disjoint routes. A reliable multipath routing protocol based on link quality and stability in urban areas (RMQS-ua) [22] was developed to choose the route that has better link quality and more stable links according to the signal-to-noise ratio and packet reception ratio.

Energy-efficient multipath routing algorithm based on ant colony optimization (EEMR-ACO) [23] was designed to provide more stable routes between the source and destination nodes. Zone-assisted mobility-aware multipath routing protocol for energy-constrained MANETs [24] was developed. In this protocol, the network area was split into zones and the routing decisions were made by determining optimal nodes. The heuristic concurrent ACO and reliable fuzzy QoS routing protocol [25] were developed. First, the ACO was modified to detect the deposit of candidate paths among a pair of source and destination. Then, the ant agents using fuzzy logic were used to choose high stable routes.

2.1 Problem definition

From the literature survey, the problems in the multipath routing protocols in MANET are:

- The threshold used to select the stable node was predefined which was not suitable to choose the optimal stable nodes.
- Most of the researches did not consider the high mobility nodes, which also impact the network efficiency.
- The computation time needed to find the optimal robust path was high for large-scale MANETs.
- Most of the protocols did not handle the obstacles between the routes and so the failed transmission of data packets was not reduced.
- Some researchers did not consider the other path stability factors such as energy, throughput and node density, which affect

the route selection processes in high-speed MANETs.

2.2 Research contribution

This research focuses on ensuring the route stability and network QoS efficiency in high-mobility scenarios by finding the optimal adjacent nodes. To achieve this, the RSTA-AOMDV routing protocol is proposed for high-speed MANETs. First, it finds multiple alternated routes with the maximum QoS efficiency by the alternated route selection scheme. After that, the major route selection scheme is executed which chooses the most reliable and stable routes having the optimal forwarding nodes to transfer the data from an origin node to the target nodes. Additionally, the chance of link failure is predicted which facilitates RSTA-AOMDV to adjust to the substantial structural alterations induced by the high mobility of nodes. The information about the design and development of this routing protocol is presented below.

3. Proposed methodology

In this section, the RSTA-AOMDV routing protocol is described briefly. Table 1 lists the notations used in this study.

Table 1. Lists of notations

Notations	**Description**
u	Source node
v	Number of forwarders
PL_{uv}	Path length between u and v
a	Adjacent node
R	Communication range
LOC_u	Position of u
LOC_a	Position of a
LOC_d	Position of destination node
R_a	Highest distance of the adjacent that is nearby to the target node
L_a	Distance that the adjacent node travels out from the communication range of the source
PL_a	Route length between the adjacent and target nodes
PL_s	Route length between the source and target nodes
θ	Angle exist at the region
v_a	Adjacent node speed
v_s	Present source speed
$\overrightarrow{V_{sa}}$	Relative speed between the source and adjacent node
N_{adj}	Number of adjacent nodes
α, β	Weight for hop count and link connectivity, respectively
ND_l	Local node density
ND_{th}	Threshold node density
wi	Wait interval
T	Total interval
T_{packet}	Time taken to send the packet frame
T_{RTS}	Time taken to send the RTS frame
T_{CTS}	Time taken to send the CTS frame
T_{ACK}	Time needed to transmit the ACK frame
NID_a	ID of the consecutive adjacent node
NID_u	ID of u that searches for a

3.1 Reliable and stable TA-AOMDV protocol design

The major role of this RSTA-AOMDV is to discover an optimal routing path between an origin node and the target with adequate transmission resources in a hop-by-hop manner. As depicted in Fig. 1, the RSTA-AOMDV protocol comprises optimal forwarding and adjacent finding stages while obtaining the most reliable routes. The optimal forwarding stage balances the path efficiency and path stability depending on the QoS requirements. The adjacent finding stage decreases the transmission overhead related to the regular HELLO packets in cases of network congestion. Additionally, an alternated route selection method is performed at the target node, which can find the required route based on the observations of associated resources distributed by the forwarding node. A detailed procedure is given below.

3.1.1. Path finding stage

During the optimal forwarding stage, the source node forwards RTS packets to the target in a hop-by-hop manner depending on local information collected from its single-hop adjacent. The choice of the successive node is depending on DRS and WCC. Algorithm 1 describes the optimal forwarding stage.

The steps in the above-mentioned Algorithm 1 are briefly discussed below.

Destination region selection (DRS): Initially, a source node desires to choose the forwarder within the destination node and transmits the RTS packets to the destination via the selected forwarder nodes. As a result, the term is defined which supports choosing the optimal path as:

$$DRS = \min\{PL_{uv}\} \tag{1}$$

In Eq. (1), u is the source node, v is the number of forwarders and PL refers to the route length.

Weighted Closeness and Connectivity (WCC): The main goal is to develop a routing protocol that

Algorithm 1: Optimal forwarding stage

```
Input: $u$, $v$ and $N_{adj}$
Output: Forwarding candidate node
1.  Begin
2.  Find $LOC_u$;
3.  Calculate $PL_a, PL_s$ and $PL_{uv}$;
4.  $u$ chooses $a$ that satisfies min{$PL_{uv}$};
5.  Each $v$ in 1-hop sends a HELLO packet to $a$;
6.  $if (PL_{uv} == min\{PL_{uv}\})$
        $u$ determines $\overrightarrow{V_{sa}}$, $LOC_a$ and $N_{adj}$ from its routing table for each $a$;
        $u$ determines $WCC$ for each $a$;
        $u$ decides $a$ with the highest $WCC$ as the forwarding candidate node;
        $u$ sends packets to $v$ via the selected $a$;
7.  $else$
        $u$ carries the packet until $v$ comes into $R_a$;
        Return to the command line 5;
8.  $end\ if$
9.  $if (PL_{uv} \neq min\{PL_{uv}\})$
        Return to the command line 2;
10. $end\ if$
11. End
```

ensures path efficiency and increases path stability. Path efficiency refers to the minimum latency in reaching a target node and is realized by transmitting on a path having fewer hops. Path stability is the long link connectivity and is realized by taking adjacent density and node mobility in the routing task. So, the WCC metric is introduced which computes the optimal successive node.

First, the source determines the highest distance toward the adjacent node, which is the nearest to the target depending on the location data acquired from each node. According to this, the following terms are adopted:

$$R = R_a + L_a \tag{2}$$

Because $PL_a < PL_s$

$$R_a = PL_s - PL_a > 0 \tag{3}$$

In Eqns. (2) and (3), a is the adjacent node, R is the communication range, R_a is the highest distance of the adjacent that is nearby to the target, L_a is the distance that the adjacent node travels out from the communication range of the source, PL_a is the route length between the adjacent and target whereas PL_s is the route length between the source and target.

To determine the link stability, the relative speed from the origin node to the candidate adjacent node and the number of adjacent nodes linked to the candidate node are determined. In determining the relative speed, consider that an adjacent node a and origin node travel in distinct directions. So, an angle θ exists at the region. Based on the cosine rule, the relative speed between the source and the adjacent node $\left(\overrightarrow{V_{sa}}\right)$ is provided by:

$$\overrightarrow{V_{sa}} = \begin{cases} \sqrt{v_s^2 - 2v_s v_a \cos\theta + v_a^2}, & \theta \neq 0 \ or \ \pi \\ v_s - v_a, & \theta = 0 \\ v_s + v_a, & \theta = \pi \end{cases} \tag{4}$$

In Eq. (4), v_a is the adjacent node speed and v_s is the present source speed. Then, the node having a minimum variance in relative speed either in a similar direction or opposite direction is chosen. This selection supports maintaining the lifespan of link connectivity for a long interval. The number of adjacent $\left(N_{adj}\right)$ maintains the link stability and quick link recovery. More adjacent nodes indicate a high chance of finding the successive path to the target when a link breaks. Thus, the candidate adjacent node having the consecutive hop of high distance, less relative speed and more adjacent nodes is chosen to balance path efficiency and stability. The WCC metric is defined as:

$$WCC = \alpha R_a + \beta \left(\frac{N_{adj}}{\overrightarrow{V_{sa}}}\right) \tag{5}$$

In Eq. (5), consider that high range of R_a refers to the minimum hop count, when a low range of $\overrightarrow{V_{sa}}$ and high range of N_{adj} denotes enhanced connectivity and stability. So, an origin node prefers to select a candidate node a having the highest value of WCC, where α, β are constant weights (α is the weight for hop count and β is the weight for link connectivity under the criteria of $\alpha + \beta = 1$.

These weight values can be modified to guarantee QoS requirements. When the origin node gets data regarding speed and location from its adjacent, it determines the WCC of each adjacent node in its adjacent list. When many adjacent nodes having similar high WCC exist in the network, the origin node will randomly choose one of them as the forwarding node. Also, the single-hop adjacent nodes are discovered to obtain alternate links if links are failed. If no hop adjacent exists, then the origin node waits for a particular time until the other in-range adjacent is discovered.

3.1.2. Adjacent finding stage

During the adjacent finding stage, all nodes

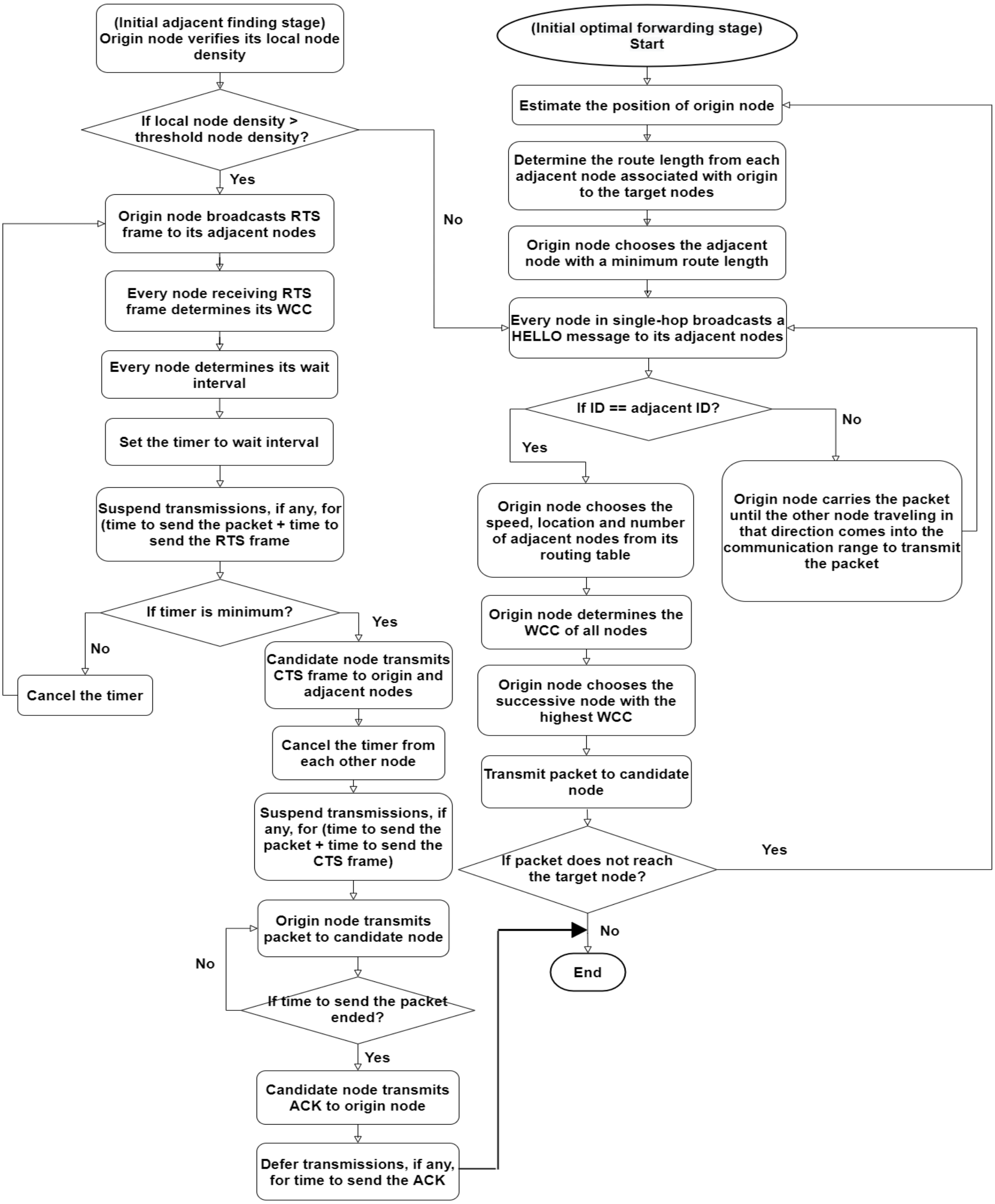

Figure. 1 Flow diagram of RSTA-AOMDV routing protocol

forward a HELLO packet to share data with its adjacent at periodic intervals. This actual data is accumulated in the adjacent lists managed by all nodes. Node density has a substantial impact on efficiency, as high node density causes severe congestion during the adjacent list modification.

As a result, frequent HELLO packets increase routing overhead, disrupt data transfer and generate traffic load. To enhance the data delivery rate in congested networks when decreasing the transmission overhead incurred in the successive node selection, a distributed hop choice mechanism is applied. Algorithm 2 describes the adjacent finding stage.

Algorithm 2: Adjacent finding stage

```
Input: $ND_l$ of $u$ and $ND_{th}$
Output: The adjacent node table of $u$
1. Begin
2. $u$ verifies its $ND_l$;
3. $if (ND_l < ND_{th})$
    a. Execute the command link 5 until the line 11 of Algorithm 1;
4. $else$
    a. $u$ broadcasts the RTS $(LOC_u, LOC_d, v_s, T_{packet})$ to each $a$;
    b. Each $a$ receiving the RTS frame determines its $WCC$ and wait interval ($wi$);
    c. $if (wi == 1)$
        i. For $T_{packet} + T_{RTS}$, reschedule transmissions;
       $elseif$
        i. Candidate $a$ transmits the CTS $(NID_a, NID_u, T_{packet})$ to $u$ and each $a$ before $wi = 1$;
        ii. Stop $wi$ for every $v$;
        iii. For $T_{packet} + T_{CTS}$, reschedule transmission;
        iv. $u$ transmits the packet to candidate $a$;
        v. $if (T_{packet}\ is\ ended)$
               Candidate $a$ node transmits the ACK to $u$;
               Reschedule transmissions for $T_{ACK}$;
               Execute the command line 9 until the command line 11 of Algorithm 1;
           $else$
               Return to 4c(iv);
           $end\ if$
       $else$
        i. Stop $wi$;
        ii. Return to 4(a);
       $end\ if$
5. $end\ if$
6. End
```

The steps in the above-mentioned Algorithm 2 are briefly discussed below.

The adjacent finding stage identifies adjacent to upgrade the adjacent list based on node density. For this purpose, local and threshold node densities are considered. The local node density (ND_l) refers to the adjacent of node u within its communication range whereas the threshold node density (ND_{th}) is utilized to assess ND_l. The starting of the adjacent finding stage is signified by the origin node while it assesses its ND_l to find the optimal forwarding node. When ND_{th} is larger than ND_l, less transmission overhead can exist in the adjacent finding stage. So, all nodes broadcast a beaconing HELLO packet to its adjacent and the adjacent list is modified by all nodes.

Considering the data collected from adjacent nodes, the packet is transmitted by the origin node to the node that is chosen as the optimal forwarding node based on the WCC value. This full procedure is continued until the packet reaches the target. On the other hand, when ND_{th} is smaller than ND_l, a high transmission overhead is obtained in the adjacent finding stage. So, the forwarding node selection is performed by the origin node by leveraging RTS/CTS packets, which prevents the transmission overhead incurred by regular HELLO packets in the scenario of a high traffic load. It utilizes relative velocity and the number of adjacent nodes. As well, the forwarding node self-selection mechanism in this protocol is employed to conduct piggybacking of data on the network RTC/CTS frames to decrease transmission overhead.

In summary, the source node first broadcasts an RTS frame to its adjacent nodes. Once the RTS frame is received, each adjacent node determines its individual WCC, residual energy, bandwidth, queue length, link failure probability, path stability probability and delay (wait interval). After that, the CTS frame is transmitted back to the origin node. The delay decides whether the node can act as a forwarding candidate node. As a result, when the delay is less, the node becomes the optimal candidate node to transmit the packet. The wait interval can be determined as:

$$wait\ interval, (wi) = \frac{T}{WCC} \tag{6}$$

In Eq. (6), T denotes the total interval, which regulates the correlation between the delay and WCC of destination. Once the CTS is received, the origin node transmits the packet to the optimal forwarding node. Finally, the forwarding node transmits an acknowledgment (ACK) of the data receipt. In this manner, the forwarding node is effectively selected without broadcasting any HELLO packets.

Further, the target node initiates the timer instantly after receiving the initial RREQ. After the timer ends, the alternated route selection strategy extracts the RREQ data to determine the cost function of the route.

3.1.3. Path reply and maintenance stages

During the path reply stage, all forwarding nodes determine the stable probability of the route that the RREP packet travels through and the entire procedure ends at the source node. Then, the primary route selection procedure will sort each alternated route in descending manner based on the stable probability of the route to choose the path for data transfer [16].

The topology change monitoring and feedback mechanisms are embedded in the route maintenance stage. In this mechanism, the node on the path monitors the probability of link stability with the next-hop node [16]. The link abnormal status notification (LASN) sent by the node contains the ID number of the corresponding node that makes up the unstable link. When an intermediate node receives RREQ, RREP and LASN, the routing update rule of the RSTA-AOMDV is invoked to update the routing table. If the intermediate node receives LASN, it deletes the route entry and looks for the reverse route to continue sending LASN. The RREP is sent from the source node to the destination node.

4. Simulation results

In this section, the efficiency of the RSTA-AOMDV routing protocol is evaluated by simulating it in Network simulator version 2.35 (NS2.35) in 2 distinct cases: (1) at different node mobility and (2) at different node densities. Table 2 presents the simulation parameters.

4.1 Evaluation metrics

The efficiency of the RSTA-AOMDV routing protocol is compared with the existing protocols such as TA-AOMDV [16], SR-MQMR [17], VaSe-MRP [18], AOMDV-FFn [19], AOMDV-MCA [21], RMQS-ua [22] and EEMR-ACO [23]. To analyze the QoS efficiency for the proposed protocol, the evaluation metrics considered in the simulation are E2E-D, throughput, NRO, PDR and MEC. They are defined below:

Table 2. Simulation parameters

Parameter	Range
Number of nodes	10 – 100
Node mobility	0 – 50 m/s
Simulation region	1500×1500m^2
Queue length	50 packet
Routing protocol	AOMDV
MAC layer	IEEE 802.11
CBR packet size	512 bytes
CBR data rate	16 Kbps
Communication range	250 m
Mobility model	Random way point
Channel bandwidth	2 Mbps
Carrier frequency	2.4 GHz
Initial energy	100 J
Transmit power	0.6 J
Received power	0.35 J
Simulation period	150 sec

- E2E-D: It is the mean duration to send a packet efficiently from an origin node to the target across the network.

$$E2E-D = \sum_{i=0}^{n}\left(t_i^{received} - t_i^{transmit}\right)\Big/_{n} \tag{7}$$

In Eq. (7), n is the number of effectively received packets, $t_i^{received}$ is the current period the target node received i^{th} packet and $t_i^{transmit}$ is the current period the origin node transmits i^{th} packet.

- Throughput: It defines the number of bits received by the target during the simulation period.

$$Throughput = \sum_{i=0}^{n} R_i^{Byte} \Big/_{t^{sim}} \tag{8}$$

In Eq. (8), R_i^{Byte} and t^{sim} are the total number of bytes received by each node and the simulation period, correspondingly.

- NRO: It is the fraction of the routing control packet to the number of packets received by the target node.

$$NRO = \frac{Total\,number\,of\,control\,packets}{Total\,number\,of\,data\,packets} \times 100\% \tag{9}$$

- PDR: PDR measures the percentage of the received packets by the destination to the data packets initially transmitted by the origin node.

$$PDR = \frac{Total\,number\,of\,packets\,received\,by\,the\,target}{Number\,of\,packets\,transmitted\,by\,origin} \tag{10}$$

- MEC: It is the total energy consumed by each node after the target node properly receives the packet.

4.2 Analysis of network efficiency under varying node mobility

In the 1st case, 50 nodes are randomly distributed in 1500 × 1500m^2 region and a fixed CBR data rate of 16Kbps is assigned. The node mobility is ranging from 0-50m/s and the simulation period is set to 150 seconds. The node begins to travel and transmit data after 10 seconds.

Fig. 2 portrays the mean E2E-D of packets against the node mobility. If the node mobility increases to 0-30m/s, then the E2E-D of all protocols remains increasing. In these ranges of node mobility, the E2E-D of the RSTA-AOMDV protocol increased from 26.9ms to 100.5ms and then reduced to 68.3ms after reaching 40m/s because of the chance of inducing LASN packet transfer increased. Also, in high mobility cases (40-50m/s), network topology changes tend to route failures, resulting in high E2E-D for retransfer. Thus, the RSTA-AOMDV protocol has a minimum E2E-D than all other protocols because it handles the link failure by choosing the best forwarding nodes within the target region.

Fig. 3 shows the mean throughput of packets against the node mobility. When the node mobility increases to 0-10m/s, the throughput of RSTA-AOMDV reduces from 246Kbps to 176Kbps. If the node mobility increases as 10-50m/s, the throughput of RSTA-AOMDV reduces from 210Kbps to 158.51Kbps; but, the throughput of RSTA-AOMDV increases than the other protocols. So, it is obvious that the RSTA-AOMDV has greater efficiency in the range of high mobility.

Fig. 4 illustrates the impact of varying the node mobility on the NRO for different routing protocols. When the node mobility increases to 0-50m/s, the NRO of RSTA-AOMDV reduces rapidly. When the node mobility is 50m/s, the NRO of RSTA-AOMDV is 30.2 %, 25.6 %, 21.2 %, 18.2 %, 15.5 %, 11.5 % and 8.3 % less than the AOMDV-MCA, AOMDV-FFn, SR-MQMR, VaSe-MRP, RMQS-ua, EEMR-ACO and TO-AOMDV, correspondingly since it reduces the number of LASN packets by deciding the most reliable paths, resulting in less link or path failure.

Fig. 5 shows the fluctuations of the PDR as a result of node mobility. If the node mobility increases to 0-50m/s, then the PDR of each protocol drastically reduces. The PDR of RSTA-AOMDV reduces from 94.6 % to 50.7 %; however, it achieves greater PDR than all other routing protocols since it

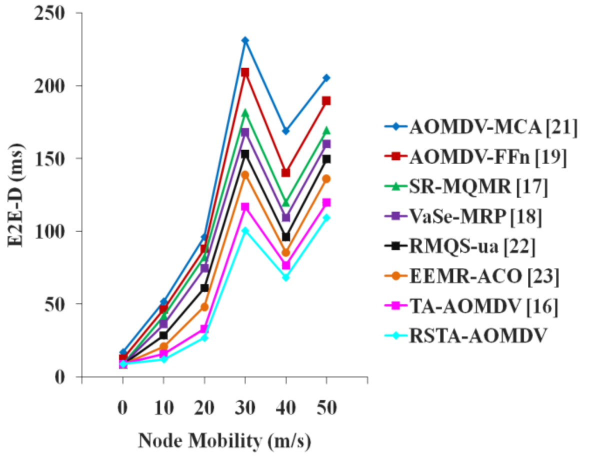

Figure. 2 E2E-D vs. node mobility

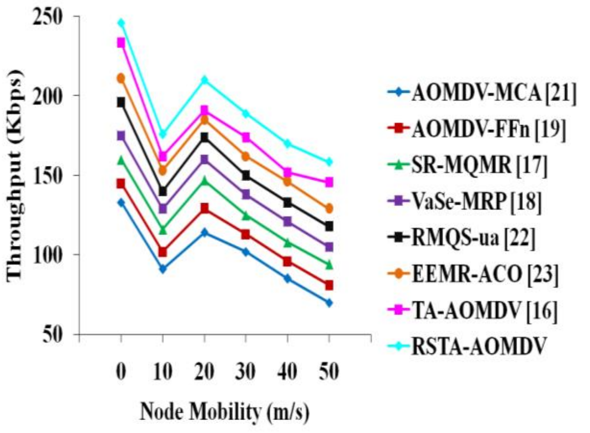

Figure. 3 Throughput vs. node mobility

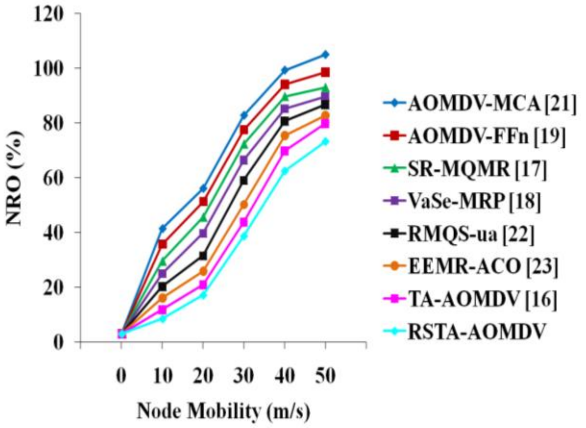

Figure. 4 NRO vs. node mobility

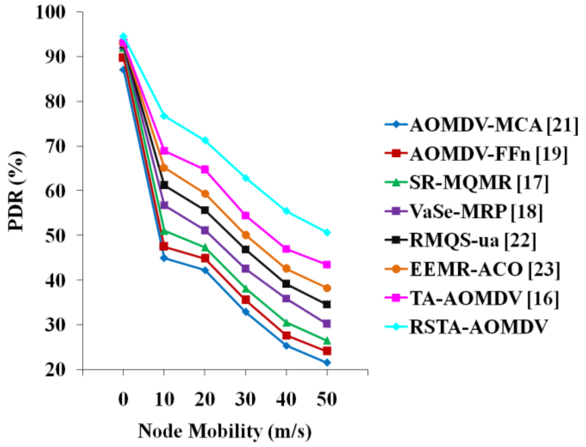

Figure. 5 PDR vs. node mobility

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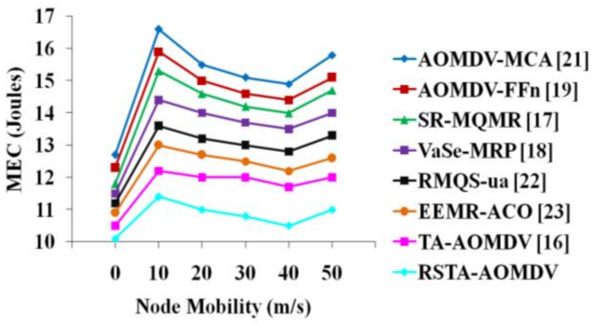

Figure. 6 MEC vs. node mobility

chooses the major route with the most stable and reliable forwarding nodes.

Fig. 6 exhibits the MEC of the different routing protocols at varying node mobility. By considering the link stability and optimal forwarding nodes, the energy depletion caused by retransfer is efficiently decreased. If the node mobility increases to 0-50m/s, the MEC of RSTA-AOMDV reduces from 11.4J to 11J and also it reduces the MEC compared to all other protocols.

4.3 Analysis of network efficiency under varying node densities

In the 2nd case, the number of nodes participating in the network is varied between 10 and 100. These nodes are randomly distributed in $1500 \times 1500\mathrm{m}^2$ region. Also, the fixed node mobility of 10m/s and CBR data rate of 16Kbps are allocated.

Fig. 7 portrays the E2E-D of different routing protocols in the case of a varying number of nodes. When the number of nodes increases in the 20-100, the E2E-D of RSTA-AOMDV reduces than the other protocols. For example, if the number of nodes is 100, then the E2E-D of the RSTA-AOMDV protocol is 53.5 %, 48.7 %, 42.9 %, 40.6 %, 35.5 %, 29.4 % and 25.7 % decreased than the AOMDV-MCA, AOMDV-FFn, SR-MQMR, VaSe-MRP, RMQS-ua, EEMR-ACO and TO-AOMDV, respectively.

Fig. 8 shows the impact of a varying number of nodes on the throughput of different routing protocols. It is addressed that when the number of nodes increases in the range of 20-100, the throughput of the RSTA-AOMDV increases from 163.8Kbps to 639.7Kbps since it finds more reliable and stable paths with optimal forwarding nodes. If the number of nodes is 100, then the throughput of RSTA-AOMDV protocol is 45.2 %, 33.2 %, 26.6 %, 20.7 %, 14.7 %, 9.1 % and 4.8 % greater than the AOMDV-MCA, AOMDV-FFn, SR-MQMR, VaSe-MRP, RMQS-ua, EEMR-ACO and TO-AOMDV, respectively.

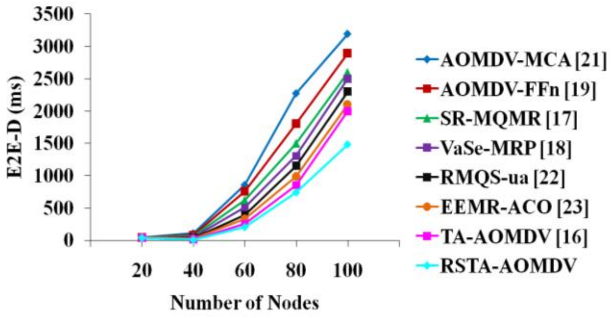

Figure. 7 E2E-D vs. number of nodes

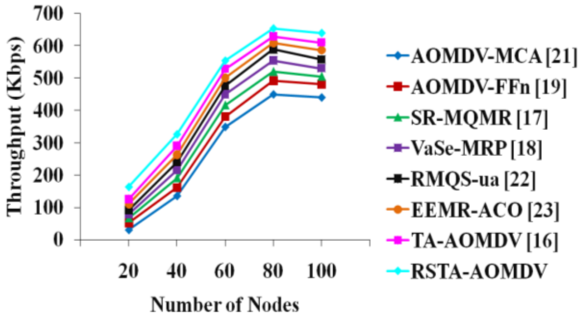

Figure. 8 Throughput vs. number of nodes

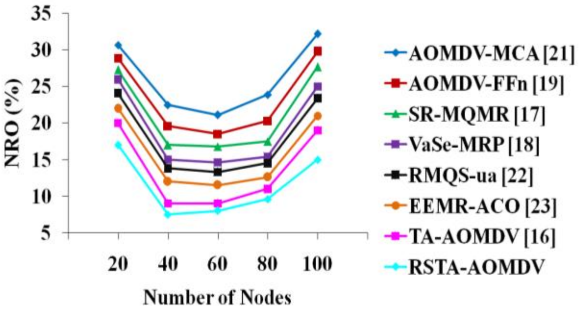

Figure. 9 NRO vs. number of nodes

Fig. 9 highlights the impact of a different number of nodes on the NRO. It is addressed that when the number of nodes increases from 20 to 100, the NRO value of RSTA-AOMDV reduces compared to all other protocols since the source node discovers the path rapidly. For example, if the number of nodes is 100, then the NRO of the RSTA-AOMDV protocol is 53.4 %, 49.7 %, 45.8 %, 40 %, 35.9 %, 28.6 % and 21.1 % less than the AOMDV-MCA, AOMDV-FFn, SR-MQMR, VaSe-MRP, RMQS-ua, EEMR-ACO and TO-AOMDV, respectively.

Fig. 10 shows the impact of a varying number of nodes on the PDR. It is addressed that when the number of nodes increases to 20-100, the PDR of RSTA-AOMDV increases compared to the other protocols because it selects a more reliable and stable route with optimal forwarding nodes for data transfer. For example, if the number of nodes is 100,

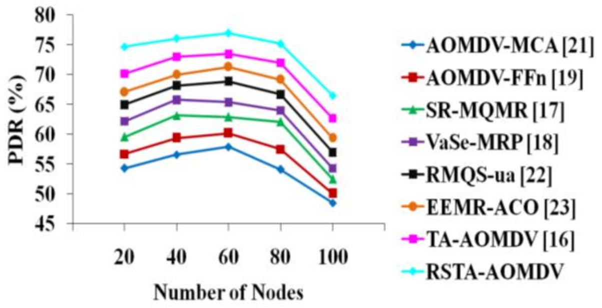

Figure. 10 PDR vs. number of nodes

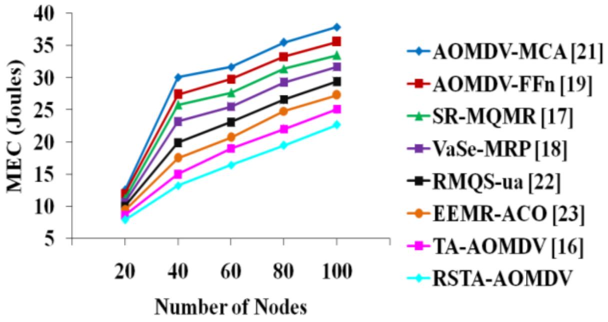

Figure. 11 MEC vs. number of nodes

then the PDR of RSTA-AOMDV is 37.1 %, 32.7 %, 26.7 %, 22.5 %, 16.7 %, 12 % and 6.1 % greater than the AOMDV-MCA, AOMDV-FFn, SR-MQMR, VaSe-MRP, RMQS-ua, EEMR-ACO and TO-AOMDV, respectively.

Fig. 11 exhibits the MEC of the different routing protocols at a different number of nodes. If the number of nodes is less than 40, the MEC of all the protocols is not highly varied. But, when increasing the number of nodes from 40 to 100, the MEC of RSTA-AOMDV significantly decreases than all other protocols because it transfers the LASN packets only with stable links.

5. Conclusion

In this article, the RSTA-AOMDV routing protocol was developed which uses the novel optimal forwarding selection algorithm to obtain highly stable and reliable routes between source and destination nodes. In this protocol, the packet is relayed from the source node to the target in a hop-by-hop fashion according to the local information captured from its single-hop adjacent node during the optimal forwarding stage. For this purpose, DRS and WCC were determined, which helps to obtain the optimal forwarding nodes within the region of the destination node. Further, a forwarding node self-selection process was conducted to decrease the routing overhead during the adjacent node finding stage. At last, the simulation findings proved that the RSTA-AOMDV routing protocol has 109.4ms E2E-D, 158.51Kbps throughput, 73.4 % NRO, 50.7 % PDR and 11J MEC when the node mobility is 50m/s (during 1st case), whereas the RSTA-AOMDV routing protocol achieves 1485.74ms E2E-D, 639.7Kbps throughput, 15 % NRO, 66.5 % PDR and 22.7J MEC if the number of nodes is 100 (during 2nd case) compared to the classical multipath routing protocols. In future work, an advanced heuristic optimization-based routing protocol will develop to handle the topology changes due to the node's high mobility by choosing the optimal network parameters.

Conflict of interest

The authors declare no conflict of interest.

Author contributions

Conceptualization, Ranjith Nadarajan; Methodology, Binuja Philomina Marydasan; Software, Simulation, Binuja Philomina Marydasan; Writing- Original draft preparation, Binuja Philomina Marydasan; Visualization, Investigation, Supervision, Ranjith Nadarajan; Reviewing and Editing, Ranjith Nadarajan.

References

[1] S. C. Mukhopadhyay, N. K. Suryadevara, and A. Nag, "Wearable sensors and systems in the IoT", *Sensors*, Vol. 21, No. 23, pp. 1-8, 2021.

[2] V. K. Quy, N. T. Ban, and N. D. Han, "A High-performance routing protocol for multimedia applications in MANETs", *Journal of Communications*, Vol. 14, No. 4, pp. 267-274, 2019.

[3] P. Sra and S. Chand, "QoS in mobile ad-hoc networks", *Wireless Personal Communications*, Vol. 105, No. 4, pp. 1599-1616, 2019.

[4] V. Tilwari, K. Dimyati, M. H. D. Hindia, A. Fattouh, and I. S. Amiri, "Mobility, residual energy, and link quality aware multipath routing in MANETs with Q-learning algorithm", *Applied Sciences*, Vol. 9, No. 8, pp. 1-23, 2019.

[5] D. Kanellopoulos and V. K. Sharma, "Survey on power-aware optimization solutions for manets", *Electronics*, Vol. 9, No. 7, pp. 1-64, 2020.

[6] Y. H. Robinson, E. G. Julie, K. Saravanan, R. Kumar, M. A. Basset, and P. H. Thong, "Link-disjoint multipath routing for network traffic overload handling in mobile ad-hoc networks", *IEEE Access*, Vol. 7, pp. 143312-143323, 2019.

[7] E. P. Jara, A. M. Mezher, M. A. Igartua, R. P.

D. Redondo, and A. F. Vilas, “QSMVM: QoS-aware and social-aware multimetric routing protocol for video-streaming services over manets”, *Sensors*, Vol. 21, No. 3, pp. 1-21, 2021.

[8] V. K. Quy, V. H. Nam, D. M. Linh, N. T. Ban, and N. D. Han, “A survey of QoS-aware routing protocols for the MANET-WSN convergence scenarios in IoT networks”, *Wireless Personal Communications*, pp. 1-14, 2021.

[9] M. A. Gawas and M. M. Gawas, “Efficient multi objective cross layer approach for 802.11 e over MANETs”, In: *Proc. of IEEE 14th International Wireless Communications and Mobile Computing Conf.*, pp. 582-587, 2018.

[10] W. A. Jabbar, W. K. Saad, and M. Ismail, “MEQSA-OLSRv2: a multicriteria-based hybrid multipath protocol for energy-efficient and QoS-aware data routing in MANET-WSN convergence scenarios of IoT”, *IEEE Access*, Vol. 6, pp. 76546-76572, 2018.

[11] A. Naushad, G. Abbas, Z. H. Abbas, L. Jiao, and F. Muhammad, “A novel dynamic link connectivity strategy using hello messaging for maintaining link stability in manets”, *Wireless Communications and Mobile Computing*, Vol. 2018, pp. 1-23, 2018.

[12] P. K. Manohari and N. Ray, “Multipath routing protocols in MANETs: a study”, In: *Proc. of IEEE International Conf. on Innovation and Challenges in Cyber Security*, pp. 91-96, 2016.

[13] P. T. Kasthuribai and M. Sundararajan, “Secured and QoS based energy-aware multipath routing in MANET”, *Wireless Personal Communications*, Vol. 101, No. 4, pp. 2349-2364, 2018.

[14] V. R. Verma, D. P. Sharma, and C. S. Lamba, “Expansion in quality of service of MANET during route determination phase by mobile software agent approach”, *International Journal of Applied Engineering Research*, Vol. 13, No. 15, pp. 11917-11922, 2018.

[15] C. Z. Sirmollo and M. A. Bitew, “Mobility-aware routing algorithm for mobile ad hoc networks”, *Wireless Communications and Mobile Computing*, Vol. 2021, pp. 1-12, 2021.

[16] Z. Chen, W. Zhou, S. Wu, and L. Cheng, “An adaptive on-demand multipath routing protocol with QoS support for high-speed manet”, *IEEE Access*, Vol. 8, pp. 44760-44773, 2020.

[17] M. G. Vaighan and M. A. J. Jamali, “A multipath QoS multicast routing protocol based on link stability and route reliability in mobile ad-hoc networks”, *Journal of Ambient Intelligence and Humanized Computing*, Vol. 10, No. 1, pp. 107-123, 2019.

[18] Z. Ma, Q. Guo, J. Ma, Z. Zhang, H. Ma, L. Peng, and Y. Li, “VaSe-MRP: velocity-aware and stability-estimation–based multi-path routing protocol in flying ad hoc network”, *International Journal of Distributed Sensor Networks*, Vol. 15, No. 11, pp. 1-17, 2019.

[19] A. Bhardwaj and H. E. Ocla, “Multipath routing protocol using genetic algorithm in mobile ad hoc networks”, *IEEE Access*, Vol. 8, pp. 177534-177548, 2020.

[20] A. Sharma, A. Bansal, and V. Rishiwal, “SBADR: stable and bandwidth aware dynamic routing protocol for mobile ad hoc network”, *International Journal of Pervasive Computing and Communications*, Vol. 16, No. 3, pp. 206-221, 2020.

[21] L. Aziz, S. Raghay, and H. Aznaoui, “Enhancing multipath routing using an efficient multicriteria sorting technique”, *International Journal of Internet Technology and Secured Transactions*, Vol. 10, No. 6, pp. 675-693, 2020.

[22] S. E. Benatia, O. Smail, B. Meftah, M. Rebbah, and B. Cousin, “A reliable multipath routing protocol based on link quality and stability for MANETs in urban areas”, *Simulation Modelling Practice and Theory*, Vol. 113, pp. 1-17, 2021.

[23] A. S. Sharma and D. S. Kim, “Energy efficient multipath ant colony based routing algorithm for mobile ad hoc networks”, *Ad Hoc Networks*, Vol. 113, pp. 1-14, 2021.

[24] P. Shailaja and C. G. Rao, “Zone assisted mobility aware multipath routing (ZM2R) for energy constrained MANETs”, *Materials Today: Proceedings*, Vol. 37, pp. 3434-3441, 2021.

[25] C. V. Subbaiah and G. Kannayaram, “Heuristic ant colony and reliable fuzzy QoS routing for mobile ad hoc network”, *Journal of Ambient Intelligence and Humanized Computing*, pp. 1-12, 2021.