AN EFFICIENT AND STABLE ROUTING ALGORITHM IN MOBILE AD HOC NETWORK

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ABSTRACT

Mobile Ad hoc Network (MANET) is mainly designed to set up communication among devices in infrastructure-less wireless communication network. Routing in this kind of communication network is highly affected by its restricted characteristics such as frequent topological changes and limited battery power. Several research works have been carried out to improve routing performance in MANET. However, the overall performance enhancement in terms of packet delivery, delay and control message overhead is still not come into the wrapping up. In order to overcome the addressed issues, an Efficient and Stable-AODV (EFST-AODV) routing scheme has been proposed which is an improvement over AODV to establish a better quality route between source and destination. In this method, we have modified the route request and route reply phase. During the route request phase, cost metric of a route is calculated on the basis of parameters such as residual energy, delay and distance. In a route reply phase, average residual energy and average delay of overall path is calculated and the data forwarding decision is taken at the source node accordingly. Simulation outcomes reveal that the proposed approach gives better results in terms of packet delivery ratio, delay, throughput, normalized routing load and control message overhead as compared to AODV.

KEYWORDS

Mobile Ad hoc Network, Energy, AODV, Routing, Random Waypoint Model.

1. INTRODUCTION

In the field of wireless communication technology, Mobile Ad hoc Networks (MANET) [1, 2] became one of the most prevalent topics among the research community. In MANET, mobile nodes move arbitrarily and communicate among themselves in wireless mode. MANET has many issues such as real-time communication, limited bandwidth, resource constraints and control message overhead. Owing to these issues, routing in this kind of networks is very challenging task. Over the past few years, many routing protocols [3] has been designed and broadly classified as reactive and proactive. These routing protocols specify the strategy through which two devices communicate with each other.

In the proactive routing approach, every node has routing information about the available routes and routing table is updated periodically. DSDV [4] and OLSR [5] are some examples of proactive routing protocols. However, these protocols are not efficient for the large and dynamic network.

On the other hand, reactive to routing protocols such as AODV [6] and DSR [7] use local information for the route establishment. Nodes do not maintain routing information periodically. The route discovery process is initiated only when a source needs to transfer data packets to a goal node. AODV is one the most widely used routing scheme in the reactive category as it performs routing operation more efficiently in dynamic environment where network topology changes frequently. If a path is not used till the expiration time, the information from the routing table automatically gets deleted.

Stable routing helps in selection of long lasting route which reduces chances of occurrences of route failure. An efficient routing protocol focuses on improving the routing performance. Consideration of stability along with efficiency gives improved results in terms of packet delivery ratio, normalized routing load, message overhead, throughput and delay. Parameters such as residual energy of a node, distance and node mobility have great impact on link stability [8]. For example, if the distance between adjacent nodes is longer then it may result in packet loss. Furthermore, weak signal strength may also cause packet drop. Nodes are dependent on battery power and consume energy during processing, receiving and transmitting packets [9]. Thus, the residual energy of a node should also be considered during route establishment process. The stability- based routing protocol should be designed in such a way that it selects the route with a longer lifetime and be more adaptive to the dynamic topology of MANET.

Therefore, in this paper, we have modified the existing AODV scheme in order to provide more stable and efficient route to the network for smooth data transmission process. Parameters such as received signal power, distance, delay and residual energy are used for the computation of route stability.

The paper is organized as follows: Section 2 explains related work done pertaining to the enhancement of AODV routing performance. In Section 3 detailed description of EFST-AODV has been presented. Section 4 presents the result and analysis along with description of simulation parameters and network scenarios that are used to validate the proposed approach. Finally, in Section 5 conclusion is drawn.

2. RELATED WORK

Enhancement of routing performance has been comprehensively researched in past few years and paradigms that are said to possess the ability to provide efficient and stable communication between sender and receiver have been designed. In this section we discuss about some related works done in the direction towards improving routing performance in MANET.

Received signal power is considered as one of the important factors in route selection criteria. It depicts the link quality between two nodes. Considering this parameter [10] proposed a technique in which node determines received signal power in order to estimate signal quality. If the estimated value of received power is below threshold, the node increases link failure factor (LFF) metric by one. After getting route reply message from all paths, the source node selects the final path with minimum LFF. Furthermore, during data transmission process energy level of the hops are continuously monitored. Another proposed Advanced AODV Link Break Prediction (AODVLBP) [11] utilizes the signal strength parameter to examine the route stability consisting of multiple links. The scheme predicts the time of link failure using Newton Divided difference method which is applied on latest three received signal strength values. In order to transmit data smoothly and efficiently authors proposed Intelligent Routing AODV (IRAODV) [12] that focuses on the improvement of battery power. In this scheme distance between two nodes is determined on the basis of received signal power. However, performance in terms of throughput and delay has not shown much improvement. Authors [13] suggested a technique by considering difference between values of last and current hop received signal power. If the difference is found below a threshold, the scheme applies local the route repairing technique.

During route construction process quality of link should also be examined. For example [14] Malwe et. al. proposed two link availability prediction scheme i.e. zone based and segment-based. In zone- based technique transmission range is divided into three zones i.e. inner, middle and outer. Nodes in the middle zone are only allowed to transmit control packets. Another proposed approach is an enhancement over zone based technique in which nodes lying in the external zone are also allowed for control packets transmission. Next hop is selected on the basis of current available position of the neighbour. In order to improve routing performance, tracking concept [15] is applied to predict node mobility. The scheme initially selects the route as per conventional AODV. During data transmission process the tracking mechanism is applied to approximate node's coordinate and correlation is established to find the node's next position. However, as the network load increases, energy consumption also increases.

Energy consumption is one of the important problems in MANET as nodes have limited battery power. In order to reduce energy consumption [16] Senthil R. et. al. proposed a technique for enhancement of AODV based on energy level of a node. The approach selects the path by investigating energy level of a node with more throughputs and less delay. In another notable work, Dhandapani et. al. proposed [17] an Energy Efficient Node Rank Based Routing (EENRR) in order to improve networks lifetime and packet delivery performance. The technique is an improvement over DSR which has almost similar working as AODV. Before forwarding route request packet, rank of the intermediate node is computed. Afterward, the energy level is compared with threshold. The node forwards the route request packet further only if the residual energy is higher than a threshold.

In order to take good routing decisions fuzzy approach is applied by considering energy parameters along with other criteria factors such as node mobility, hop count and distance to improve routing efficiency. For example in [18] used a fuzzy approach by considering residual energy, distance and node mobility in route selection criteria. However, the technique has a higher delay. In [19] Fuzzy AODV technique computes the trust level of a node to select an optimal route by considering parameters such as node energy, mobility and hop count. These parameters are fed into the fuzzy inference system and nodes with the highest trust values are chosen to establish final route towards the destination.

From the analysis, it can be concluded that most of the aforementioned techniques consider received signal power and energy parameters during the route discovery process but do not achieve better performance in every aspect. For example, the mechanisms applied in [10] [16] and [18] have a higher delays. While in [14] control message overhead is more. In [13] simulation has not been performed to analyze the results. In [19] and [11] performance in terms of throughput and packet delivery ratio has not shown significant improvement. Considering these drawbacks, in this paper, our technique provides more stable and efficient route by incorporating some major parameters in order to investigate the quality of nodes and links during the route discovery cycle. The performance of the work has shown significant improvement in terms of delay, packet delivery, normalized routing load, control overhead and throughput.

3. PROPOSED WORK

The main aim of the proposed EFST-AODV is to enhance the routing performance by providing a stable and efficient route. Link failure, node mobility and limited energy are major issues in MANET routing. Therefore, in this work, we have considered delay, distance and received signal power parameters in order to estimate link quality and residual energy for investigating node status so that the final chosen path can perform data transmission process more efficiently.

3.1. Parameters Considered

In EFST-AODV, following parameters are taken into account during route establishment process.

3.1.1. Residual Energy

Each node acts differently as per the amount of remaining energy. The proposed technique considers the energy level of a node during route selection process. Every mobile node consumes energy mainly in transmitting, receiving and idle mode [20]. Therefore, the total energy consumption of a particular node N_i till the current time can be calculated using the following equation 1.

$$E_{con\,i} = E_{ri} + E_{idi} + E_{tr\,i} \quad (1)$$

Where E_{ri} is total energy consumed in sending mode.

E_{idi} is total energy consume in idle mode

E_{tri} is total energy consumed in receiving mode.

Further the consumed energy E_{con} is subtracted from initial energy E_{in} to get node's residual energy E_{re} as in equation 2

$$E_{re} = E_{in} - E_{con} \quad (2)$$

3.1.2. Distance

Distance parameter is used in order to determine link connectivity status between adjacent nodes. In this paper, distance between two nodes, let's N_i and N_j at time t is determined using Euclidian distance formula as in equation 3.

$$D_{ij} = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2} \quad (3)$$

Where (x_i, y_i) and (x_j, y_j) are the current position of node N_i and N_j respectively.

If the distance is less than threshold θ, the nodes are said to be neighbours. Threshold θ is determined using equation 4.

$$\theta = C_r * a \quad (4)$$

Where value of a is .96 and Cr is the communication range= 250 m.

3.1.3. Delay (Del)

Delay is the difference between receiving time and sending time. It also shows congestion level between adjacent nodes. If the delay between nodes is higher, it leads to the delay in overall routing process.

3.1.4. Received Signal Power

Received signal strength measures signal quality. The value comes from the physical layer to choose stable and efficient links by monitoring link quality [21]. The two ray propagation model [22] is used to estimate received signal power. In the proposed approach, this parameter is one of the main factors in modifying the routing strategy.

Following equation 5 is used to estimate received signal power.

$$P_r = \frac{G_{transm} * G_{receiv} * P_{transm} * {H_{transm}}^2 * {H_{receiv}}^2}{d^4\, L} \quad (5)$$

Where P_r is received signal power, G_{transm} and G_{receiv} are transmitted and received antenna gain respectively, H_{transm} and H_{receiv} are heights of antennas, d is distance and L is path loss.

3.2. Route Establishment Process

The proposed scheme establishes the route by considering more criteria factors. The route establishment procedure is mainly performed in two phases i.e route request and route reply. In the route request stage, the originator node initiates route-finding operation by broadcasting route request (RREQ) packets. In route reply phase the destination node sends a route reply (RREP) packet to the originator that has complete routing information.

3.2.1. Route Request Phase

Whenever the source node has to transmit the packet to a goal node and it has no information about the path. The node broadcasts the RREQ packet towards its neighbor. However, the conventional AODV algorithm does not consider neighbor connectivity and energy status that may lead to route failure. In order to enhance route lifetime, the RREQ packet is modified slightly by adding fields such as packet sending time, node's position and one more field i.e. cost metric field which represents the stability level of a path from source to destination. The modified packet format is shown in Figure 1.

SA	DA	SSN	DSN	X pos	Y pos	CMFR	HC

Figure 1: RREQ Packet Format (SA-Address of Source, DA - Destination Address, SSN : Source Sequence Number, DSN - Destination Sequence Number, X pos - position of X, Y pos -position of Y , CMFR- Cost Metric of Forward Route, HC - Hop Count)

Value of Cost Metric is initialized to 0. Nodes receiving packet calculates distance and received signal power as per equation 3 and 5 respectively. In order to examine link quality these parameters are compared with respect to their thresholds as shown in equation 6.

$$\begin{cases} (D_{ij} > D_{thr})\ and\ (SS > SS_{thr}) & Estimate\ CMFR \\ Otherwise & Discard\ Packet \end{cases} \quad (6)$$

Where D_{ij} is the distance between two nodes, $D_{thr} = \theta, SS = P_r$ and SS_{thr} is signal threshold.

If a receiving node satisfies the packet acceptance criteria, it further calculates CMFR (Cost Metric of Forward Route) using equation 7 and the value is appended in RREQ's CMFR field which is further broadcasted and processed until it reaches the goal node.

$$CMFR = \left(k1 * \frac{1}{Del}\right) + \left(k2 * \frac{1}{\boldsymbol{D_{ij}}}\right) + (k3 * E_{re}) \quad (7)$$

Once the destination node receives first RREQ packet, it immediately replies to the source node through route reply packet. Later, when another RREQ packet with better cost metric arrives, that packet is sent towards the originator for further processing.

The whole Route Request Phase is represented through following pseudo code.

Let P be the RREQ packet
CMFR be the cost metric of forward route whose value representing the route stability.
$\boldsymbol{CMFRprev}$ be the $\boldsymbol{CMFR}$ value of previous packet
$\boldsymbol{D_{ij}}$ **and** $\boldsymbol{D_{thr}}$ be the distance and distance threshold respectively.
$\boldsymbol{SS}$ **and** $\boldsymbol{SS_{thr}}$ be the received signal power and its threshold respectively.
Route Reply Phase
Step1: Estimate $\boldsymbol{D_{ij}}$ and $\boldsymbol{SS}$ using equation and respectively.
Step 2: If $(\boldsymbol{D_{ij}} > \boldsymbol{D_{thr}})$ $\boldsymbol{and}$ $(\boldsymbol{SS} > \boldsymbol{SS_{thr}})$
Evaluate $\boldsymbol{CMFR}$
Else
Discard P
Step 3: Evaluate $\boldsymbol{CMFR}$ using equation
Step 4: If first packet is received
Store $\boldsymbol{CMFR}$ in a table and send reply to S
Else
If $(\boldsymbol{CMFR} > \boldsymbol{CMFRprev})$
Send RREP to S
Else
Discard P

Figure 2: Pseudo code for Route Request phase

3.2.2. Route Reply Phase

During route reply phase each intermediate node receiving RREP estimates residual energy and current delay between sender and receiver and adds this information into the RREP field before forwarding the packet to the next hop towards source node. The RREP packet format is modified as shown below in Figure 3:

SA	DA	SSN	DSN	HC	AVG_DEL	AVG_ENG

Figure 3: RREP Packet Format (SA- Address of source, DA - Destination Address, SSN : Source Sequence Number, DSN - Destination Sequence Number, , HC - Hop Count, AVG_DEL - Average Delay, AVG_ENG- Average Residual Energy)

Once the source node receives the packet, it first estimates Cost Metric of Backward Route (CMBR) using equation 8 as follows

$$CMBR = AVG\_ENG * \alpha + AVG\_DEL * (1 - \alpha) \quad (8)$$

Where AVG_ENG is average energy and AVG_DEL is average delay and α is weighting factor. At a later stage, if before the expiration time, the second packet RREP arrives at the source node, CMBR is estimated by the receiving node. If the value is higher than the previous received packet, rest data packets are transmitted through new route. Otherwise, the received packet is simply discarded and the flow continues with the previous route. The working flow of the route reply packet is shown in Figure 4.

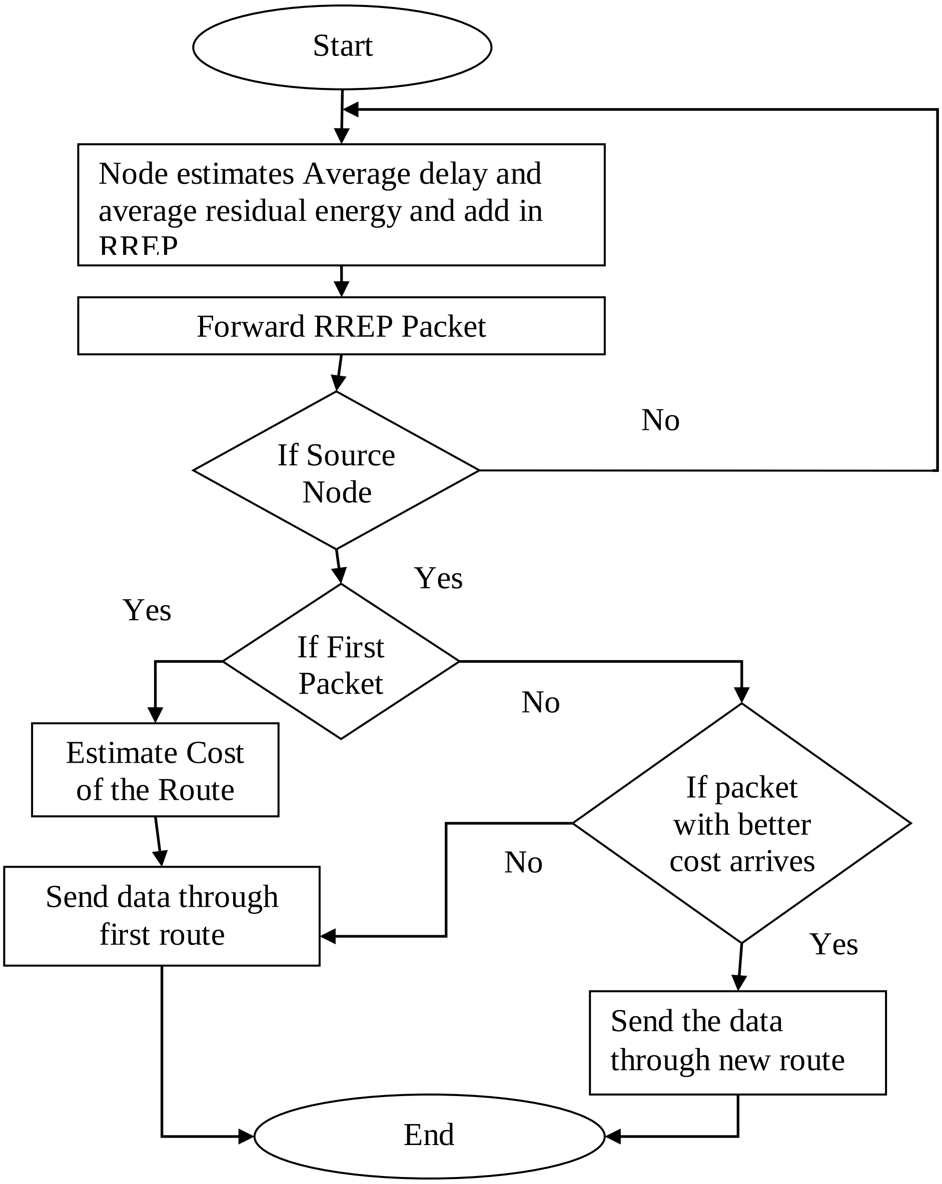

Figure 4: Working Flow Route Reply Phase

4. SIMULATION, RESULTS AND ANALYSIS:

4.1. Simulation Environment

Network Simulator 2.35 [23] is used to evaluate performance of proposed EFST-AODV scheme under Ubuntu operating system. It is a discrete event object -oriented simulator. The simulation script is written using OTCL programming language. In the scheme, Random Waypoint [24] mobility model is used for node movement in which the node waits for a certain pause time before it moves to a new location and constant bit rate (CBR) is used as a traffic source. Total 60 nodes are arbitrarily deployed in the simulation region of 900 m x 900 m. The simulation parameters used in this approach are shown in Table 1.

Table 1 : Main Simulation Parameters

Simulator	NS 2.35
Simulation Area	900x900
Traffic	CBR
Mobility Model	Random Way Point
Antenna	Omni Directional
Propagation Model	Two Ray Ground
Pause Time	2, 4, 6, 8, and 10 seconds
Simulation Time	100, 200, 300, 400 and 500 seconds
Number of Nodes	60
Packet Rate	5 packet/sec
Node Speed	30 m/s
Routing Protocol	EFST-AODV and AODV

4.2. Performance Metrics

In order to evaluate the performance of a proposed approach, the following performance metrics have been considered.

Packet delivery ratio: It is the proportion of total data packets received by the goal node to the total packets generated at the source.
Throughput (in kbps): It is the number of bytes received by target node per unit of time.
Normalized routing load: It depicts the number of control packets required in sending a single data packet from source to goal node.
Control Overheads (packets): It is the total amount of control messages generated by the routing algorithm during entire simulation.
End-to-end delay (seconds): The average time taken by routing algorithm to transfer data packets from source to destination is known as end-to-end delay.
A Total number of received packets: It indicates total amount of data packets received by the destination during the entire simulation.

4.3. Results and Analysis

In this section, obtained results are represented in the graph and analysis of the results has been discussed in depth. Figure 5 and 6 shows the snapshots of network animator used for visualization purpose. Figure 5 represents the initial deployment of nodes. Figure 6 is the snapshot taken during communication. The Encircled node represents communication range and along with it packet dropping can also be seen in the figure.

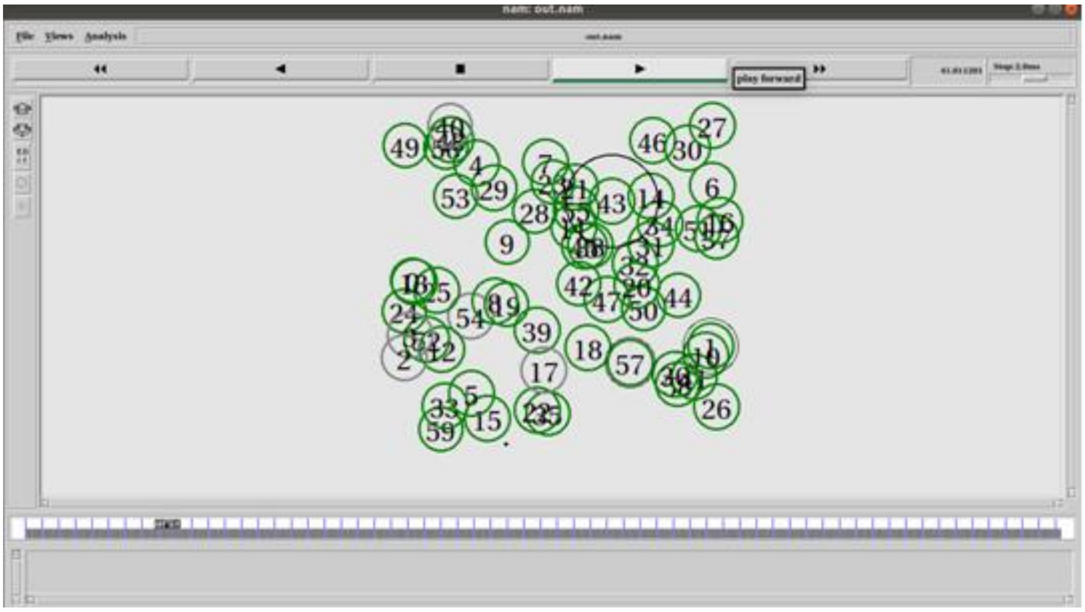

Figure 5: Snapshot of Network Animator during node deployment

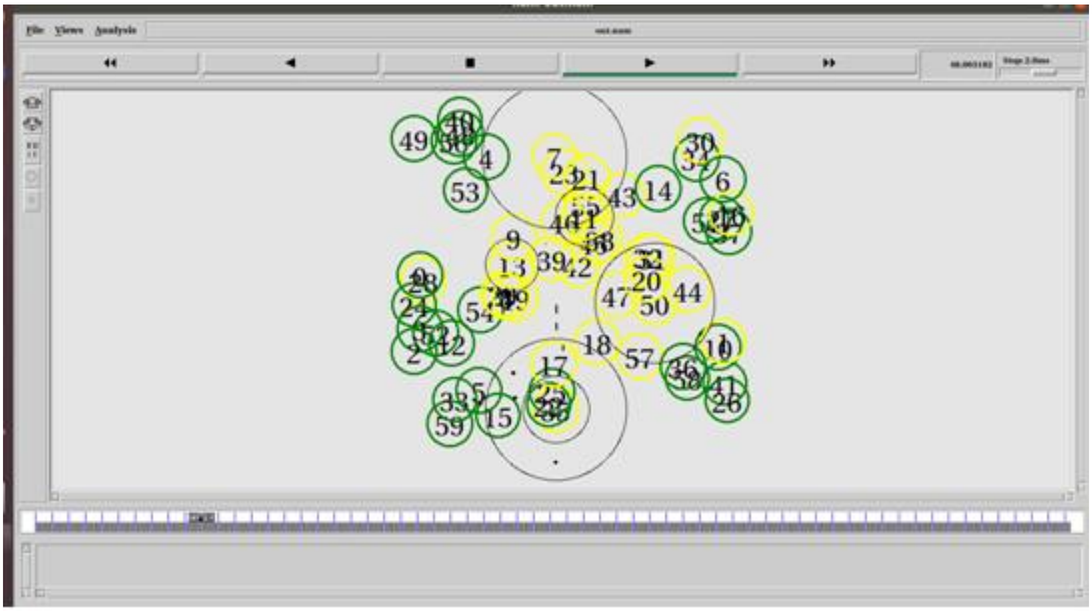

Figure 6: Snapshot of Network Animator showing communication

4.3.1. Impact of Varying Pause Time:

Simulation has been conducted by varying pause time to 2, 4, 6, 8 and 10 seconds in each case with maintaining node speed to 30m/s.

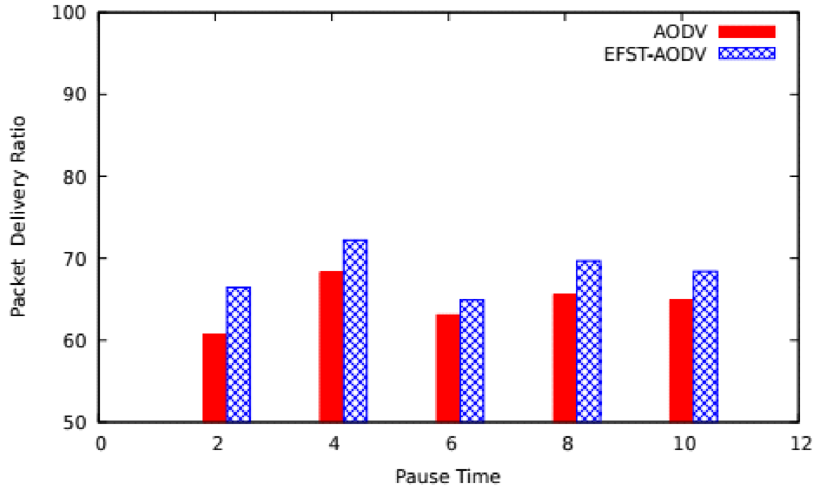

Figure 7: Packet Delivery Ratio Vs Pause Time

Figure 7 illustrates the packet delivery ratio (PDR) performance of proposed and conventional routing. Based on results the PDR of the proposed approach is 5.41% higher than conventional. This is due to the capability of EFST-AODV in coping with the link quality by examining distance and received signal power at receiving RREQ packets.

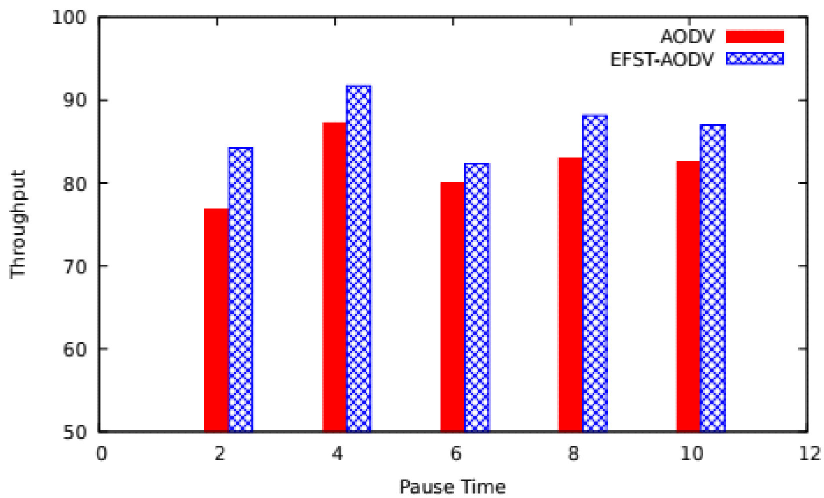

Figure 8: Throughput (in kbps) Vs Pause Time

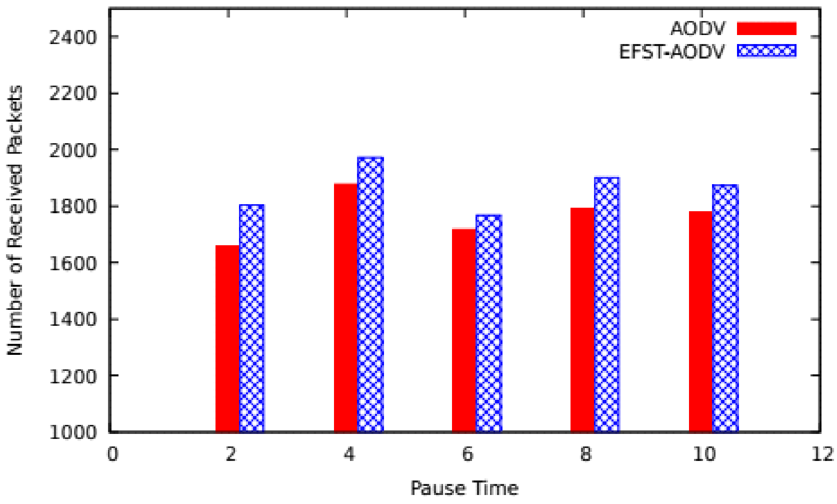

Figure 9: Number of Received Packets Vs Pause Time

Figure 8 shows aggregated throughput performance. It can be seen that EFST-AODV outperforms AODV. The proposed approach has 5.86 % higher throughput. Similarly, a number of received packets is 5.67 % more than the standard AODV as shown in Figure 9. This is because, the scheme estimates the cost in terms of distance, delay and residual energy during route request and route reply phase which leads to an increase in rote stability and thus more packets are delivered to the destination.

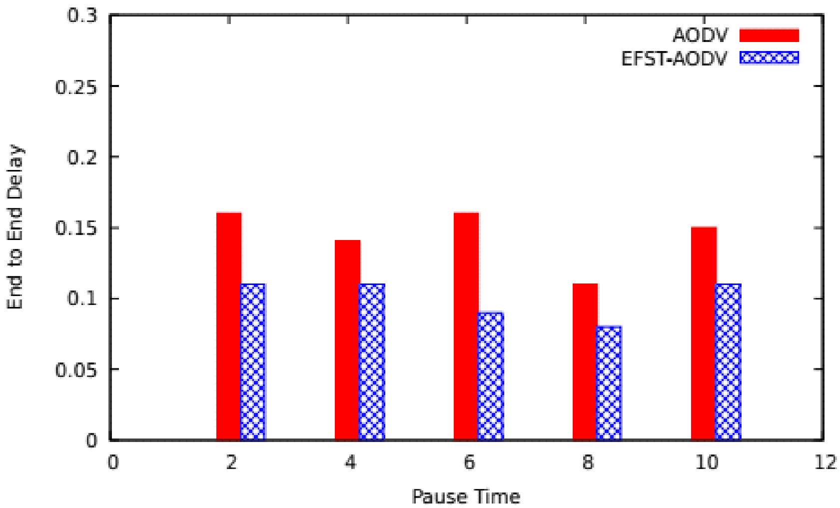

Figure 10: End to End Delay Vs Pause Time

Figure 10 depicts delay performance by varying pause time. The proposed EFST-AODV approach has 28.57% less delay in comparison with AODV. This is because, during the route establishment process, delay parameter is taken into account by the proposed scheme. Moreover, the scheme provides a stable route resulting in a reduction of re-route discovery process.

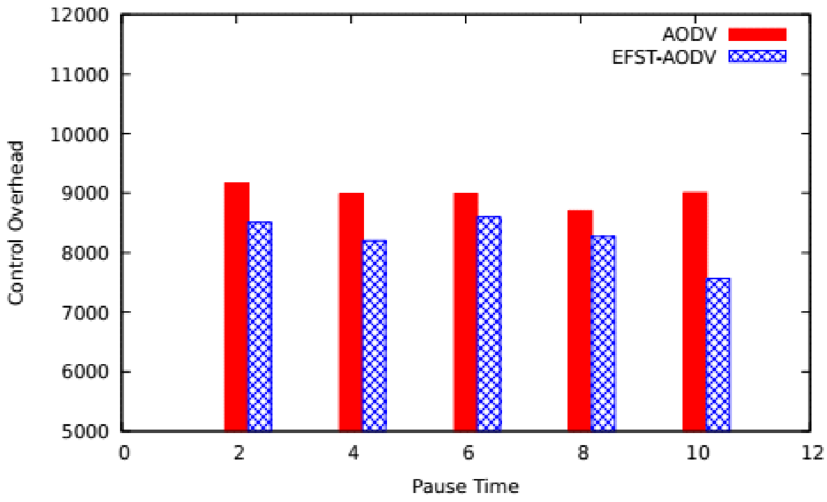

Figure 11: Control Message Overhead Vs. Pause Time

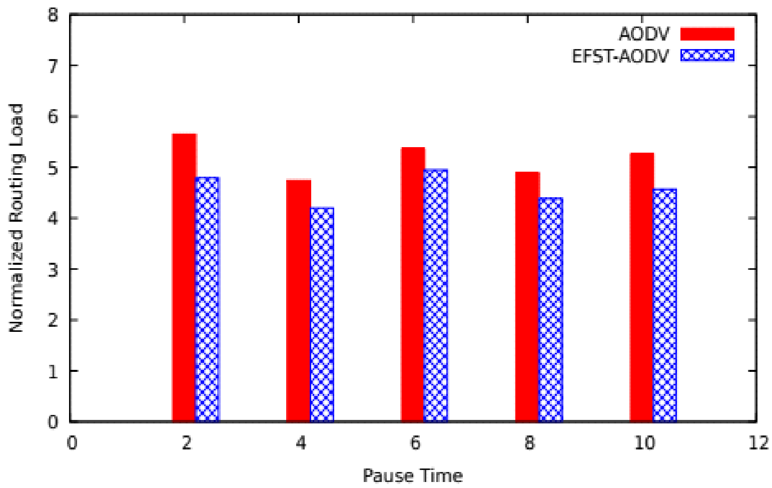

Figure 12: Normalized Routing Load Vs Pause Time

Figure 11 and Figure 12 show control overhead and normalized routing load performance respectively by varying pause time. In EFST-AODV the control overhead is reduced by 8.24% when compared with standard AODV. Similarly, normalized routing load is also reduced to 11.58% as compared with conventional ones. This is because during the route request phase inefficient nodes are filtered and thus control message load on each node in finding data packets is reduced.

4.3.2. Impact of Varying Simulation Time

In the second experiment, the time of simulation was varied to 100, 200, 300, 400 and 500 seconds.

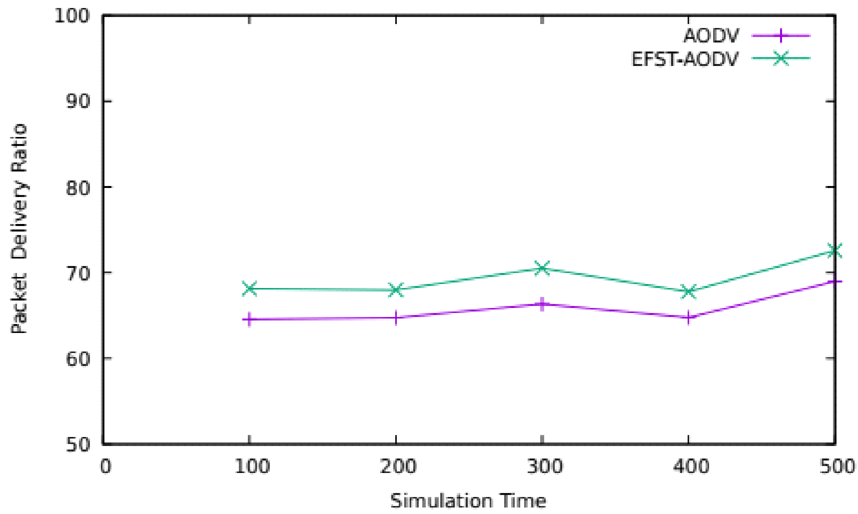

Figure 13: Packet Delivery Ratio Vs Simulation Time

Figure 13 shows the packet delivery ratio (PDR) performance of EFST-AODV and AODV. From the graph, it can be concluded that PDR of the suggested technique is 5.36% higher than the standard AODV. This is because; the proposed work focuses on making the route stable and efficient which leads to less packet drop.

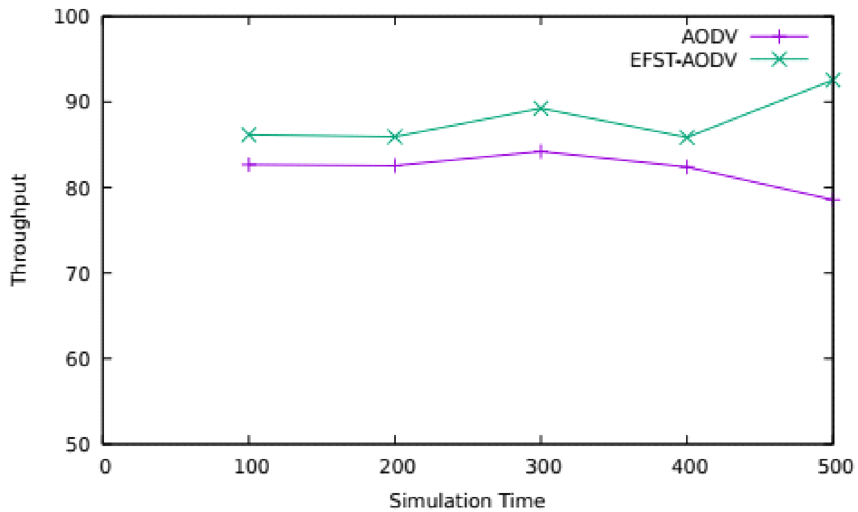

Figure 14: Throughput Vs Simulation Time

Figure 14 depicts throughput performance by varying simulation time. From the figure, it can be concluded that the proposed approach achieves 7.16 % better throughput. This is due to the reason that the proposed approach constructs a stable route by focusing on signal power, delay and distance parameters. Consideration of these help in examining link quality more accurately during route establishment thus the packets are forwarded through a more efficient link leading to increase in throughput performance.

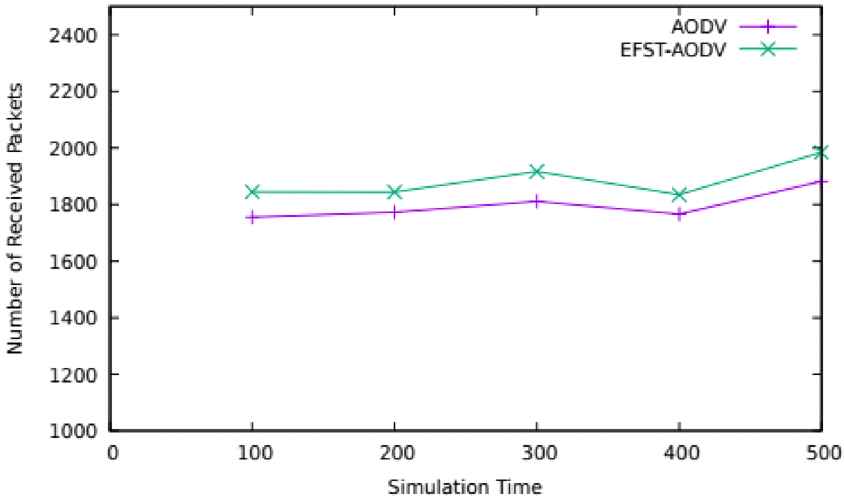

Figure 15: Number of Received Packets Vs Simulation Time

Figure 15 depicts performance of the proposed approach in terms of total received packets. From the graph, it can be concluded that the number of received packets are increasing with an increase in simulation time. The proposed approach has 4.90% higher performance in terms of received packets as compared to AODV. This shows that the approach constructs a more stable and long-lasting route.

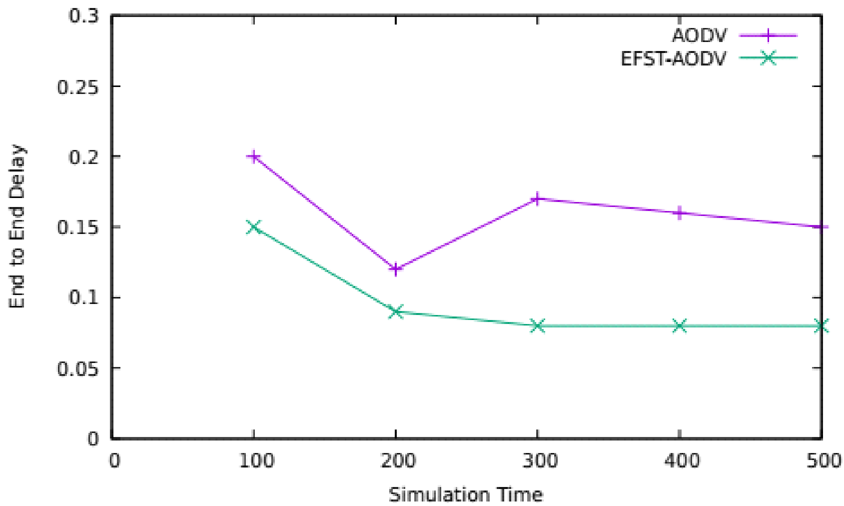

Figure 16: End to End Delay Vs. Simulation Time

Figure 16 illustrates the delay performance of the EFST-AODV and AODV. There is a drastic reduction in delay using EFST-AODV algorithm. The proposed scheme has 43.75% less delay as compared to the standard algorithm. This is due to the reduction in occurrence of route failure as the breakage causes initiation of a new route discovery process which ultimately increases overall routing delay in delivering data packets.

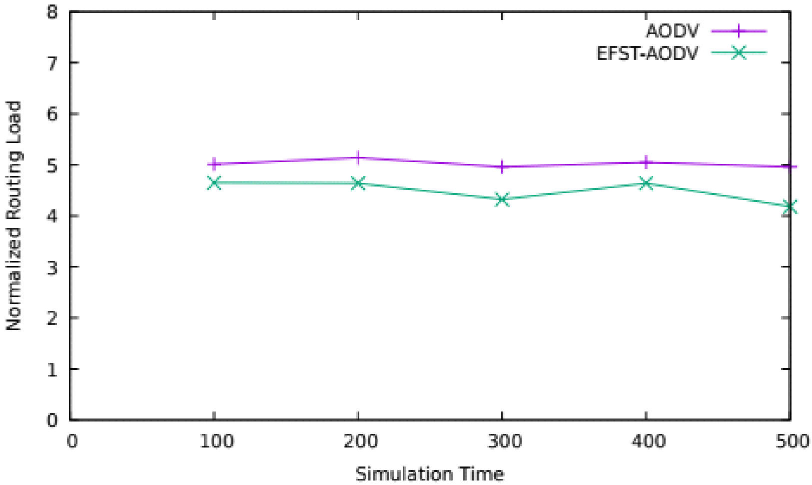

Figure 17: Normalized Routing Load Vs. Simulation Time

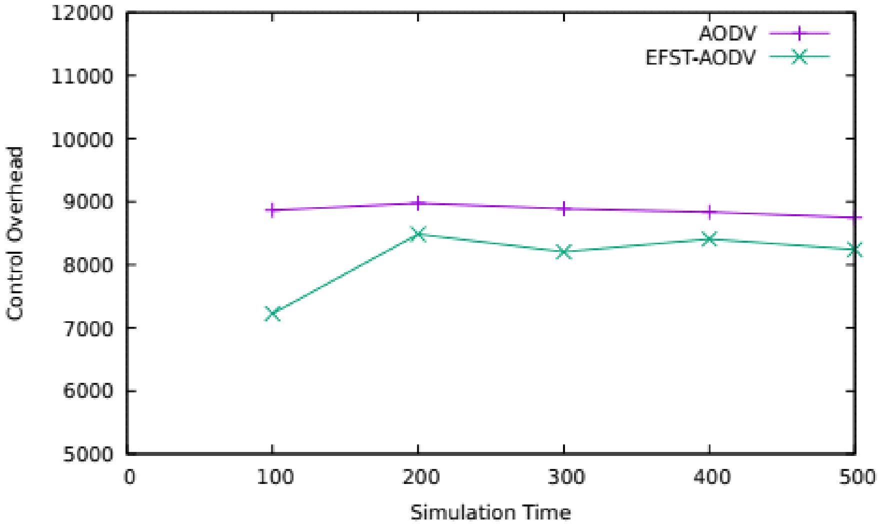

Figure 18: Control Overhead Vs Simulation Time

The graph in Figure 17 shows the performance of routing protocols in terms of routing load. The load in the case of the suggested EFST-AODV is 9.66% less as compared to AODV. Similarly, the control message overhead is also reduced by 8.46 % as compared to AODV as shown in Figure 18. This is because; the proposed approach discards those control packets that are coming from either an efficient node or a link.

5. Conclusion

In this paper, an efficient and stable routing algorithm has been proposed to enhance the performance of the AODV routing protocol. The scheme is divided into two phases route request and route reply. During the route request phase, link quality is monitored before broadcasting the RREQ packet. Furthermore, the cost metric for a forward route is estimated and added in RREQ field. Similarly, during route reply phase, delay and residual energy parameters are taken into account. By simulation study, it can be concluded that the proposed approach performs efficiently in different network scenarios i.e. by varying pause and simulation time. The technique achieves higher throughput, has better packet delivery ratio, less control message overhead, normalized load and delay as compared to AODV. In the future, an energy conservation technique can be incorporated which may further increase network lifetime. Moreover, security features can also be added to improve routing performance.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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