Energy - Optimized Route Discovery in AODV

Gagandeep Singh
Lovely Professional University, Phagwara
Punjab, India
gagandeep.17672@lpu.co.in

Ashok Kumar Sharma
Lovely Professional University, Phagwara
Punjab, India
sharmaashok1989@gmail.com

Onkar Singh Bawa
Lovely Professional University, Phagwara
Punjab, India
bawa_onkar@yahoo.com

***Abstract*--Energy is a scarce resource in the Mobile Adhoc network. The efficient usage of the energy resources in mobile Adhoc environment is a big challenge. Sometimes few paths are utilized more than the other available routes from source to destination. Due to excessive use of that path, the energy of the node is exhausted and the node switched off itself. This paper will discuss about a new approach for efficient route discovery which works on the concept of residual energy available. By integrating the residual energy into consideration the lifetime of the network can be optimized. The performance of the modified protocol is simulated in Ns2 (2.35).**

Keywords--MANET, AODV, RREQ, RREP, RREP-ACK, RFC, REER.

I. Introduction

Mobile Adhoc network doesn’t use any infrastructure for communication. The network doesn’t need a centralized infrastructure for controlling and monitoring the ongoing communication among the nodes. The nodes are mobile in the mobile Adhoc network. In MANET, if we want to establish communication between two nodes and they are within the vicinity of each other then they can communicate with each other directly. If they are not in the vicinity of each other then they communicate with the help of the intermediate node. This intermediate node is called the relaying node because it is responsible for the traffic between the source and destination.

Routing protocol defines the set of procedures or functions which are used to construct the path from the source and destination and maintain the route during the lifetime of the network. Ad-hoc On-demand Distance Vector works on the principle of reactive routing protocol. This is also called reactive routing protocol because these types of routing protocol react on demand i.e. when the route from the source and destination is desired then the route is constructed.

AODV routing protocol works on the principle of shortest hop. When a route is desired between two nodes for the transfer of data, the route discovery procedure is initiated. The route maintenance procedure is invoked when a route failure is detected during the lifetime of the route. HELLO messages are shared between the nodes to detect the connectivity among the nodes. When the HELLO messages are not received during the HELLO INTERVAL, the path is said to be broken.

The AODV protocol builds the shortest path between the source and destination. The shortest path is selected between the source and destination is selected based on the minimum hop count without considering any other parameters. When a single path is utilized more between source and destination, the energy of the nodes in that path gets depleted and after some time the route is broken. This paper provides a novel approach for discovering routes between source and destination considering the residual energy of the nodes. The approach is described in section III and results are discussed in section V in the graphical representation.

II. Related Work

The AODV is a reactive routing protocol. Reactive routing protocol acts on demand i.e. routes from source to destination is not constructed in advance. No periodic messages are sent for the route update. So in the reactive routing protocols, the overhead is low [8].

Ad-hoc On-demand Distance Vector routing protocol is defined in RFC 3561. This document describes the basic functionality of the AODV routing protocol. It describes the entries in routing table of a node, fields in the control packets such as RREQ, RREP, RERR, and HELLO etc. It also describes route discovery and route maintenance procedure. It describes the packet format for the RREP-ACK and gratuitous RREP [1].

In MANET, all the nodes are mobile and they have limited resources such energy, bandwidth etc. Energy is a scarce resource in the Mobile Adhoc Network. So the efficient usage of the energy resources is a big issue in the MANET. There are many metrics which are based on the efficient utilization of the power. The power metrics are categorized into four categories. The first category is based on the minimum transmission power required by the node to perform transmission of the packet from the source to destination e.g. Minimum Transmission Power Routing (MTPR). The second category is based on the concept of remaining energy of the nodes. The path from source to destination is constructed based on the level of remaining power in the nodes. The third category takes remaining level of energy on nodes into consideration which can be seen as an extension of the second category. The fourth category is the combination of the first and the second category [2].

Authors describe the approach to maximize the lifetime of the network. The concept of the recharge quantum which is the amount of energy which is provided when the energy of the gets depleted. In the network startup time, the nodes are not fully recharged. They are provided the energy on demand. They emphasize on maximizing the lifetime of the network [3]. Some of the authors suggested to defining the cost of each node. The path is selected based on the minimum cost. The cost of the node is based on the zone in which the node resides. The zones are defined on the basis of energy levels of the nodes. Lower the residual energy, higher the cost of the node [4].

Some authors describe the cross-layer approach for constructing the route based on the energy. In cross-layer approach, the two layers communicate with each other to fulfill certain task. They use the concept of the energy threshold which is estimated on the base of the session duration for which the data have to be transmitted which is provided by the application layer [5].

Some of the authors use the concept of the delay RREQ. According to this concept, the received RREQ by the intermediate node is delayed for some time which is calculated based on the amount of energy remaining in the node. If the remaining energy is low then the time for which the RREQ is hold by the intermediate node is high otherwise vice versa [6].

Another method to **c**ompute the threshold based on the energy of its neighboring nodes. The energy of the neighboring nodes is exchanged with the help of the HELLO messages. As the request packet travels through the route, the total energy is summed up. If the residual energy remaining on the node is less than the threshold energy then the request packets are dropped [7].

III. Proposed Approach

The proposed approach finds the routes from source to destination founded on the basis of remaining energy of the nodes. The proposed approach is almost similar to the basic AODV routing protocol except some of the modification.

The proposed approach works in two phases:

1) Route Discovery: The first phase is the route discovery phase. When one node desire to establish communication with the other node, then it searches its routing table for the entry for the destination. If it finds an active route, it immediately starts the data transfer on that path. If the source node doesn't find any valid route to the destination then it starts the route discovery procedure.

For carrying the remaining energy of the bottleneck node some fields are added to the RREQ and RREP packet. First, the source prepares the RREQ packet and initializes the energy field properly and broadcast the RREQ packet. When the intermediate node receives the RREQ packet, it calculates its remaining energy and compares it with the threshold. If its energy is above the threshold then it sends the RREQ packet further otherwise it drops the RREQ packet. If its energy is lower than the energy in the RREQ packet than it replaces with its own energy otherwise the energy remains unchanged.

At last the different RREQ are reached at the destination. When the first RREQ is received at the destination it will start timer and wait for RREQs. After the timer is finished, the destination chooses the route whose bottleneck node energy is highest among the received RREQ without any consideration of the shortest path. Then the route reply is sent to the source.

In the Fig. 1, there is two source and destination pair. In the shown topology, the node 12 is the network critical node and whose energy is very low 0.05 joule. The basic AODV chooses the path S1-5-12-D1 and S2-6-12-D2 which passes through the network critical node. After some time the energy of node 12 is exhausted and the node 12 switched off itself. So the network becomes partitioned.

The proposed approach chooses the path based on the residual energy. So the proposed approach chooses the path S1-1-2-3-D1 and S2- 9-10-11-8-D2 which is shown by the dashed line. Although the hops between the source and destination increases but the lifetime of the network is increases as all the nodes have enough residual to energy to sustain the network for long time. The lifespan of the communication network is defined as the difference between the network startup time and the first node failure time [3].

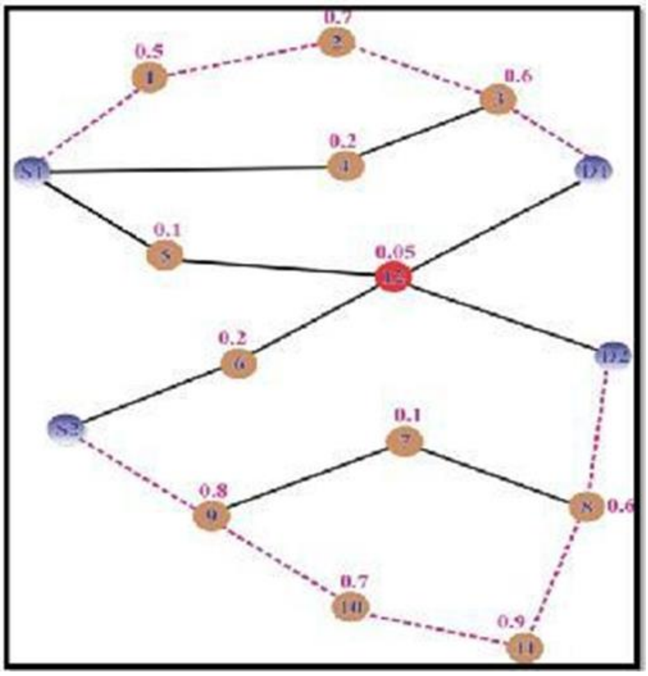

Fig. 1. Proposed approach

Other parameters such as the packet delivery ratio, average energy deviation, throughput etc. are improved.

2) Route Maintenance: Whenever there is a route failure detected on the route the process of route maintenance starts. The process is initiated when the route failure is detected in the active path. There are mainly two reasons for the route failure:

- Mobility
- Power exhaustion

The first reason for route failure is the mobility of the node. As we know that nodes are mobile in nature in MANET. When the node move away from the active path the route failure is detected and the RERR are initiated by the route failure detecting node. The RERR message is sent in the upstream direction to the source. The intermediate node which receives the route error message deletes the route entry for the destination and invalidates the route. When the source receives the RERR message, it invalidates the route. If it has more data to send then starts the route discovery procedure is reinitiated.

Another reason for the route failure is power exhaustion of the node. When the energy of the node in the active path is exhausted, the node shut down itself and the route failure happens. In the proposed approach, when the energy of the bottleneck node goes below the critical threshold, then the WARNING message is sent to the source. If the source has more data to send then it can reinitiate the route discovery and can start the data transfer on that path.

In Fig. 1, node 1 is the bottleneck node for the source 1 whose energy is 0.5 joule. When its energy goes below critical threshold then the node 1 send the WARNING message to the source whose path passes through it.

For the source 2, node 8 is the bottleneck node whose energy is 0.0 joule.

IV. IMPLEMENTATION

The Pseudo-code for the proposed approach describes the functionality of the proposed approach. The threshold is used to find the higher energy path from the source to destination. The pseudo-code of the proposed approach is described below:

1. If valid route in routing table then Start the data transmission.
   Else
   Start the route discovery again.
2. If (intermediate node && Residual_Energy > threshold1) then
   Rebroadcast the request.
   Else
   Drop the request.
3. If (destination==TRUE) then Send the RREP to destination.
4. If (residual_energy < critical_threshold) then Send the WARNING message to source. Else
   Continue to data transfer.
5. EXIT.

V. SIMULATION RESULTS

The simulation of the proposed approach is done in the NS-2.35 [9]. The performance of the protocol is evaluated on the base of different performance parameters. The simulation results are described in two parts:

A. Simulation Parameters
B. Performance Evaluation

A. Simulation Parameters: The proposed approach is simulated on the NS-2.35. The mobility of the node is random in the Simulation. The area of the simulation is 1800 X 1800 m^2. There are 30 nodes in the topology. The configuration of the simulation is shown in the tabular form.

TABLE I. SIMULATION PARAMETERS

S. no.	*Parameter*	*Value*
1.	Simulation Area	1800 X 1800 m^2
2.	Number of Nodes	30
3.	MAC protocol	802.11
4.	Initial Energy	50 Joule
5.	Tx Power	1.0 Joule
6.	Rx Power	default
7.	Simulation Time	200 ms
8.	Source-Destination Pair	3
9.	Traffic Type	Constant Bit Rate

B. Performance Evaluation: The performance of the proposed approach is evaluated on the based on the different performance metrics. The proposed approach performs slightly improved than the basic AODV routing protocol. The green line indicates the proposed routing protocol and the red line indicate the basic AODV routing protocol. The comparison between the proposed protocol and basic AODV is shown in graphical representation. The performance metrics are explained below:

1) Throughput: Throughput is defined as the number of data packets received per unit time. Throughput defines the performance of the proposed routing protocol in term of data delivery per unit time.

The throughput of the proposed routing protocol is better than the basic AODV routing protocol because in the proposed approach the higher energy path is chosen in the route discovery procedure.

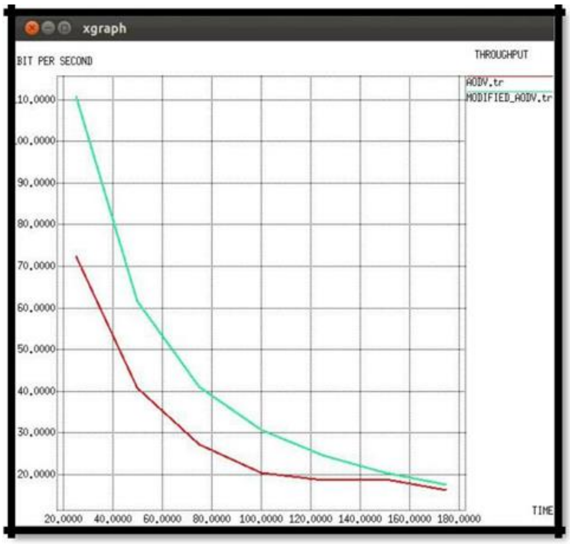

Fig. 2. Throughput

2) Energy Deviation: Energy Deviation describes the utilization of the network in term of energy. Energy deviation is explained as the average of the sum of the deviation of individual node energy from the average. Sometimes it is also termed as the average energy deviation. The energy deviation of the proposed approach is lower than the basic AODV routing protocol. This shows that the network is effectively utilized in the proposed approach.

Fig. 3. Energy Deviation

3) Energy of Network-Critical Node: The node which is only the single node which joins the two partitions called the network critical node. In the basic AODV, after the excessive use of the network critical node the energy of the nodes are exhausted, and the network becomes partitioned.

In proposed approach, if the energy of the network critical node is low then the source chooses another path from the source to destination. So ultimately it increases the lifetime of the network.

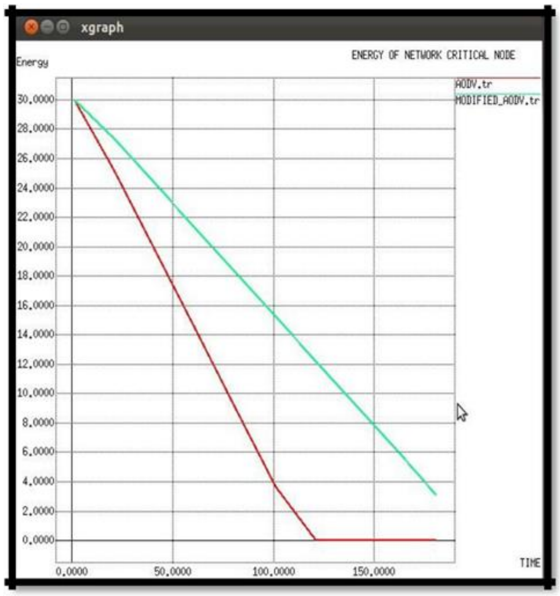

Fig. 4. Energy of network critical node

In basic AODV routing protocol, the lifetime of the network is 114.614741ms. In the proposed approach, the lifetime of the network is increased by 114.614741ms.

4) Packet Delivery Ratio: Ratio between the number of received packets and the total number of packets sent over the network is known as packet delivery ratio. The packet delivery ratio of the new proposed approach is better than the basic AODV routing protocol because the basic AODV protocol chooses the path of shortest hop which passes through the node whose energy is critical. After some time the energy of the node is exhausted and the node shut down itself. This contributes to packet loss and this ultimately affects the packet delivery ratio. On the other side, the proposed approach chooses the high energy path. So, the route failure doesn't happen in the proposed approach. The selection of a path with high residual energy leads to a better packet delivery ratio.

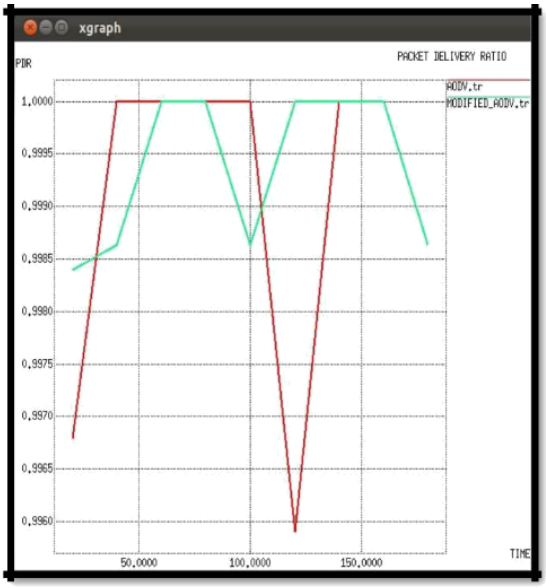

Fig. 5. Packet Delivery Ratio

5) Packet Loss: The packet loss metric defines the number of lost data packets in the network.

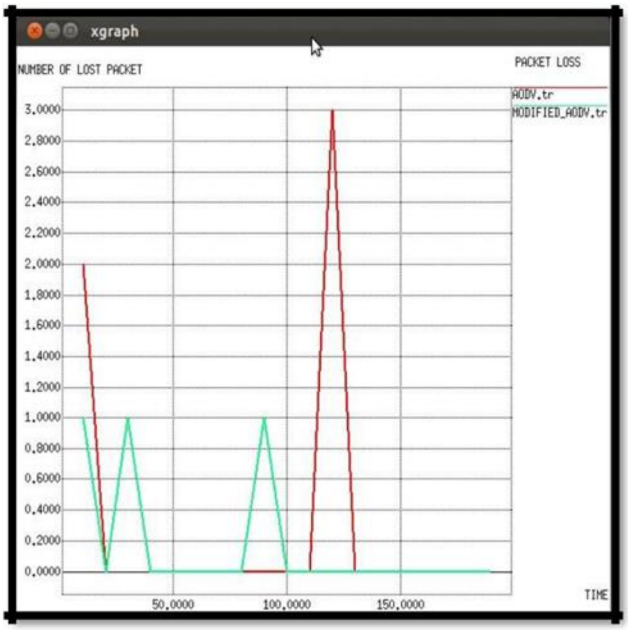

Fig. 6. Packet Loss

VI. CONCLUSION

The proposed approach works on the principle of efficient usage of the available energy resources present on the network. It considers the residual energy of the node during route discovery in the network.

This new approach tends to maximize the overall lifetime of the network. The performance of the new protocol is slightly better than the basic AODV routing protocol. The performance of the proposed approach is same as the basic AODV routing protocol when the amount of energy resources on the communicating nodes is sufficient to take part in the route discovery procedure otherwise it choose the higher energy paths. The number of hop count may be large but this increases the lifetime of the network, packet delivery ratio, throughput of the network.

The performance of the proposed approach is shown in the graphical representation. The graphical representation for the average energy deviation, packet delivery (PDR) and throughput are analyzed in this paper. The proposed approach performs better than the basic AODV routing protocol when the network lifetime is our prime concern and the energy resources are limited.

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