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Efficient Neighbor Routing in Wireless Mesh Networks

V. Lakshmi Praba
Assistant Professor
Govt.Arts College for Women, Sivaganga, India

A. Mercy Rani
Research Scholar
Manonmaniam Sundaranar University, Tirunelveli, India

ABSTRACT

Wireless Mesh Network (WMN) is a rising technology in the wireless field and has the advanced features like self-healing, self-configuring, low deployment cost, easy network maintenance and robustness. The latest research is paying more interest on the efficient route construction of the networks. The efficient route can be constructed by choosing the best neighbor for transmitting the packets. The on-demand protocol AODV selects a route based only on the minimum hop-count, but this is not enough for constructing the best route. For selecting the best route, node's energy is an important constraint. This paper considers maximal net energy neighbor for routing the packets. The AODV protocol is enhanced to construct a route with maximal energy. For the performance evaluation the packet delivery ratio, dropped packets, and energy consumed per packet metrics were analyzed using NS-2 simulator by varying energy ranges. The observed results prove that there is a substantial increase in packet delivery ratio and decrease in dropped packets and energy consumed per packet.

Keywords

Net Energy, Efficient Neighbor, Energy Consumption, Route lifetime.

1. INTRODUCTION

Wireless Mesh Network (WMN) is a communication network made up of radio nodes organized like a mesh topology. Wireless mesh networks often consist of mesh clients, mesh routers and gateways. The mesh clients are often stationery devices, laptops, mobile phones and other wireless devices. The mesh routers forward messages to and from the gateways and it also forwards the packets to distant nodes through another router located within a few hops. Gateway may connect to the Internet by a wired or wireless link. A mesh network is reliable and provides redundancy. When one node fails in the network, the rest of the nodes can communicate with each other, directly or through one or more intermediate nodes [1][2]. WMN possess the advanced features of robustness, wide area coverage, easy network deployment and maintenance, self-healing, self-configuring, low deployment cost and self-organizing. Due to these features WMN is mainly used in Healthcare, Disaster recovery, Home Automation, Historical Monuments and Industries [3].

The on-demand routing protocols such as AODV (Adhoc On-Demand Distance Vector) [4] and DSR (Dynamic Source Routing) [5] are designed for finding the route from the source to the destination nodes using minimum-hop count. It is not assured that all minimum-hop count routes will always lead to quick and successful delivery of packets to the destination. Node failure in the route would generate a route discovery frequently to find another path for transmitting the packets. The on-demand protocols are designed to get routing information only when it is desired. The nodes will maintain only the desired routes. The drawback of this approach is, in intermittent-data applications and population scenarios the route discoveries are increased when a new route is requested [6]. Frequent route discovery attempts lead to high route discovery latency and can affect the network performance.

In some applications there is a necessity to have a stronger route for delivering more packets in shorter time and to increase the route lifetime. These can be achieved if the node participate in the route has a maximum net energy to support the communication. Node's energy is an important constraint for selecting the best node to forward the packets. Since maximum energy node will stay active for a longer time in a route, which improves the network performance by increasing the throughput and route lifetime. In this paper we aim to enhance the AODV protocol for mesh networks to construct the efficient routes based on maximum net energy nodes. The paper is organized as follows: Section 2 deals with the architecture of WMN; section 3 shows related work; section 4 discusses the proposed AODV in WMN. Section 5 describes simulation process and results and section 6 presents the conclusion and future scope.

2. ARCHITECTURE OF WIRELESS MESH NETWORK

The architecture of Wireless Mesh Network consists of Mesh Routers, Mesh clients, and Gateway. Mesh clients are mobile devices such as mobile phones, laptops, PDA etc and mesh routers and gateways are immobile nodes. Immobile mesh routers form the mesh backbone network. Mesh clients access the network through mesh routers as well as directly connecting with each other. The gateway is also a mesh router with a high bandwidth wired connection to the Internet. Figure 1 shows the architecture of Wireless Mesh Network.

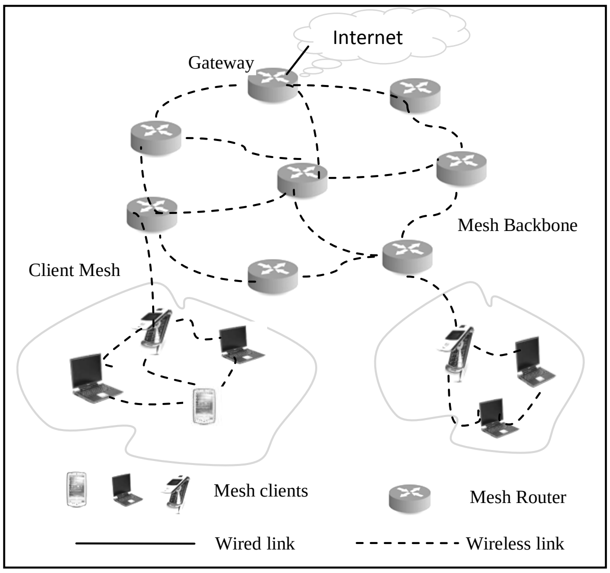

Figure 1. Architecture of Wireless Mesh Network

The mesh backbone connected to Internet through Gateway using a wired connection whereas the other connections such as Mesh Clients to Mesh Routers in the network are wireless connections. The Mesh Routers are connected with each other to share their information. The Internet connection is an optional one. The Mesh Routers and Mesh Clients are connected in a multihop style. Each Mesh Router and Mesh Client is connected to more than one Mesh Routers and Mesh Clients, so that if a mesh client or mesh router in the network fails, it automatically finds a different route for sending the packets to the destination.

3. RELATED WORK

In communication network energy based routing has been studied in multihop wireless networks. Few of the important findings in WMN and Adhoc networks are listed below.

Yumei et al [6] proposed a routing protocol which exploited maximal minimal nodal remaining energy concept. It balanced the nodal energy consumption. This protocol found the minimal nodal remaining energy of each route in the route discovery process, then sorted the multi route by descending nodal net energy and used the route with maximal minimal net energy to forward the data packets. Vazifehdan et al [7] proposed energy-aware routing algorithms for ad hoc networks with both battery-powered and mains-powered nodes. The results showed that it reduces the routing overhead and increases the network lifetime.

Visu et al [8] proposed energy efficient routing protocols using Artificial Bee Colony (ABC) based routing algorithm. The performance of the proposed algorithm was discussed in terms of response time and throughput. Getsy et al [9] proposed a new on-demand protocol E^2AOMDV for saving battery energy in a dense mobile network with high traffic loads. Ajitsingh et al [10] presented a survey on energy efficient routing protocols for wireless Ad Hoc networks. Survey focused on recent development and modifications in this widely used field.

Shivendu et al [11] measured the energy consumption in traffic models using routing protocols namely AODV, OLSR and AOMDV and observed that AOMDV consumed less energy than OLSR and AODV with increasing number of nodes, average speed and send rate. Antonio et al [12] proposed a novel routing algorithm for 802.11 based wireless mesh networks called Energy and Throughput-aware Routing (ETR). The design objectives of ETR were to provide flows with throughput guarantees, and to minimize the overall energy consumption in the mesh network.

Annapurna et al [13] proposed the design of a protocol that is a combination of two energy cost metrics in a single protocol and evaluated the performance of the proposed protocol against the two protocols chosen for combination and against the traditional AODV. The various performance metrics were analyzed in the proposed protocol.

All the above works proposed several routing protocols to construct a route with minimum energy. This paper proposes an enhanced version of AODV by selecting the efficient neighbor with the maximum net energy for routing the packets since the maximum energy based node will stay active for a longer time in the route.

4. PROPOSED AODV IN WMN

In WMN, the route and link failures occurred when the nodes in the path have lesser power or energy. This leads to frequent route discovery. This can be avoided by selecting the maximum net energy node for transmitting the packets to the destination. This increases the performance of the network obviously. On considering this feature the proposed protocol has been designed in WMN for selecting the efficient neighbor with maximum net energy. The proposed protocol is compared with AODV by taking the energy ranges as 0-25, 25-50, 50-75, 75-100 and 100-125 in joules.

4.1 Efficient Neighbor Selection

Selection of maximum energy neighbor for transmitting the packets from source to destination is the key approach used in this paper. The proposed protocol is an extension of AODV. In this proposed protocol each node in the network transfers the HELLO messages with their net energy value. Initially each node in the network has been assigned with the maximum energy of energy range. Adjacent node’s energy values are stored in the

neighbors table of the communicating nodes with its neighbor-id and net energy value. The energy threshold is the energy range's minimum energy. The nodes are allowed to participate in the route selection process when their net energy value is above the energy-threshold.
The control packets RREQ and RREP of AODV protocol are used for setting up the communication with the nearby nodes. In the proposed protocol the RREQ packet is made stronger with two additional fields RREQ_ENERGY and FRWD_NBR and the RREP packet with one additional field RREP_ENERGY.

RREQ_ENERGY field has been assigned the ENERGY_THRESHOLD value. The node which has the energy below the ENERGY_THRESHOLD discards the packets. FW_NBR field will store the neighbor's node-id that possesses the maximal net energy value among the neighbors. RREP_ENERGY field in RREP packet has been assigned with their net energy at the time of reply.

The MaxNBR() procedure integrated in the existing protocol AODV determines the nodes with the maximal net energy among the neighbors of the current node. The proposed protocol maintains the list of neighbors of each node. The MaxNBR() procedure retrieves the neighbor-id which possess the maximal net energy by giving the node-id as a parameter. The returned neighbor-id is stored in FW_NBR field of RREQ packet. The source sends the RREQ packet to all its neighbors. The neighbors receive the RREQ packet and checks whether their energy is above or below the RREQ_ENERGY to accept or reject that route are explained in the algorithm.

4.2 Algorithm

Step 1: Initialize ENERGY_THRESHOLD as the energy range's minimum energy.
Step 2: The source node does the following before sending the RREQ packet.
- i) Set RREQ_ENERGY field of RREQ packet as ENERGY_THRESHOLD.
- ii) Source node calls the MaxNBR() procedure to do the following:
  - a) Find the neighbor which has maximum net energy.
  - b) Assign its node-id to FW_NBR field of RREQ packet.

Step 3: The node that receives the RREQ packet does the following:
- i) Calculate the net energy of a node using the energy model.
- ii) Check if CurNode's net energy is less than the RREQ_ENERGY and CurNode is not a destination then drop the packet. goto step 4.
- iii) Check if it is the destination then goto step5.
- iv) Otherwise check if FW_NBR field of RREQ, matches with CurNode.id and if CurNode.id is a destination then goto step 5.
  - a) Otherwise forwards the RREQ packet.

Step 4: Step 3 is repeated for each neighbor until a destination is found.
Step 5: Send RREP packet to select the route for transmitting the data packets.

When the destination is reached the net energy of a current node is assigned to RREP_ENERGY field of RREP packet. The further process is similar to AODV. The route is made available by unicasting a RREP back to the origination of the RREQ. Each node receiving the request caches a route back to the originator of the request, so that the RREP can be unicast from the destination along a path to that originator, or likewise from any intermediate node that is able to satisfy the request. Finally, the proposed protocol selects a route with maximal net energy for transmitting the packets from the source to the destination.

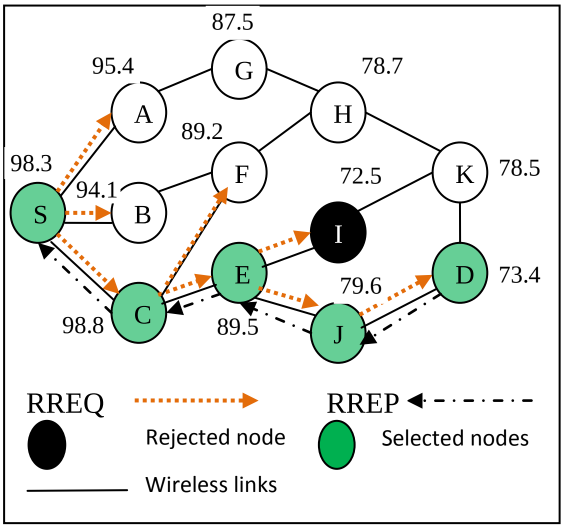

Figure 2. Efficient neighbor selection process

Figure 2 shows the efficient neighbor selection process with the proposed protocol by considering the energy range as 75-100. Each node in the network shows its net energy value and RREQ_ENERGY has been assigned an ENERGY_THRESHOLD as 75. Initially, the neighbors A, B and C of Source S receive the RREQ packet. The neighbor which has maximum net energy is chosen for forwarding the packets. In this example, neighbor C is selected. Next, C forwards the RREQ packet to its neighbors E and F from which E is selected. E forwards RREQ packet to its neighbors I and J, I is rejected since its net energy is less than the ENERGY_THRESHOLD and not even considered for MaxNBR() procedure. J is selected for forwarding the packets. Now J forwards the packet to its neighbor D. Even though the net energy of D is less than the ENERGY_THRESHOLD it is considered in the selection process since it is the destination node. After reaching the destination, it sends the RREP packet to the source through the selected nodes. Throughout the process, the route with maximum net energy nodes (S->C->E->J->D) are selected for transmitting the data packets to the destination. Table 1 shows the summary of the above process.

Table 1. Efficient neighbor selection process summary

Source/ Intermediate node on the route	Neighbors Receive RREQ	Rejected : net energy < energy threshold	Selected for forwarding due to maximum net energy
S	A, B and C	-	C
C	E, F and G	-	E
G	I and J	I	J
J	D	-	D

5. SIMULATION PROCESS & RESULTS

The Simulations are performed using Network Simulator 2 (NS-2) [14]. For the performance evaluation of the proposed protocol in WMN, a network with 5 Mesh Clients, 8 Mesh Routers and one Gateway has been created. The simulation layout is shown in Figure 3. The gateway, mesh clients and mesh routers are placed in an area of 800 x 800 meters. Mesh routers are placed fixedly so that it assists the mesh clients in establishing reliable connections to the gateway and also to other mesh routers and mesh clients. CBR connections are created to establish connection between gateway, mesh routers and mesh clients.

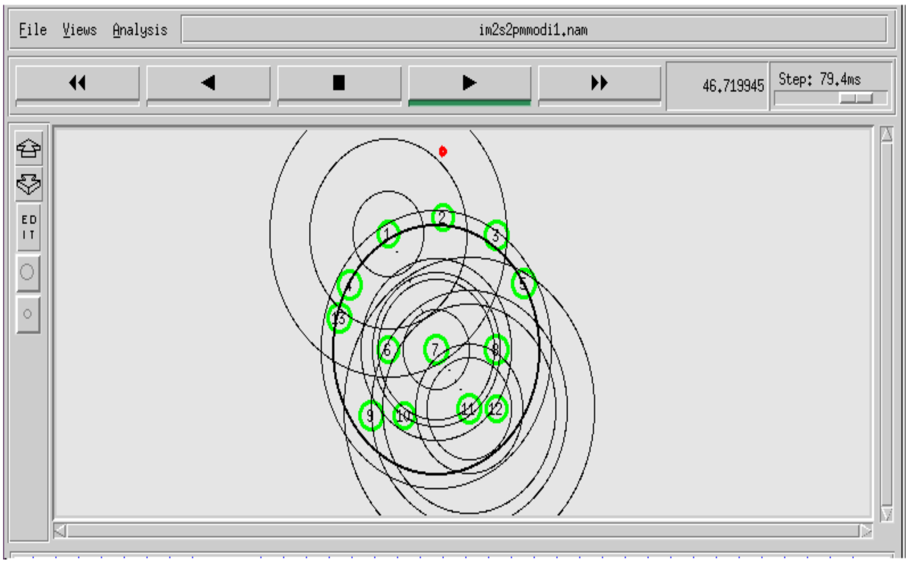

Figure 3. Simulation layout

The simulation layout as shown in Figure 3 serves as the basis for evaluating the performance of the proposed protocol. The Table 2 shows the simulation parameters used for evaluating the performance.

Table 2. Simulation parameters

Parameter	**Value**
Simulation	NS-2
Simulation area	800 x800m
Simulation time	200 s
Transmission range	200 m
Packet Size	512 bytes
Transmission rate	1Mb
No. of Mesh Clients	5
No. of Mesh Routers	8
No. of Gateway	1
Routing Protocol	AODV
Packets	CBR
Energy Ranges	0-25, 25-50, 50-75, 75-100, 100-125 joules
Initial Energy	25,50,75,100, 125
Energy Threshold	0,25,50,75,100
rxPower	35.28e-3 W
txPower	31.32e-3 W
idlePower	712e-6 W
sleepPower	144e-9 W
transitionTime	0.003 s

5.1 Performance Metrics

5.1.1 Packet Delivery Ratio

The ratio between the numbers of packets successfully received at the destinations and the total number of packets sent by the sources.

5.1.2 Dropped Packets

No. of packets dropped during transmission.

5.1.3 Energy Consumed/packet

The total energy consumption is divided by the total number of packets received at the destination. This metric reveals the energy efficiency of the proposed protocol.

This paper considers the packet delivery ratio, dropped packets and energy consumed per packet as performance metrics which were analyzed by varying the energy ranges.

5.2 Simulation Results

The performance analysis was conducted in the simulation layout to evaluate the performance of AODV protocol in WMN by varying energy ranges. The simulation results are shown in the form of graphs. The proposed protocol is compared with AODV by taking the energy ranges as 0-25, 25-50, 50-75, 75-100 and 100-125 in joules. Figure 4 to 6 show the graph for the considered metrics.

Figure 4 shows the performance of the proposed protocol and AODV on the basis of considered performance metrics by varying energy ranges. For each energy range its respective lowest energy is set as the energy threshold.

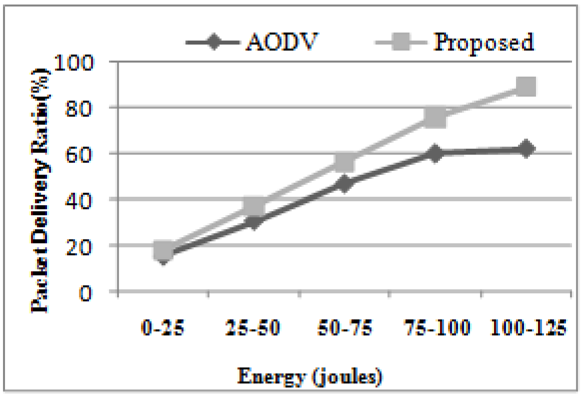

Figure 4. Packet delivery ratio Vs Energy

From Figure 4, it is observed that the PDR value of proposed protocol is better when compared to the existing AODV for various energy ranges.

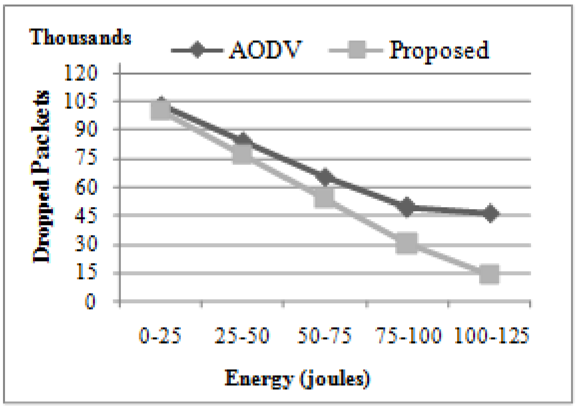

Figure 5. Dropped packets Vs Energy

From Figure 5, it is observed that the dropped packets have decreased significantly when compared to the existing AODV.

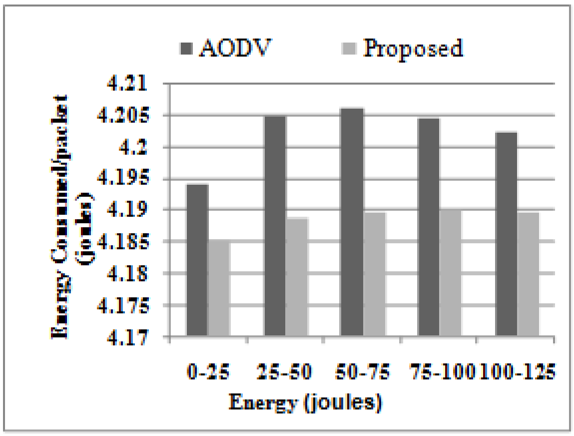

Figure 6. Energy consumed per packet Vs Energy

From Figure 6, it is observed that the proposed protocol consumed less energy for transmitting a packet in all energy ranges when compared with the existing AODV.

5. CONCLUSION

In this paper an effective routing protocol is proposed to improve the performance of the wireless mesh network. This proposed protocol selects the efficient neighbor for the route construction. Due to this efficient neighbor selection the route lifetime is increased and more number of packets is transmitted when compared to the existing AODV which increases the PDR value and decreases the dropped packets. Even though this proposed protocol uses the maximum energy neighbor for routing, the energy consumed per packet is reduced when compared with exiting AODV. Future work will be focused on finding the optimal route for transmitting the packets by considering various other metrics.

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