Energy Based Shortest Routing in Multi-Channel Multi-Interface Wireless Mesh Network

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***Abstract*— With the rising features of Wireless Mesh Networks (WMN) the research is focused on increasing the capacity and throughput of the network. One way to increase the capacity of the network is by the use of multiple channels and multiple interfaces. Furthermore, the performance of the network can be increased by selecting efficient route for transmitting packets from source to destination. The efficient route selection is a major challenge in multi-channel multi-interface WMN. The existing AODV protocol selects a route for transmitting packets from source to destination based on the minimum-hop count. This route may weak due to less energy and causes route request repeatedly. Hence, in this paper, the existing AODV protocol is enhanced for the selection of maximum energy with minimum hop count route. This route selection not only increases the route lifetime but also increases the network capacity, throughput and packet delivery ratio. For the performance evaluation throughput, packet delivery ratio and number of dropped packets was analyzed using NS-2 simulator under two different scenarios, one by varying energy ranges and the other by varying channel capacity.**

***Keywords*— Network Capacity, Maximum energy, Multi-Channel, Multi-Interface**

I. INTRODCUTION

In recent years, Wireless Mesh Network(WMN)[1] is a promising technology in which the end users are provided with high speed Broadband Internet access without any interference. WMN has the features of self-organizing, self-healing and Self-configuring. These differ WMN from traditional networks and leads to offer wide area coverage, low deployment cost, installation of networks in historical monuments and easy network maintenance etc.Due to these abilities features, the WMN attracts Internet Service Providers(ISP) and end users for establishing reliable and robust internet services at the lowest cost[2]. The applications of WMN is wider in the range of Home Automation to Disaster recovery[3].

Wireless Mesh Network consists of three components such as mesh clients, mesh routers and gateways. The mesh routers and gateways are static nodes whereas the mesh clients are mobile or stationary nodes. The mesh routers form a mesh backbone infrastructure while the mesh cleints forwards the traffic between the clients through mesh routers. The gateways connect the network to the Internet[1].

Usually the on-demand routing protocols such as AODV (Adhoc On-Demand Distance Vector) [4] and DSR (Dynamic Source Routing) [5] are designed to find 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 successful delivery of packets to the destination. The route may need to rediscover frequently due to loss of energy in the route. The on-demand protocols are designed to obtain routing information only when it is needed. The nodes will maintain only the needed routes. The difficulty may arise of this approach is that there is considerable route discovery latency when a new route is requested each time in intermittent-data applications. This degrades the network performance unfavorably.

To overcome these issues, the constraint node's energy is considered for constructing the route besides of hop count. Node's energy plays a vital role in route construction to create a stronger route in the network. The maximum energy with minimum hop count route is selected for transmission so that, it will stay alive for a longer time and it improves the network performance and throughput considerably. In this paper, the AODV protocol is enhanced in multi-channel multi-interface mesh networks to select an efficient route based on maximum remaining energy and minimum hop count.

The paper is organized as follows: Section 2 deals with related work, section 3 describes multi-channel multi-interface and section 4 discusses energy based route in multi-channel multi-interface WMN. Section 5 depicts simulation process and results. In section 6 the conclusion and future scope is presented.

II. RELATED WORK

In communication system energy based routing has been studied in multi hop wireless networks. Some of the important routing protocols proposed that do not consider the features of multi-channel and multi-interface and some of the findings only consider the energy as a constraint.

Campista et al[6] analyzed the recent metrics and various routing protocols in Wireless Mesh Network. The performance results of different metrics are obtained in WMN testbed. The routing protocols are analyzed based on their algorithms. Parissidis et al[7] studied the various routing metrics in wireless mesh networks. The considered metrics have the different optimization objectives and it uses different methods for collecting the required information and different ways to find the route between source and destination. Further, the metrics used for the survey are related with one another and it described the strengths and weaknesses of all metrics. Antonio et al [8] 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. The proposed research approach is thoroughly evaluated and has proved to outperform previous approaches very substantially both in terms of throughput and energy consumption. Kokkinos et al[9] proposed an energy-efficient multi-cost routing algorithms for wireless mesh networks. Each network link is assigned with a vector of cost parameters. The network chooses an optimal path by combining the parameters using various optimization functions. The proposed algorithm is evaluated under the network evacuation model and dynamic on-to-one communication model. The proposed work increases the lifetime of the network and achieves the overall network performance. Entezami et al[10] studied the different types of link metrics in wireless mesh networks. The link-quality and traffic-aware metrics in multi-channel and cognitive radio networks have been analyzed.

III. Multi-Channel Multi-Interface Approach

Usually, in traditional routing protocols each node is equipped with one interface. The capacity and throughput of the WMN can be increased by using the multiple interfaces [11][12]. The routers in the mesh network provided with multiple interfaces increase the throughput considerably. In infrastructure-based wireless networks, multiple channels are incorporated by assigning different channels to adjacent mesh routers to minimize interference. The increase in throughput demand can be achieved through this multi-channel and multi-interface approach. When more than one channel is assigned to the adjacent mesh routers having multiple interfaces then parallel communications are possible on various channels. In a scenario where several channels are opened and each node uses two interfaces then, one channel is used for transmitting data while the other receives data. Under the circumstance the throughput achieved is nearly doubled when compared with single-interface approach. In this paper the multi-interface approach presented by Ramon [13] is implemented.

IV. Proposed Work

In WMN, even though the mesh routers are static, the mesh clients which are dynamic leads to link failure and route break frequently. In [14], this issue is overcome by selecting the maximum energy neighbor for the transmission. However, the combined features of energy as well as the hop count make the route healthy and shortest. Thus the proposed work of this paper is concentrated on choosing the route by considering maximum remaining energy and minimum hop count for transmitting the packets to the destination. This obviously increase the performance of the network. In view of this facet the existing AODV protocol has been enhanced to discover the maximum energy with minimum hop count route in Multi-Channel Multi-Interface WMN.

A. *Enhancing AODV Protocol*

The RREQ packet of AODV protocol is modified with the additional field Node_Energy for maintaining remaining energy. The RREP packet is modified with one more field REP_Energy for carrying the energy at the time of reply and at the time of sending hello messages.

In the proposed work, the node's current energy is identified by sending the HELLO messages. Initially each node in the network has been given with an initial energy of 100 joules. Nearby nodes energy values are stored in the neighbors table of the communicating nodes with neighbor-id and its remaining energy value. The energy-threshold has been assigned as 20% of its initial energy.

The node's remaining energy is calculated frequently using the energy model of ns-2 to maintain the energy of a node at the particular time. When a route is required by a source node to the destination, it checks its routing table. If the route is not available in the table, then the source node sends the RREQ packet to all interfaces of its neighbouring nodes. The neighbours who share at least one common channel with the sender node receive the packet.

1) *Route Entry Process*

The nodes check its remaining energy in Node_Energy. If it is below the energy-threshold, then the node discards the RREQ packet. Otherwise, the value of Node_Energy is added with REP_Energy field of RREP packet. Only the neighbors who have energy above the energy-threshold is included in the route entry process. However, the destination is included irrespective of its remaining energy. The destination is included in the route entry list even if it has energy value less than energy threshold.

2) *MaxEnergy MinHop Route Selection*

When the destination is reached, the destination sends the RREP packet with its REP_Energy and hop count. The source chooses the route with the maximum RREP_Energy and minimum hop count. The sequence number of route in the routing table and RREP packet is compared, if both are equal, then checks the hop count, if the hop count in RREP is less than the hop count in the routing table then it updates the routing table with the new route in RREP packet.

V. Simulation Analysis

The simulations are carried out with the help of Network Simulator-2 (NS-2) [15] tool. For the performance evaluation of the proposed protocol in WMN, a network with 6 Mesh Clients, 8 Mesh Routers and one Gateway has been created. Each mesh router is equipped with two interfaces. The simulation layout is shown in Fig. 2. The gateway, mesh clients and mesh routers are positioned in an area of 500 x 500 meters. The mesh routers are sited fixedly so that it assists the mesh clients in forming reliable connections to the gateway and between other mesh routers and clients. Three CBR connections are created to establish the connections between the nodes in the network.

The simulation layout as shown in Fig 1 serves as the basis for evaluating the performance of the proposed work. The

Table 1 shows the simulation parameters used for evaluating the performance.

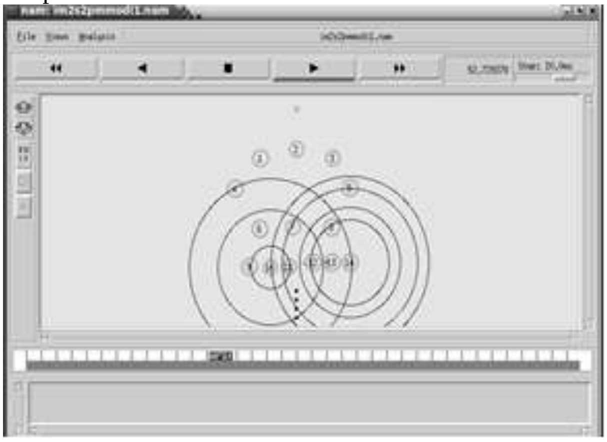

Fig.1 Simulation Layout

TABLE 1

SIMULATION PARAMETERS

Parameter		Value
Simulation		NS-2
Simulation area		500 x 500m
Mac Protocol		IEEE 802.11
Simulation time		200 s
Transmission range		200 m
Channel Capacity		3, 4, 5, 6 7, 8, 9, 10
Packet Size		512 bytes
Transmission rate		1Mb
Traffic Type		CBR(UDP)
No. of Mesh Clients		6
No. of Mesh Routers		8
No. of Gateway		1
Routing Protocol		AODV
Packets		CBR
Interfaces		2
Channels		3
RxPower		35.28e-3 W
TxPower		31.32e-3 W
IdlePower		712e-6 W
sleepPower		144e-9 W
Scenario 1	Energy_threshold	0, 25, 50 ,75 joules
	Initial Energy	25,50,75,100 joules
	Channel Capacity	8 Mb
Scenario 2	Initial Energy	100 joules
	Energy_threshold	20% of Initial Energy
	Channel's Capacity	3, 4, 5, 6 7, 8, 9, 10 Mb

A. Performance Metrics

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.

PDR = received packets/sent packets * 100

2) *Throughput (Kbps):* It is a measure of the amount of data successfully transmitted in a unit period of time (second). i.e. average number of bits delivered per second.

Throughput = No. of bits successfully delivered/1000

3) Dropped Packets: No. of packets dropped during transmission.

Dropped packets = sent packets - received packets

B. Simulation Results

For the analysis of the proposed work, the simulation uses the packet delivery ratio, dropped packets and throughput as the performance metrics by varying the energy ranges and channel capacity under two different scenarios.

In Scenario 1, the performance metrics are analyzed by various energy ranges. The proposed protocol is compared with AODV protocol by taking the energy ranges as 0-25, 25-50, 50-75 and 75-100 in joules with channel capacity as 8 Mbps. Fig. 3.1a to 3.1c shows the graph for the considered metrics in scenario 1.

In Scenario 2, the performance metrics are analyzed under different channel capacity. The proposed work is compared with AODV by varying the channel capacity from 3 Mbps to 11 Mbps with energy threshold as 20% of its initial energy. Initial energy is taken as 100 joules. Fig. 3.2a to 3.2c shows the graph for the considered metrics in scenario 2.

1) Scenario 1:

Fig.3.1 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 own lowest energy is set as the energy threshold.

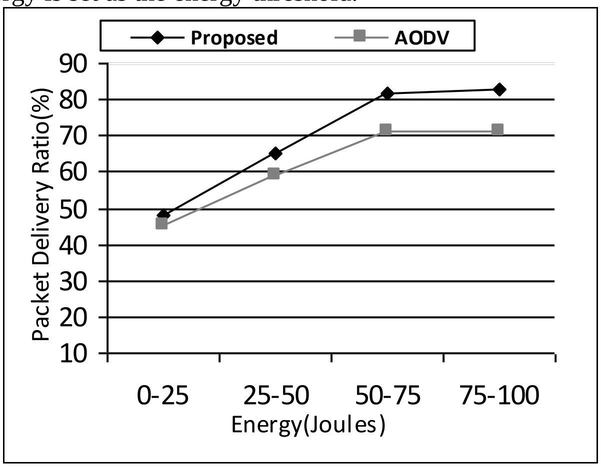

Fig. 3.1a Packet Delivery Ratio Vs Energy

From Fig.3.1a, it is observed that in proposed work there is a minimum increase in PDR of 5.77% when compared with AODV in the range of 0-25 joules and a maximum increase in PDR of 14.20% in the energy range of 75-100 joules.

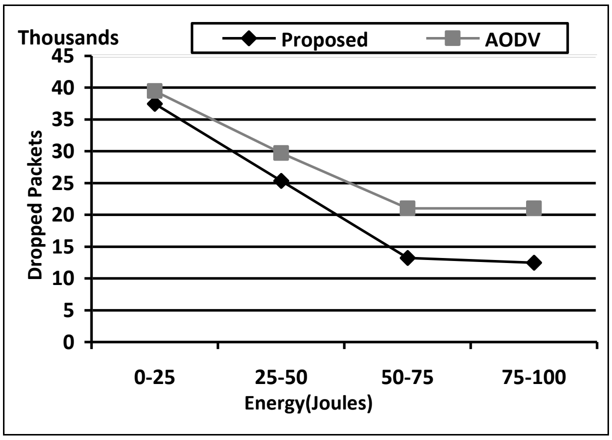

Fig. 3.1b Dropped Packets Vs Energy

From Fig.3.1b, it is clear that in proposed work there is a minimum decrease in dropped packets of 5.40% when compared with AODV in the range of 0-25 joules and a maximum decrease in dropped packets of 40.57% in the energy range of 75-100 joules.

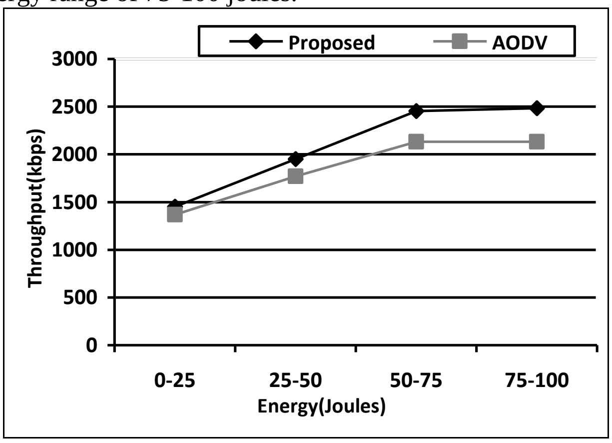

Fig. 3.1c Throughput Vs Energy

Fig.3.1 Scenario 1

From Fig.3.1c, it is observed that in proposed work there is a minimum increase in throughput of 5.77% when compared with AODV in the range of 0-25 joules and a maximum increase in throughput of 14.20% in the energy range of 75-100 joules.

2) Scenario 2:

Fig.3.2 shows the performance of the proposed work and AODV on the basis of considered performance metrics by varying channel capacity with energy threshold as 20 joules.

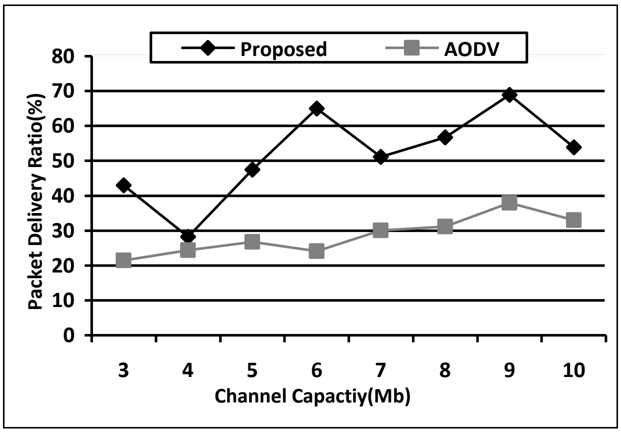

Fig. 3.2a Packet Delivery Ratio Vs Channel Capacity

From the obtained results it is observed that in proposed work there is a minimum increase in PDR of 13.37% when compared with AODV with the channel capacity of 4 Mb and a maximum increase in PDR of 62.82% in channel capacity of 6 Mb which is shown in Fig.3.2a.

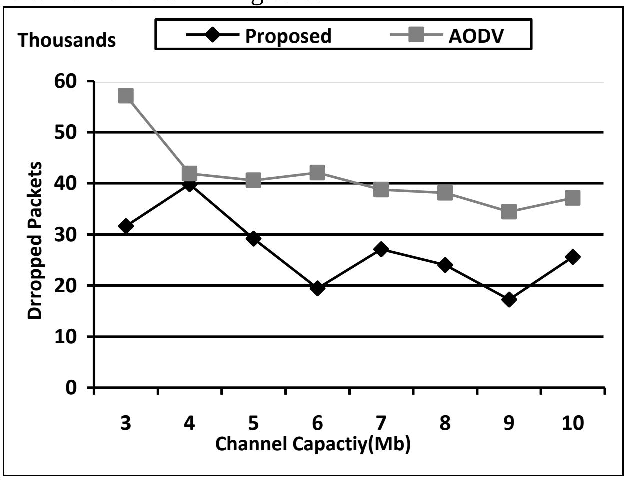

Fig.3.2b Dropped Packets Vs Channel Capacity

From the obtained results it is clear that in proposed work there is a minimum decrease in dropped packets of 5.01% when compared with AODV with the channel capacity of 4 Mb and a maximum decrease in dropped packets of 53.75% in channel capacity of 6 Mb which is shown in Fig.3.2b.

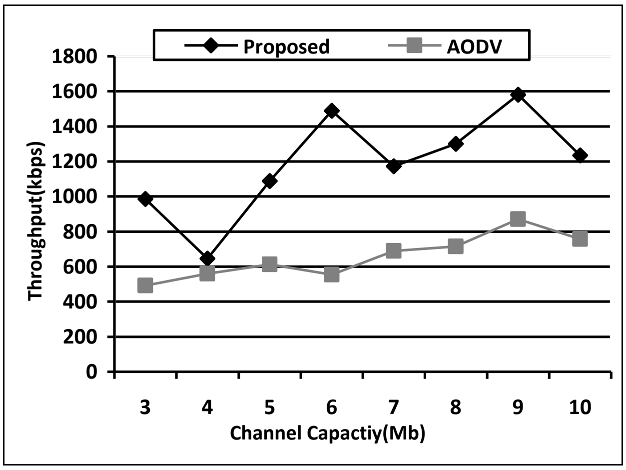

Fig.3.2c Throughput Vs Channel Capacity

Fig.3.2 Scenario 2

From the obtained results it is observed that in proposed work there is a minimum increase in throughput of 15.43% when compared with AODV for the channel capacity of 4 MB and a maximum increase in throughput of 62.80% in channel capacity of 6 MB which is shown in Fig.3.2c.

VI. Conclusion

In this paper an effective energy and hop count based routing is proposed in multi-channel multi-interface wireless mesh networks to improve the system throughput and network capacity. This proposed work selects the route based on the maximum remaining energy and minimum hop count for transmitting the packets from source to destination. This route selection increases the route lifetime so that it reduces the route discovery latency and also increases the network capacity, throughput, packet delivery ratio in multi-channel multi-interface WMN. The future work can be focused on finding the optimum route for transmitting packets by considering the other factors such as link quality, queue size, bandwidth etc.

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