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ENERGY-AWARE FOR DH-AODV ROUTING PROTOCOL IN WIRELESS MESH NETWORK

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ABSTRACT

Wireless Mesh Networks (WMNs) can be the key technology for the future of wireless networks. However, WMNs implementation still has many issues to be resolved especially on finding the best path to forward information. According to many researches, one of the most important component in WMNs is the routing protocol and how to make it efficient in performing the requirements of WMNs. Directional Hierarchical Ad-hoc On-demand Distance Vector (DH-AODV) routing protocol, proposed to enhances Ad-hoc On-demand Distance Vector (AODV) routing protocol for WMNs. DH-AODV is performing well for WMN, but in this routing protocol no mechanism is considered to deal with the energy consumption of the nodes in the network. Therefore, in this paper we propose an Energy-aware DH-AODV (E-DH-AODV) routing protocol to select a path toward a gateway based on the energy balance. Furthermore, E-DH-AODV can reduce the number of broadcasting route request (RREQ) packets, by sending these packets toward the gateway considering the nodes with less hop-count only. The simulation results shows that E-DH-AODV can reduce the energy variance consumption by 10%, increase the packet delivery ratio (PDR) by 9%, and reduce the overhead by 5% in comparison with DH-AODV.

Keywords: WMN, E-DH-AODV, MATLAB simulator, energy consumption, PDR, overhead.

1. INTRODUCTION

Wireless Mesh Networks (WMNs) has become an attractive topology nowadays; due to its architecture efficiency that can reduces the cost and improves the communication of the nodes in the network. WMNs is still ongoing Researches area as considering this network topology will fit with the future technology requirements [1]. This topology consists of mesh clients and mesh routers. The mesh routers are static nodes that represent the backbone of the network between the internet and the clients [2], as shown in Figure-1.

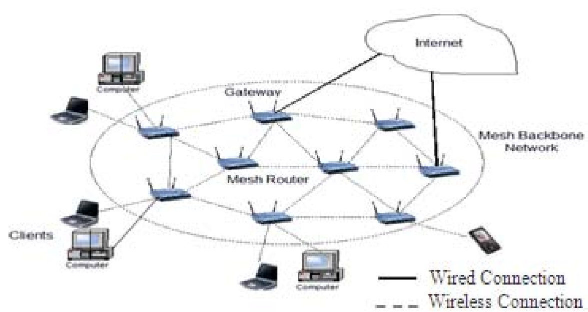

Figure-1. Wireless Mesh Network (WMN) architecture.

WMN has several specifications due to its behavior. Firstly, it can delivers much better services for the end user devices in the network by using the mesh routers, which provides multi-hop communications between the clients and the internet. Secondly, it can deals with the existing networks such as Wi-MAX and Wi-Fi, because of its bridge functionality/gateway in its topology. Lastly, it is an access architecture not stand alone like traditional ad-hoc network, and at the gateway of WMN most of the traffic terminate and originate [3]. Therefore, by using WMNs we can obtain an efficient network performance.

In WMNs one of the most important components is the routing protocol, which can determine the best path for the packets in the network toward the gateway. The main challenges that can face researchers is on how to provide an effective routing protocol that can significantly improves the performance metrics of WMNs. Based on that many researches have been proposed to improve ad-hoc routing protocols for WMNs. Such as DH-AODV [4], AOMDV-LR [5], RM-AODV [6], AODV-MR [7], D-AODV [8].

DH-AODV routing protocol proposed to improve the basic AODV routing protocol for WMN. DH-AODV has achieved high performance in case of throughput, packet loss and end-to-end delay comparing with AODV. This routing protocol is performing well in WMN, but it lack a mechanism to deal with the energy consumption of the nodes in the network. Furthermore, DH-AODV is flooding the network by broadcasting route request (RREQ) packets to each neighbor node that can also effect on the energy consumption of the nodes and increase the traffic load. In WMNs frequent link failure is probable when the network is deployed in such areas that lack a power supply, which require nodes to be battery-powered [9]. So that any power failure in the network can effect on the network transmission. Therefore, it is very important to consider a mechanism that can deal with the energy consumption of the nodes in the network in order to avoid transmission failure [10].

The purpose of this study was to propose an efficient routing protocol that can fully meet the requirements of WMNs, especially for such networks that have battery-powered nodes. In this paper we propose

Energy-aware Directional Hierarchical Ad-hoc on-demand Distance Vector (E-Dh-AODV) routing protocol. This routing protocol uses the hop-count in order to send the RREQ packets to the neighbor nodes with less hop-count toward the gateway and ignore the rest. Furthermore, E-DH-AODV has considered the battery power level of each node in the path of route discovery, in order select the nodes with highest battery power and avoid the nodes with low power to prevent transmission failure. E-DH-AODV has significantly reduced the load on the network based route discovery within WMNs. The comparison between DH-AODV and E-DH-AODV routing protocols has been done using MATLAB simulator to measure the performance.

This paper is organized as follow: Section II represents the related researches proposed for WMNs. In section III, the proposed E-DH-AODV has been described. The results have been mentioned in section IV. Finally, this research is concluded in section V.

2. RELATED WORKS

AODV is a reactive routing protocol that a node requests for a route entry only when it wants to sends data packet. Each node in this protocol has a routing table with one route entry to the destination. The route discovery in this protocol is based on Route Request (RREQ) and Route Reply (RREP) packets [11].

When the source node wants a route to the destination, first it generates a RREQ and broadcasts it to all its neighbors. Ones the neighbor receives the RREQ; it rebroadcasts the packet to its neighbors if it is not the destination or it has an expired route entry to the destination. The destination node receives the RREQ and it unicasts a RREP packet to the neighbor who first delivered the RREQ. The RREP packet is routed back toward the source node considering the reverse path through the intermediate nodes. These nodes set one forward route entry in their routing table base on the RREP packet received. The HELLO message used in ADOV protocol to maintain the connection between nodes and to make each node in the network indicates the presence of its neighbors [12].

Since most of the traffic flow in Wireless Mesh Networks (WMNs) are either form/to the gateway only, and AODV is flooding the network with many control packets. Thereby, several researches has been proposed to improve AODV for WMNs in order to reduce the number of control packets and improve its performance. In [8], proposed Directional AODV (D-AODV) which is based on hop-count to a gateway. The hop-count used to reduce the number of RREQ packets in the route discovery. This hop-count to a gateway is assigned to each node in WMN based on the HELLO message broadcasted by the gateway. When a node receives the HELLO message from the gateway it assigns its hop-count based on the received HELLO message hop-count. Then it increases the hop-count number of the HELLO message with 1 and rebroadcasts it to its neighbors. Therefore, each node in the network will knows how far its form the gateway in WMN using the hop-count. To discover the route toward the gateway, first the node has to generate a RREQ packet that has the hop-count value same as its hop-count value, then it broadcasts the RREQ to each neighbor. Ones the neighbor receives the RREQ packet it checks the RREQ hop-count number and compares it with its own hop-count number. If the hop-count of the RREQ packet is equal or less than the node hop-count, it discards the packet. Otherwise the node accepts the RREQ packet and assigns its hop count number to the RREQ pack and rebroadcast the packet. The RREQ packet reaches the gateway and it unicast a RREP pack to the source node using the same process of AODV.

In [4], they found that D-AODV routing protocol is focusing on how to deliver the packet at the shortest path in WMN, but this shortest path may not be the perfect since they are not considering the quality of this path. Therefore, they proposed an enhancement on the protocol called hierarchical directional AODV (DH-AODV) routing protocol. DH-AODV is the same as D-AODV in case of HELLO message for hop-count discovery and RREQ packet for route discovery. But the enhancement in this routing protocol has been done based on the RREP packet. After the gateway receives the RREQ it generates a RREP and unicast this packet to the reverse path of RREQ with consideration to the latest sequence number received. Therefore, a node receives the RREP it checks the neighbor nodes in the reverse path of RREQ, and resends the RREP to the neighbor node with highest sequence number that represent the freshest path. DH-AODV has improved the throughput and packet loss compared with D-AODV.

In [13], proposed an enhancement for WMNs that installed with power saver mode (PSM). PSM works to changes the status of node form idle to active whenever the node receives or sends packets. This node has to stay in active mode until it transmits all the packets in its buffer. But the node in this network keep sends and receives packets whenever required, and it is unawares about its battery power level which can reduce the packet delivery ratio and increase the packet loss if power failure occur during the transmission. Therefore, they have proposed an Energy Aware PSM (EAPSM) mechanism to calculate the remaining battery power level of the node and compare it with the minimum battery power threshold required. If the node battery power level is more than the minimum battery power threshold required, the node has to be participated in the network transmission to send and receive packets. Otherwise the node changes its status to deep idle that will not sends and receives any packets in order to avoid transmission failure and improve the quality of service in WMNs.

In [5], they found that Ad-hoc On-demand Multipath Distance Vector (AOMDV) routing protocol [14] lacks a mechanism to deal with link failure in WMNs. Where link failure is frequent in this network which can reduce the reliability of the network. Therefore, they have proposed an enhancement for AOMDV called AOMDV Local Repair (AOMDV-LR) routing protocol for WMNs. In AOMDV-LR each node send the RREQ packet will wait for certain amount of time to receive the RREP packet. If the time counter is expired and no RREP received, the node will assumes that route failure is occurred in the network. Therefore, the node will searches for alternate path within its routing table list, if an alternate path is available the source node will forwards the packet to the alternate node. Otherwise, the node will searches for another paths out of its hop-count routing table toward the gateway. If the source node finds another node within its communication rang, it forwards the packet to that node. Otherwise, the source node unicasts the Route Error to the original source node.

3. E-DH-AODV: ENERGY-AWARE DH-AODV

In this section we present E-DH-AODV routing protocol. E-DH-AODV is basically based on the classical DH-AODV routing protocol in case of HELLO message to inform each node in the network about the gateway presence using the hop-count. In this section the operation of E-DH-AODV has been mentioned and focused on the hop-count discovery and the route discovery.

The main drawback of DH-AODV that there is no consideration for the energy consumption for such networks with battery-powered nodes as mentioned in the previous section. Firstly, the node in DH-AODV broadcasts the RREQ packet to each neighbor, and those neighbors will compare the hop-count of RREQ with their own hop-count. If the hop-count of the RREQ is greater than the neighbor node hop-count, neighbor node will considers that has shorter path than the source node toward the gateway, and will rebroadcast the RREQ packet. Otherwise, the neighbor node discards the RREQ packet considering longer path toward the gateway. The process of broadcasting the RREQ packet to each neighbor is increasing the traffic load and wasting the battery power of the nodes. Secondly, in DH-AODV there is no consideration for battery power level of the nodes. DH-AODV has only focused on the hop-count and the sequence number in the route discovery, so that when it considers a path with very low battery power nodes, a risk of route failure might happen due to the power failure.

In E-DH-AODV each node in the network knows how far it is form the gateway using the hop-count number. The hop-count number is assigned to each node by using the HELLO message that is broadcasted by the gateway. Furthermore, E-DH-AODV has reduced the traffic load in the route discovery by giving each node a routing table of neighbor's hop-count information, in order to enable the node to sends the RREQ packet only to the neighbors with less hop-count toward the gateway. Secondly, E-DH-AODV considers the battery power level of the nodes in the path of route discovery. The consideration for the battery power level was done based on unicasting the route reply (RREP) packet toward the source node using the intermediate nodes with highest battery power. So that can save the nodes with low battery power and avoid transmission failure.

3.1 HELLO Message

In DH-AODV the HELLO message is used to indicate the presence of the gateway. As for the initial phase of the network, the gateway broadcasts the HELLO message with hop-count variable that assigned to each node in the network. This procedure can enable the node in the network to know its hop-count number toward the gateway. In E-Dh-AODV the process of hop-count discovery using HELLO message is the same as in DH-AODV. But in E-DH-AODV each node receive the HELLO message has to assign in its routing table the hop-count number of the neighbor node where the HELLO message came from, in order to enable the nodes to select the neighbors with less hop-count to the gateway.

Figure-2 illustrates the process of hop-count discovery used in E-DH-AODV. The gateway generate the HELLO message with 1-hop count value and broadcast it to the neighbor nodes. The neighbor nodes receive the message and they assign the hop-count value which is 1-hop count from the gateway. Later these nodes increase the hop-count value with 1 and rebroadcast the message to their neighbor nodes. Neighbor nodes assign the value of the message which 2-hop count, so that they knows they are 2-hop away from the gateway, and so on. If the intermediate node receives the second HELLO message with hop-count value greater than its hop-count value, it will not assign the value of this message to its own value, but it will just saves the value in its routing table in order to know the neighbor node hop-count and discard the message. In this case each node in the network knows its hop-count number and its neighbor nodes hop-count number so that the node can select the neighbor with less hop-count than its hop-count toward the gateway.

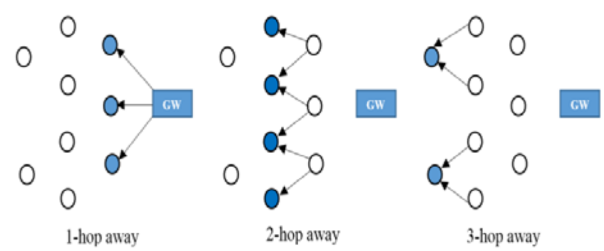

Figure-2. HELLO message process.

3.2 Route discovery

E-DH-AODV is reactive routing protocol that searches for a route toward the gateway on-demand only. In this routing protocol RREQ and RREP packets are used for the route discovery. RREQ packets are directed toward the gateway based on the hop-count using the shortest path. Furthermore, each node in the network is expected to update the battery power level status of the neighbor nodes, through the received RREQ packets. By doing that the RREP packet can be directed toward the source node using the intermediate nodes with highest battery power level.

When a node in the network has data packet and need to send it to the gateway, it has to generate a RREQ packet in order to discover the path. The source node will send the RREQ only to the neighbor nodes with less hop-count than its hop-count. The neighbor node receives the RREQ; this packet will carry the information of battery

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power level for the current node. Then this node will do the same process of sending the RREQ to the neighbor nodes with less hop-count. The neighbor node receives the RREQ, first it updates its routing table with the status of battery level for the node who sent the RREQ, then the RREQ packet will also carry the information of battery power level for the current node, and send it until the packet reaches the gateway. Each node receives RREQ packet establish reverse path in its routing table toward the source node in order to use this path later for the RREP packet, as shown in Figure-3.

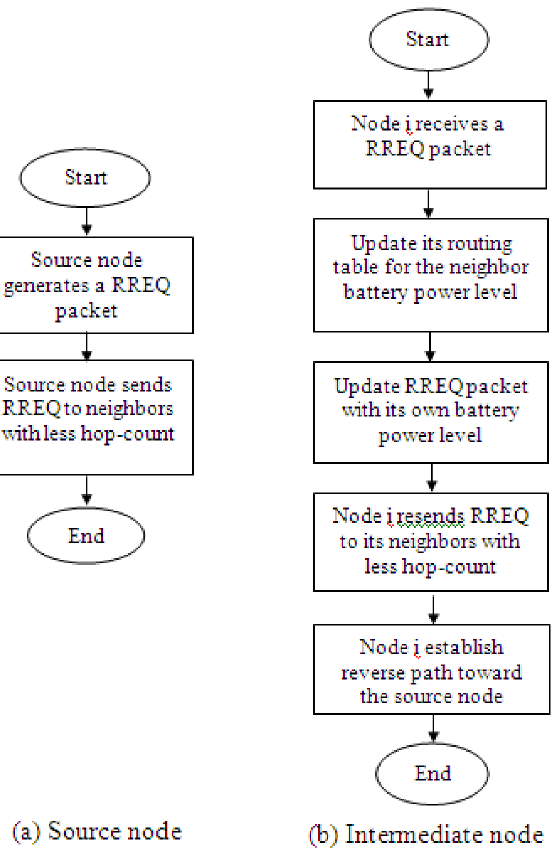

Figure-3. The follow chart of RREQ process.

The gateway receives the RREQ packet, it generates a RREP packet and unicast it. The intermediate nodes receive the RREP set up a forward path toward the gateway in its routing table and path with maximum battery power is discovered.

In the proposed E-DH-AODV routing protocol, the gateway has to generates RREP packet after it receives the RREQ. Then it checks the neighbors ID, if one of the neighbors is the source node, so it send the RREP to that source node. Otherwise, gateway checks the battery power statues of each node has sent the RREQ packet. The gateway will unicast the RREP only to the node with highest battery level and ignore the other nodes. Ones the node with highest battery power receives the RREP, it set up forward path to the gateway and checks the neighbors ID, if one of the neighbors is the source node it send the RREP. Otherwise, the node unicasts the RREP toward the source node considering the reverse path with highest battery power. The source node receives the RREP packet that has path toward the gateway with highest battery power, and it's ready to send the data packet, as shown in Figure-4.

The route error is used in this routing protocol when the neighbor node be unreachable or the packet has been expired in the path due to the delay. Ones the route error reaches the source node, it will requests for new route discovery if needed.

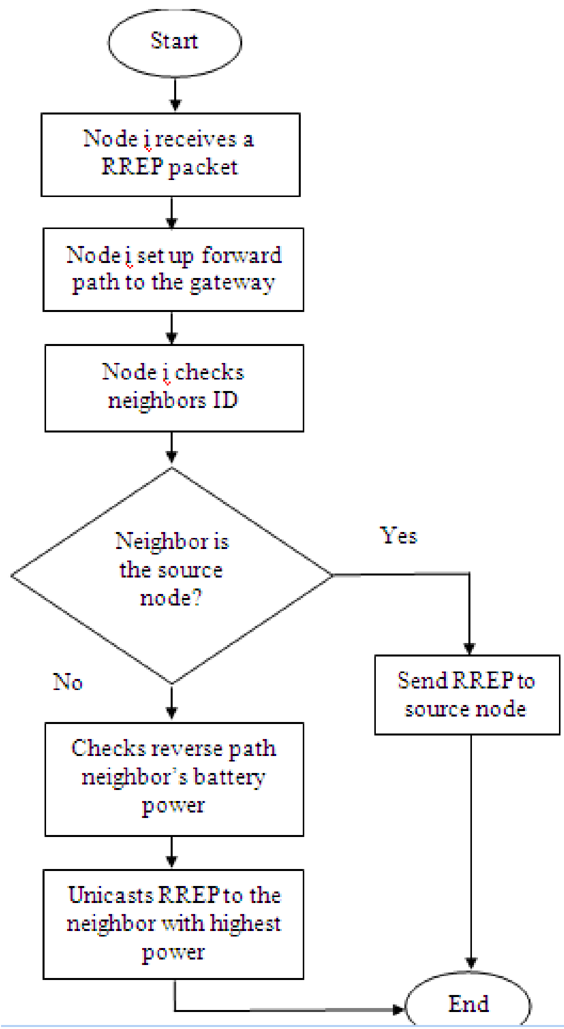

Figure-4. The follow chart of RREP process.

Figure-5 illustrates the procedure of route discovery in E-DH-AODV using the shortest path in RREQ based on the hop-count number, and highest battery power nodes considered in the path of RREP.

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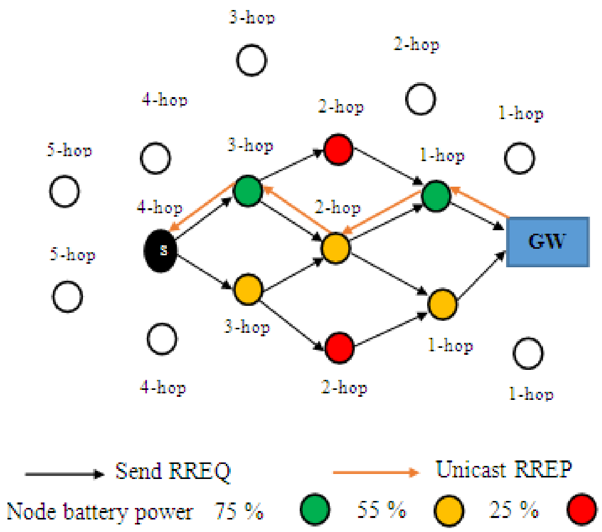

Figure-5. The procedure of route discovery in E-DH-AODV.

4. PERFORMANCE EVALUATION

This section indicates to the simulation environment that used for E-DH-AODV and the classical DH-AODV. Three performance metrics have been considered in this research to clarify the efficiency of the both routing protocols using MATLAB simulator. The metrics are: energy variance consumption, overhead and packet delivery ratio (PDR).

4.1 Simulation environments

Our Simulation is based on random topologies, used for 55 nodes distributed in area size of 1000m x 1000m. The nodes are assumed to be static (no mobile nodes are assumed), and each node has the Communication range of 250 m. The type of channel used in this network is wireless channel. The simulation time was done on 50 seconds. Each node in the network has a routing table with a size of 10, so that it can store the information of 10 neighbors considering the hop-count, sequence number, energy level, and neighbor ID. As shown in Table-1.

Table-1. Simulation environment.

Parameter	Value
Simulator	MATLAB
Channel type	Wireless
Area m^2	1000 x 1000
Number of nodes	55
Simulation time (sec)	50
Communication range (m)	250
Routing table size	10

4.2 Performance metrics

To evaluate the performance of E-DH-AODV and DH-AODV, three metrics have been considered as follow:

- Packet Delivery Ratio (PDR): Define the ratio of successful packets delivered to the gateway and compared with the ratio of packets sent form the source nodes.
- Routing overhead ratio: The ratio of routing overhead is calculated based on the total number of control packets divided by the total number of the received control packets.
- Energy variance consumption: This metric is utilized in this research in order to calculate the total energy consumption for each node in the network within the given simulation time. The calculation for the energy consumption was considered based on the energy level of each node at the beginning of the simulation and compared with the energy level for each node at the end of the simulation in order to present the energy variance of the nodes.

4.3 Simulation results

Figure-6 shows the comparison between E-DH-AODV and DH-AODV based on the energy variance consumption. This figure illustrates that at the beginning of the simulation both routing protocols are the same in energy consumption level. But ones the simulation goes for longer time E-DH-AODV outperform DH-AODV that can achieves lower energy variance consumption with longer simulation time. Therefore, the result shows that at the end of the simulation E-DH-AODV has reduced the energy variance by 10% compared with DH-AODV.

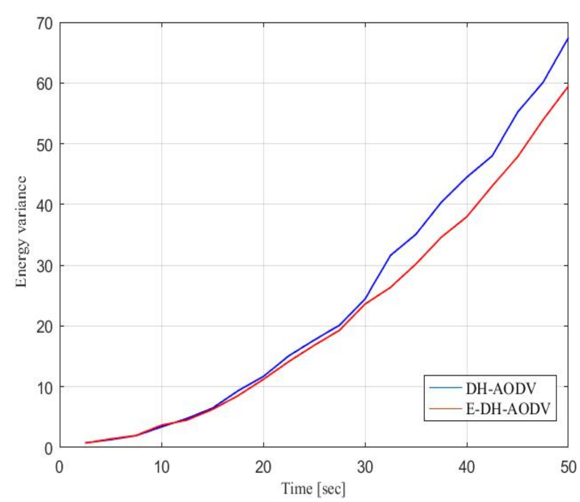

Figure-6. E-DH-AODV vs. DH-AODV based energy consumption.

Figure-7 shows the comparison between E-DH-AODV and DH-AODV based on the overhead. This figure clarifies that E-DH-AODV has outperformed DH-AODV in the overhead. The result shows with longer simulation

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time E-DH-AODV and DH-AODV get almost similar overhead, but E-DH-AODV is still better than DH-AODV. Therefore, E-DH-AODV has achieved less overhead by 5% than DH-AODV.

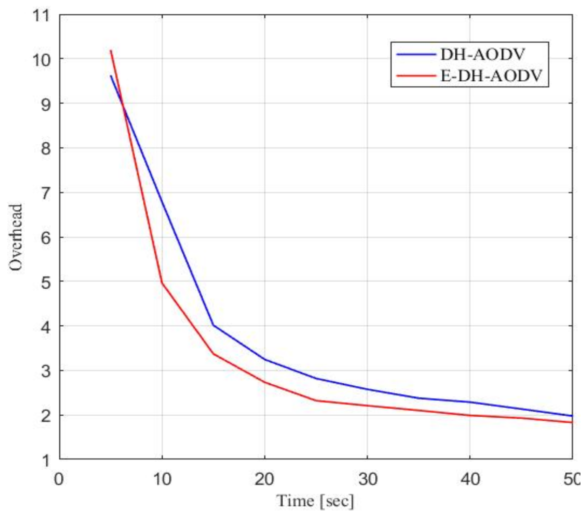

Figure-7. E-DH-AODV vs. DH-AODV based overhead.

Figure-8 shows the comparison between E-DH-AODV and DH-AODV based on the PDR. This figure illustrates that at the beginning of the simulation both routing protocols present almost the same PDR. But ones the simulation goes for longer time E-DH-AODV outperform DH-AODV that can achieve higher PDR. Therefore, the result shows that at the end of the simulation E-DH-AODV has achieved 9% more PDR than DH-AODV.

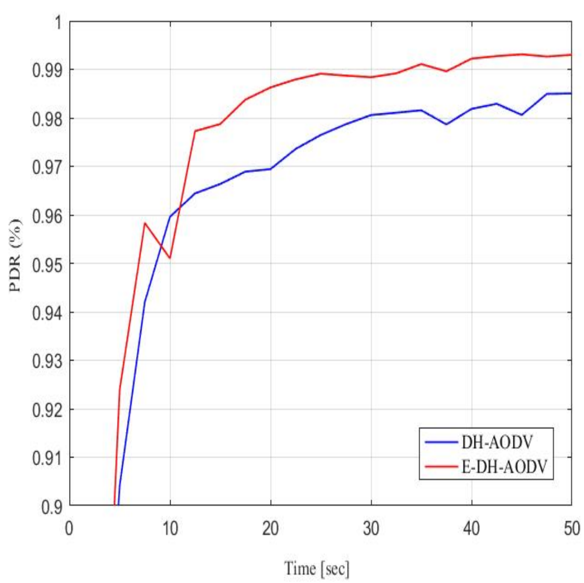

Figure-8. E-DH-AODV vs. DH-AODV based PDR.

5. CONCLUSIONS

Energy-aware DH-AODV (E-DH-AODV) routing protocol has been proposed in this paper for Wireless Mesh Network (WMN). We used in this routing protocol the hop-count for route request (RREQ) packets, in order to define the neighbor nodes with smaller hop-count toward the gateway, so that can reduce the traffic load. Furthermore, a consideration for highest battery power has been applied with the route reply (RREP) packets to avoid nodes with low battery power that can fail the transmission in WMN. MATLB simulator has been used in our research to evaluate the performance of E-DH-AODV and DH-AODV. The performance metrics has shown that E-DH-AODV achieved better performance in case of PDR, E2E delay and overhead compared with DH-AODV.

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