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Performance Appraisal of an On-Demand Routing Protocol AODV in Different Ad Hoc Networks

Banani Das*
Department of IT
Assam University Silchar, India

Rohit Kumar Das
Department of IT
Assam University Silchar, India

Sudipta Roy
Department of IT
Assam University Silchar, India

Abstract— AODV is one of the most popular on-demand routing protocol. In AODV, the routes are maintained just as long as it is necessary. In AODV broadcasting of every change in the network to every node is not necessary. At any instant of the network, if any link breaks it does not affect the ongoing transmission and also no global broadcasting is required, only the affected nodes are informed locally. The aim of the paper is to study the performance of AODV in different ad hoc network scenarios. The study is carried out in two ad hoc networks, viz. MANET and Wireless Mesh Network (WMN). The AODV protocol is implemented to work with both the network scenarios. The simulation of the comparative study of AODV in MANET and in WMN is shown in this paper. And the simulation results clearly depicts that the AODV routing protocol in WMN performs much better than in MANET, as WMN is more stable in comparison to MANET. Hence it could be suggested that, AODV routing protocol is an idle choice for WMNs.

Keywords— Ad hoc network, Routing protocol, AODV, Wireless mesh network, MANET.

I. INTRODUCTION

A wireless network [1] is a type of computer network that uses wireless data connections for connecting network nodes. There are mainly two modes of Wireless Network and these are Infrastructure-based and Infrastructure-less. In infrastructure-based mode, terminals communicate to an access points. But in case of infrastructure-less, terminals communicate in a peer-to-peer basis without any access point and this mode is also known in Ad-Hoc mode network.

The ad hoc network [1] is defined by the mobile nature of the nodes and the removal of the requirement for an infrastructure based network i.e. the use of routers and gateways. Ad hoc Network is a Latin phrase which means "for this purpose". The connection is established for the duration of one session and requires no base station. Every node in ad-hoc network operates as both host and router. This decentralized nature of the Ad hoc networks make them suitable at places where a single central node acting as a base station does not work efficiently or the terrain is not suitable to deploy stationary nodes which are connected via wired links. This makes Ad hoc networks very useful in emergency condition.

Ad hoc networks are of three types: (i) Mobile Ad hoc Networks (MANETs), (ii) Wireless Mesh Networks (WMNs) and (iii) Wireless Sensor Networks (WSNs). The paper is concerned only with the first two types of ad hoc networks. MANETs are sometimes also known as a mobile mesh network. The main difference between them is that WMNs provide an infrastructure while MANETs completely mobile, i.e. infrastructures.

The objective of this paper is to implement the on demand routing protocol, AODV, in both the ad hoc network scenario and hence to compare its performance in both types of networks. The comparison study has been made with respect to different performance metrics to consider the different aspects of the whole network.

The remaining of the paper is organized as follows: Section II provides a brief description about the ad hoc networks along with its important features and also listed the different types of ad hoc networks. The comparison of MANETs and WMNs with respect to different issues has been discussed in section III. Section IV discusses about the on demand routing protocol, AODV and the complete steps in detailed, which are followed in AODV. This section also discusses about the behaviour of AODV in MANETs as well as in WMNs. Next the simulation setup and results are presented in Section V. And lastly, Section VI concludes this paper.

II. AD HOC NETWORKS

The Ad hoc network [5] is defined by the mobile nature of the nodes and the removal of the requirement for an infrastructure based network i.e. the use of routers and gateways. Ad hoc networks [6] generally work in clusters i.e. the grouping of wireless mobile devices (computers or embedded devices which is based on efficient communication between all the nodes). The infrastructure is auto generated by converting the all ready existing nodes into routers, repeaters or gateways [5].

A. *Features of Ad Hoc Networks*

1) *Mobility:* The nodes can reposition themselves in matter of seconds, making the mobility pattern of the nodes non deterministic.

2) *Multi hop Network:* Since the nodes work as group, a multi hop network is created so that even if a node is not in direct contact with the cluster head it can still get the information via the intermediate nodes by forwarding the same data.
3) *Multiple roles for a node:* The Ad hoc networks should be able to organize itself by generating routers, gateways etc. to maintain communication with all the other nodes.
4) *Energy Constraints:* In an Ad hoc network the nodes are mobile and communicate over a wireless channel. Being mobile the power is used from a battery and the size needs to be kept at a minimum. Hence there is a need to manage the battery power consumption, so that they do not drop out of the network prematurely due to low power.

B. Types of Ad hoc network

Ad hoc Networks are classified into three main categories as shown in Fig. 1 and are discussed in brief in this section. This paper is concerned about only the first two types of ad hoc networks, i.e. MANETs and WMNs. Thus a comparative study of both the networks has been carried out in the following section.

1) *MANET:* It stands for mobile ad hoc network [4] and is a self-configuring network of mobile devices connected by wireless links. Each device in a MANET is free to move independently in any direction, and will therefore change its links to other devices frequently. Each must forward traffic unrelated to its own use, and therefore be a router.
2) *Wireless Mesh Network (WMN):* WMN [2] [3] is a communication network made up of radio nodes organized in a mesh topology. It is a mesh network that is built upon wireless communications and allows for continuous connections and reconfiguration around blocked paths by "hopping" from node to node until a connection can be established.
3) *Wireless Sensor Network (WSN):* It is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations. These are a special category of ad hoc networks that are used to provide a wireless communication infrastructure among the sensors deployed in a specific application domain. A sensor network is a collection of a large number of sensor nodes that are deployed in a particular region.

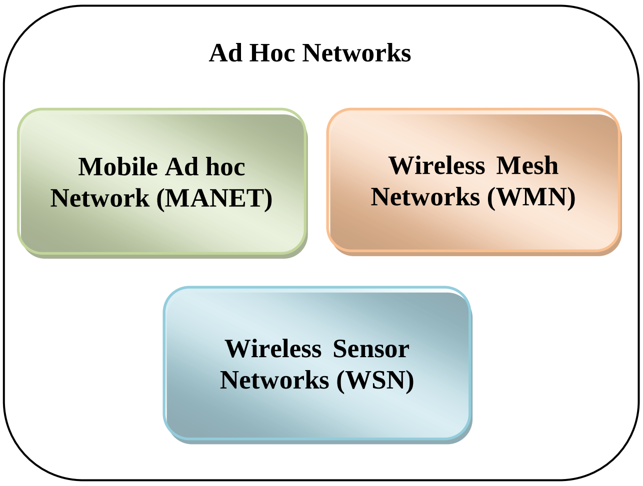

Fig. 1 Classification of Ad-hoc Networks

III. MANETs vs. WMNs

The most important differences between MANET and WMN are mobility of nodes and topology of network. MANETs are high mobility networks where the topology of the network changes dynamically. While, WMNs have a relatively static network with most relay nodes fixed. Hence, the network mobility of WMNs is very low in comparison to the MANETs. The topological difference of these two networks is also responsible for the different routing performance.

The Networks are also different with respect to their application scenario. WMN are used for both military and civilian applications whereas MANET is mainly used for civilian applications. The comparisons are listed in Table 1.

TABLE I COMPARISON OF MANETS AND WMNS [1]

ISSUES	MANETs	WMNs
Network Topology	Highly dynamic	Relatively Static
Mobility of Relay Nodes	Medium to High	Low
Energy Constraint	High	Low
Application Characteristics	Temporary	Semi-permanent or Permanent
Infrastructure Requirement	Infrastructure less	Partial or Fully fixed Infrastructure
Relaying	Relaying by Mobile nodes	Relaying by Fixed Nodes

Routing Performance	Fully distributed on-demand routing preferred	Fully distributed or partially distributed with table-driven or hierarchical routing preferred
Deployment	Easy to deploy	Some planning required
Traffic Characteristics	Typically user traffic	Typically user and sensor traffic
Popular Application Scenario	Tactical Communication	Tactical and civilian communication

IV. AODV-ON DEMAND ROUTING PROTOCOL

AODV, which stands for Ad hoc On demand Distance Vector routing protocol [7], is a on demand routing protocol and hence it is mainly designed for Ad hoc network. AODV can perform both unicast as well as multicast routing. The phrase 'on demand' means that the routes between a source node and destination node are establishes only when it is required.

AODV [8] mainly deals two types of packets and these are RREQ and RREP, which are discussed in details in the following steps of AODV. AODV assumes symmetric, i.e. bi-directional links. It uses bandwidth efficiently and is responsive to changes in topology, is scalable and ensures loop free routing [3].

A. AODV Routing Algorithm

Step 1: Route or Path Discovery

AODV is started with this Phase, which is initiated whenever a source node needs to communicate with another node. Every node maintains two separate counters: a node sequence number and a broadcast id. The source node initiates path discovery by broadcasting a route request, namely RREQ, packet to its neighbors.

The nodes enrooted the packet to the destination, upon receiving the packet checks if the destination address on the packet matches with the receiving node's address. If it matches, then destination is reached or else it will just forward the request packet to its neighbors. When an intermediate node receives a the RREQ packet, if it has already received a RREQ with the same broadcast id and source address it drops the redundant RREQ and does not rebroadcast it. If a node cannot matches the RREQ it keeps track of the following information in order to implement the reverse path setup, as well as the forward path setup. The RREQ packet as shown in Fig. 2 contains the following fields:

<Source address, source sequence, broadcast id, destination address, destination sequence, hop count >

0---32 bits-----------------------------------31		
Type	**Reserved**	**Hop Count**
Broadcast ID		
Destination IP Address		
Destination Sequence Number		
Source IP Address		
Source Sequence Number		
Request Time		

Fig. 2 RREQ (Route Request) Packet Format

Step 2: Reverse Path Setup

There are two sequence numbers, which are included in a RREQ: the source sequence number and the last destination sequence number known to the source. The source sequence number is used to maintain freshness information about the reverse route to the source and the destination sequence number specifies how fresh a route to the destination must be before it can be accepted by the source as the RREQ travels from a source to various destinations it automatically sets up the reverse path from all nodes back to the source.

To set up a reverse path a node records the address of the neighbor from which it received the first copy of the RREQ. These reverse path route entries are maintained for at least enough time for the RREQ to traverse the network and produce a reply to the sender. The formation of forward path and reverse path are shown in Fig. 3(a) and Fig. 3(b).

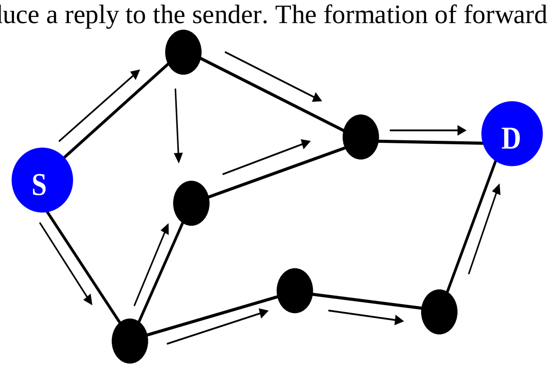

Fig. 3(a) Forward Path Formation by RREQ Broadcasting

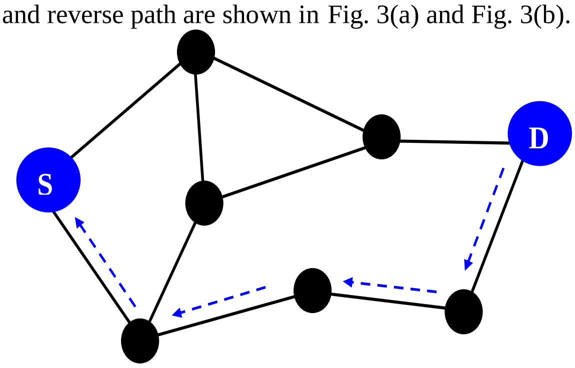

Fig. 3(b) Reverse Path Formation for RREP path

Step 3: Routing Table Management

During this phase the intermediate nodes receive initial feedback from their immediate neighbors and construct their local forwarding table or routing table at each node. Following the flooding of route discovery phase, the destination node creates a packet RREP with two fields namely: (a) node ID, which contains the ID of the node from which the packet has been received and (b) hop count, it contain the number of hops to the destination from.

Formation of RREP of Forwarding Table:

1) When an intermediate node receives a RREQ Then it checks for a route entry in its routing table. If an entry is present for the desired destination then it will check for the destination sequence number.
- If the RREQ's sequence number is greater than the destination sequence number of its own route entry then the intermediate node just rebroadcasts the RREQ.
- Else it will use the recorded route to respond to the RREQ.

2) Once a node determines that it has a current route to respond to RREQ i.e. has a path to destination. It creates a route reply packet, i.e. RREP packet as shown in Fig. 4, and it contains the following information:

<source address, destination address, destination sequence, hop count, lifetime>
- If *RREP* is being sent by destination then it contains:
  <current sequence of destination, hop-count=0, life-time>
- If RREP is sent by an intermediate node then it contains:
  <destination sequence number, hop count=its distance to destination, its value of the life-time>

3) Then the RREP packet is sent back to its neighbour from which it received the RREQ. When an intermediate node receives the RREP, it sets up a forward path entry to the destination in its route table.
- Forward path entry contains the following information:
  <destination address, address of node from which the entry arrived, hop-count to destination, life-time>
- To obtain its distance to destination i.e. hop-count, a node increments its distance by 1
- If route is not used within the life time, it gets deleted.

After processing the RREP, the node forwards it towards the source.

<table>
<tr><td colspan="7">0 -- 32 bits ---------- -- 31</td></tr>
<tr><td>0 ------ 7</td><td colspan="3">8 -------------------- ----------- 15</td><td colspan="2">16 --------------- --------- 23</td><td>24 -------- ------ 31</td></tr>
<tr><td>0 …. .. ..7</td><td>8</td><td>9</td><td colspan="2">10 ....………..….. .... 18</td><td>19........... ..... 23</td><td>24 ..…....... ..... 31</td></tr>
<tr><td>Type</td><td>R</td><td>A</td><td colspan="2">Reserved</td><td>Prefix Size</td><td>Hop Count</td></tr>
<tr><td colspan="7">Broadcast ID</td></tr>
<tr><td colspan="7">Destination IP Address</td></tr>
<tr><td colspan="7">Destination Sequence Number</td></tr>
<tr><td colspan="7">Source IP Address</td></tr>
<tr><td colspan="7">Source Sequence Number</td></tr>
<tr><td colspan="7">Request Time</td></tr>
</table>

Fig. 4 RREP (Route Replay) Message Format

Step 4: Routing Phase

The packets are routed in consultation with the forwarding tables, i.e. routing table, which are maintained at the nodes. Routing from the source nodes to the destination is realized with the help of the routing table constructed during the previous phase and the entries in the table are continuously updated based on the system state. And the process is repeated until the desired destination node is reached, i.e. destination id of the packet matches with the receiving node's id.

B. Behaviour of AODV in MANETs and WMNs

The on-demand routing protocols perform better in wireless ad hoc networks [9] [10], such as in MANET. On the other hand the relatively static hierarchical or table-driven routing protocols perform much better in WMNs. Due to the static topology, formed by fixed relay nodes, of WMNs, most WMNs have better energy storage and power source, thus removing one of the biggest constraints in MANETs [4], as the energy constraint is one of the major issues of MANETs.

Thus the paper implements the on-demand routing protocol, AODV, in both the scenarios, i.e. in MANETs as well as in WMNs. The studied the performance of the AODV in both of the ad hoc networks with respect to the different parameters of the network, so as to compare the performance of AODV.

V. SIMULATION

A. Experimental Setup

This section describes the simulation setup for the implementation of AODV [11] in different types of ad hoc networks. The simulation is done in ns-2 [12]. The basic configuration is that our testing is in a 500 * 500 square with total 50 nodes. The traffic sources are CBR (constant bit rate). The performance of AODV, in case of both the ad hoc networks, has been compared by varying the numbers of nodes and the average queue length of the nodes. The simulation parameters are listed in Table 2.

TABLE II SIMULATION PARAMETERS

Parameter	Values
Simulator	NS 2.34
Traffic Type	CBR/TCP
Simulation Area	1000X1000m
MAC Layer Protocol	802.11
# No. of Nodes	5 - 50
Simulation Time	150 sec
Routing Protocol	AODV
Node Placement	Randomly

B. Simulation Results & Discussion

A WMN scenario is simulated with a few stationary nodes which are considered as relay nodes, on the other hand all the nodes in MANET scenario are considered to be mobile. And the on demand ad hoc routing protocol, AODV [11], is implemented in both the ad hoc network scenario and its performance is observed with respect to different performance measures. The performance comparison of AODV protocol in both the scenarios, MANET and WMN, is done by some of the most important performance metrics which are discussed in this section along with the simulation results.

***1) Throughput Comparison*:** It is a performance metric which measures the rate of information transfer. It is the rate of successful message delivery over a communication channel. The throughput is usually measured in bits per second (bit/s or bps), and sometimes in data per second or data packets per time slot.

$$\frac{Number\ of\ Channels}{Number\ of\ Nodes}$$

The throughput of WMNs and MANETs with AODV is compared by varying two different parameters. First, varying the number of nodes and then varying the queue length. The simulation results are listed in Table 3 and Table 4 respectively and their corresponding graphical representation is in the Fig. 5 and Fig. 6 respectively. From Table 3 and Fig. 5, it is clear that with the increase in number of nodes, i.e. network size, AODV provides a considerably higher rate of throughput in WMN than in the MANET. Also Table 4 and Fig. 6 shows that as the queue lengths increased, the throughput of the network got decreased in case of both the network scenario and still AODV provides better result with WMN than that of MANET. Thus it can be concluded that AODV will increase the throughput of WMNs in case of large network size and with a low value of average queue length of the nodes.

TABLE III THROUGHPUT COMPARISON WITH NO. OF NODES

No. of Nodes	MANETs	WMNs
5	510.86	585.24
10	719.54	747.85
15	650.10	624.88
20	778.14	673.94
25	807.43	780.81

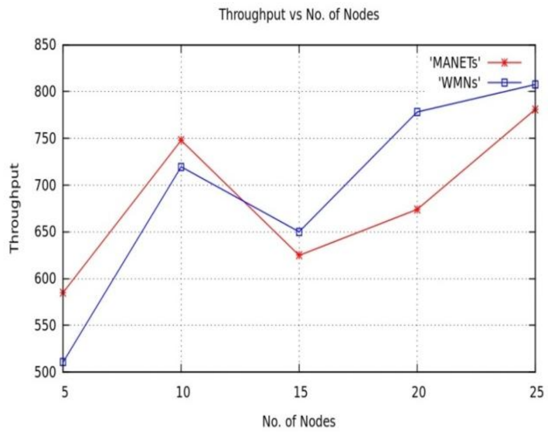

Fig. 5 Throughput Comparison with No. of Nodes

TABLE IV THROUGHPUT COMPARISON WITH QUEUE LENGTH

Queue Length	MANETs	WMNs
5	617.03	572.79
15	572.38	543.63
25	567.19	536.80
35	564.93	546.77
45	544.47	551.28

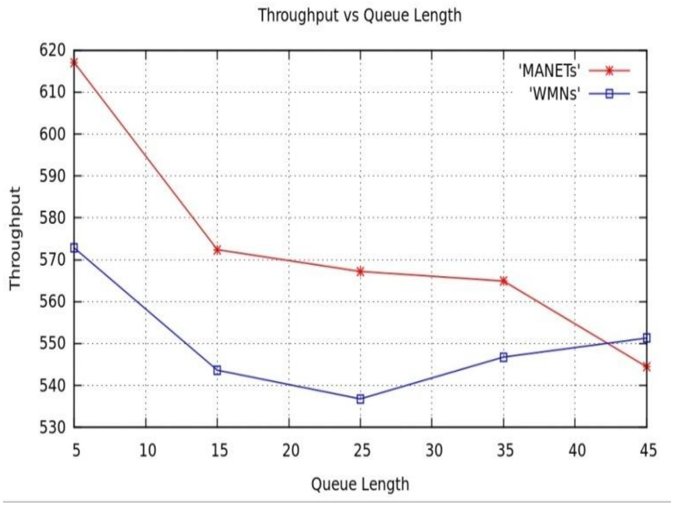

Fig. 6 Throughput Comparison with Queue Length

2) End-to-End delay Comparison**:** Average end-to-end delay includes all possible delays. It refers to the time taken for a packet to be transmitted across a network from source to destination. The delay is affected by high rate of CBR packets as well.

$$\frac{\sum(Packet\ Arrival\ Time\ at\ Destination - Packet\ Sent\ Time\ frm\ Source)}{Total\ No.of\ Connection\ Pairs}$$

The end-to-end delay of AODV is tabulated in Table 5 for different network size in both the network scenarios, i.e. MANET and WMN. The simulation results is also depicted graphically in Fig. 7 and from which it is clear that AODV provides less end-to-end delay in WMN when the network size is low, i.e. as the network size increases AODV performs better in MANET scenario. So it shows that, for small WMNs AODV is an idle choice.

TABLE V END-TO-END DELAY COMPARISON

No. of Nodes	MANETs	WMNs
5	485.24	410.86
10	910.85	809.54
15	724.88	639.1
20	673.94	778.14
25	371.81	407.43

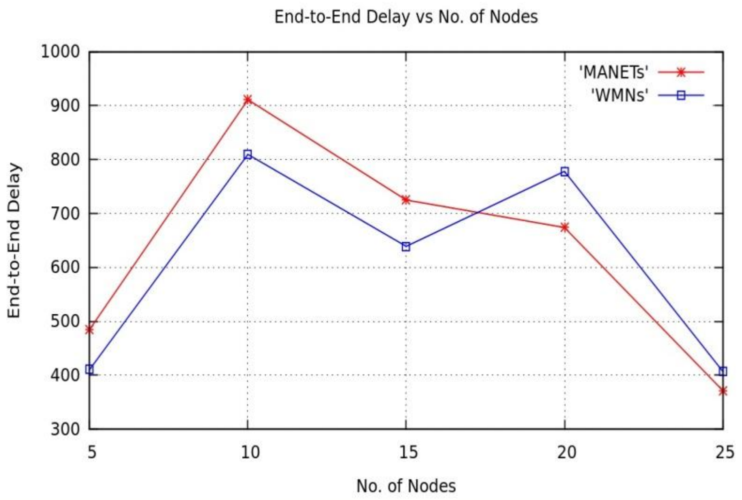

Fig. 7 End-to-End Delay Comparison

3) Normalized Routing Load Comparison*:* The number of routing packets transmitted per data packet delivered at the destination. Each hop-wise transmission of a routing packet is counted as one transmission. The routing load metric evaluates the efficiency of the routing protocol.

$$\frac{\sum Number\ of\ Routing\ Packets}{\sum Number\ of\ Received\ Packets}$$

The normalized routing load of WMN and MANET with AODV is tabulated in Table 6 by varying the network size, i.e. the total number of nodes. The simulation result is also depicted graphically in Fig. 8 and from which it is clear that AODV in WMN provides a considerably low routing load of the network than that with AODV in MANET. So it shows that, to achieve a normalized routing load for WMNs, AODV is the best option.

TABLE VI NORMALIZED ROUTING LOAD COMPARISON

No. of Nodes	MANETs	WMNs
5	0.011	0.015
10	0.109	0.048
15	0.162	0.141
20	0.141	0.123
25	0.381	0.314

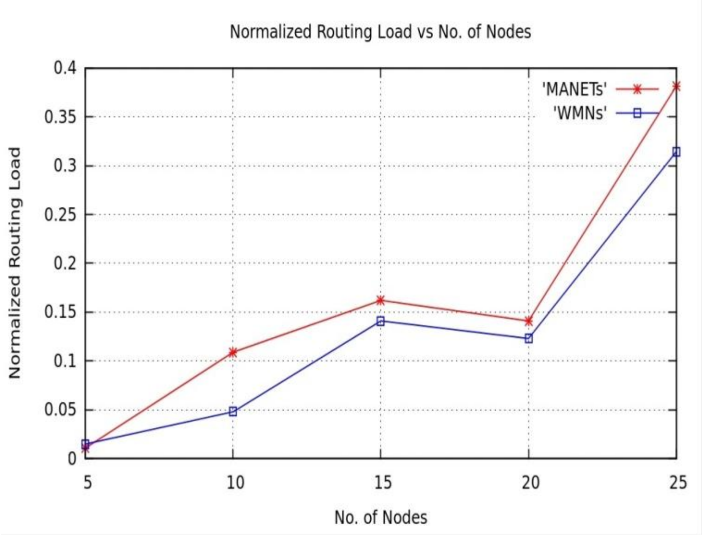

Fig. 8 Normalized Routing Load Comparison

VI. CONCLUSIONS

AODV is one of the most popular on demand routing protocol because of its numerous advantages over the others but till now it is mainly considered for MANETs. This paper analyzes the performance of AODV in WMNs, another type of ad hoc networks. The AODV is implemented in WMNs, one of the ever growing wireless networks, and its results are compared with that of MANETs to analyze its performance. Different parameters of the network have been considered for the performance measure and a comparative study is done. The simulation results conclude that AODV will increase the throughput of WMNs in case of large network size and with a low value of average queue length of the nodes. It has less end-to-end delay in WMN when the network size is low, i.e. as the network size increases AODV performs better in MANET scenario. So it shows that, for small WMNs AODV is an idle choice. Lastly, from the simulation results it can be concluded that to achieve a normalized routing load for WMNs, AODV is the best option. In future the AODV will be further explored and modified to deal with the significant features of WMNs and to provide better performance in all due prospects.

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