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Performance Evaluation of Existing Ad HOC Routing Protocols

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Abstract:
Mobile ad hoc network (MANET) is a special type of wireless network in which a collection of wireless mobile devices (called also nodes) dynamically forming a temporary network without the need of any pre-existing network infrastructure or centralized administration. Currently, Mobile ad hoc networks (MANETs) play a significant role in university campus, advertisement, emergency response, disaster recovery, military use in battle fields, disaster management scenarios, in virtual classrooms, in emergency search and rescue operations, data acquisition in hostile environments, communications set up in exhibitions, conferences and meetings, in sensor network, extension of cellular networks, at airport terminals for workers to share files and so on. In MANETs, there is no pre-established infrastructure to facilitate the routing activity and hence communication between mobile nodes can be achieved through the mobile nodes using multi hop wireless technique. Routing in ad-hoc networks is nontrivial due to highly dynamic environment. In recent years several routing protocols targeted at mobile ad-hoc networks are being proposed and prominent among them are DSDV, AODV, and DSR. This paper has made a simulation comparison among three existing routing protocols (AODV, DSR, and DSDV) and described the performance of each routing protocols by using a number of evaluation metrics. From the comparison of the three routing protocols, it can be seen that AODV routing protocol performs better in all the considered performance metrics.

Keywords: Destination Sequenced Distance Vector (DSDV); Dynamic Source Routing (DSR); Ad -hoc On demand Distance Vector (AODV)

1. INTRODUCTION

MOBILE *ad hoc* network (MANET) [1], [2], [3] is a self-organizing and self-configuring multihop wireless network, which is composed of a set of mobile hosts (MHs) that can move around freely and cooperate in relaying packets on behalf of one another. MANET supports robust and efficient operations by incorporating the routing functionality into MHs. In MANETs, the unicast routing establishes a multihop forwarding path for two nodes beyond the direct wireless communication range. Routing protocols also maintain connectivity when links on these paths break due to effects such as node movement, battery drainage, radio propagation, and wireless interference. In multihop networks, routing is one of the most important issues that have a significant impact on the performance of networks. The characteristics of MANETs have led to the development of MANET specific routing protocols. MANET routing protocols could be broadly classified into three major groups based on the route discovery and routing information update mechanisms: proactive (table-driven), reactive (on-demand) and hybrid [4]. Proactive routing protocols: Proactive routing protocols find routes in advance for all source and destination pairs and continuously learn the topology of the network by exchanging routing information from each node to any other nodes in the network. This routing strategy maintains valid routes to all destinations at all time even if the routes are not needed. However, these protocols have the disadvantage of introducing more control packets that is continuously needed to update stale route entries even if no traffic is affected by the changes [5, 6]. Especially in dynamic environments, the problem is more severe and requires a significant number of communication overheads to implement a proactive algorithm, leading to quick exhaustion of node's battery. This is due to the fact that in mobile scenarios there is a frequent changes of network topology and hence to maintain obsolete routes, the newly routing information is propagated throughout the network regardless of whether the affected link is transmitted packets or not [5, 7]. In this category, Destination Sequenced Distance Vector (DSDV) [9] and Optimized Link State Routing (OLSR) [11] can be included. Reactive routing protocols: Reactive protocols proceed for establishing route(s) whenever there is a need for a route from any source to destination. Therefore, when a source code requires a route to a destination, it initiates a route discovery process by flooding a route request (RREQ) packet through the entire network. Once a route has been established by receiving a route reply (RREP) packet at the source node, it is maintained until either the destination becomes unreachable or until the route is no longer needed. Route maintenance procedure is used to maintain active routes. Since these protocols remove unnecessary routing propagation of inactive topological information, they have less control overhead, use less bandwidth, consume small amount of energy, and better scalability compared to proactive routing protocols. Typical and well-known examples of reactive routing protocols are Dynamic Source Routing (DSR) [8], Ad hoc On-demand Distance Vector (AODV) [10]. Hybrid routing: A hybrid routing protocol attempts to combine the properties of proactive and reactive routing protocols. Hybrid protocols divide the network into areas called zones or clusters. The proactive routing protocol is used inside the zones to establish and maintain routes within the zones. On the other hand, the reactive protocols are exploited for determining and maintaining routes far away nodes or are applied between regions or zones. Zone-based routing protocol (ZRP) [12] and sharp hybrid adaptive routing protocol (SHARP) falls in to this category [13]. This paper is not first to provide a quantitative analysis of routing protocols for ad-hoc networks. But all these

Papers [4] [5] [6] [7] did the comparison considering only few characteristics that should be possessed by routing Protocols. This paper is comprehensive study and considers most of the characteristics as suggested by RFC 2501. The rest of this paper is organized as follows. 2. Routing Protocols Overview, 3. Simulation environment. 4. Analysis of routing protocols. 5. Conclusion and future work

2. ROUTING PROTOCOLS OVERVIEW

2.1 Ad hoc On-demand Distance Vector (AODV)

AODV is a reactive routing protocol that establishes a route to a destination based on a needed basis, i.e. a route is established only when a source node needs to communicate with another one for which it has no valid routing information in its table. Furthermore, optimal route among possible routes is selected based on the shortest path between source and destination pairs. This is useful for mobile environments such as MANETs since it minimizes communication overhead and battery consumption compared to the traditional wired routing protocols. Routing in AODV consists of two phases; route discovery and route maintenance.

2.11 Route Discovery

When a source node wishes to send data, but does not have a valid route information to the destination, it initiates a route discovery process to find the destination node. Path discovery process is initiated by generating and broadcasting route request (RREQ) message to its neighbors that in turn forward this RREQ packet to their neighbors and so on, until the destination node is received or an intermediate node that knows the destination is encountered. If a node could receive a RREQ more than once, it simply drops the redundant ones. The RREQ packet contains the following main fields: Source IP Address, Destination IP Address, Source Sequence Number, Destination Sequence Number (last sequence number received in the past by the source from the destination node), Broadcast ID and Hop Count. Each route request packets is uniquely identified by the pair of Broadcast ID and source IP address. Broadcast ID is incremented by one from the last broadcast ID whenever the source node initiates a route request. AODV uses sequence number to guarantee loop-free and to discover fresh paths [10]. If a node receiving the RREQ packet has a route to the destination, destination sequence number is used to determine whether this route is fresh enough to use as a reply to the route request.

Otherwise the freshness of a route is determined by source sequence number. Each intermediate node while receiving an RREQ packet builds a reverse route back to the source node by recording the address of the neighbor from which it received the first copy of the RREQ in its routing table before forwarding it. Once the RREQ packet reaches the destination or an intermediate node with a fresh enough route, the destination or intermediate node generates a route reply (RREP) packet that is sent back to the source node through the reverse route set up by the RREQ. While the RREP traverses along the reverse route, the intermediate nodes along the route has also recorded the address of the neighbor from which they receive the RREP, just like the intermediate nodes do with the RREQ, thus setting up the forward route. When the RREP reaches its destination, a forward and a reverse path are built between the source and the destination of the RREQ. Finally, each node along the established route is not required to have knowledge of other intermediate nodes on the path other than the next hop.

2.12.Route Maintenance

The next phase of the routing process is the route maintenance procedure which is initiated during broken link due to nodes movement or battery failure. After the route discovery process, the intermediate nodes along an active route keep its connectivity by means of a periodic exchange of “hello” packets to its 1-hop neighbors. If local Hello messages stop arriving from a neighbor beyond some time threshold, the connection is assumed to be stale or expires. When a node detects that a route to a neighbor node is no longer valid it removes the routing entry and sends back a route error (RERR) message towards the affected source nodes. A source node receiving an RERR can initiate a new route discovery if the route is still needed [10, 14].

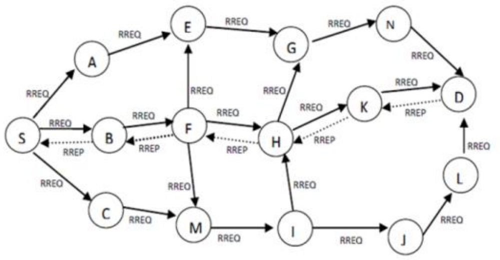


Figure.a) Initiation of RREQ and RREP dissemination in AODV

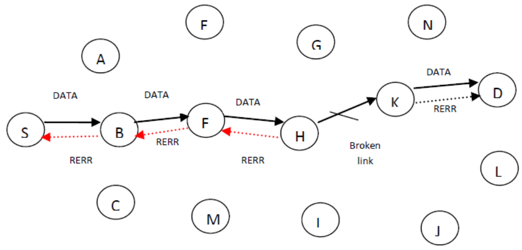


Figure.b) Initiation of RREP in AODV

Figure.2.1: Illustration of the route discovery and route maintenance processes in AODV between Source node S and Destination node D

As can be seen from Figure 2.1(a), let us assume that there are fifteen nodes in the network. The source node S initiates a route discovery process using an RREQ packet and floods it in the network to find a route for destination node D. When node S broadcasts a RREQ, nodes A, B and C receive the RREQ packet. Accordingly, nodes A, B and C record node S on the routing table as a reverse path for node S. After this, nodes A, B and C rebroadcast the RREQ packet as it is assumed that they do not have a valid route to node D. Nodes E, F and M receive the RREQ from nodes A, B and C, respectively. Hence, nodes E, F and M record nodes A, B and C on the routing table as a reverse path for S respectively. Then E, F and M rebroadcast the RREQ packets. When node F rebroadcasts, node E and M receives the duplicated RREQ packet. Nodes E and M simply discard the duplicated RREQ from node F. The process will continue till the RREQ reaches destination node D. Finally, When the RREQ packet reaches the destination node D, node D prepares an RREP packet and sends it back to node S along the reverse route having minimum hop count. Figure 2.1 (b) shows the maintenance procedure due to link failure. When a link fails, the source and destination nodes notified. For example, when the link between node H and K is failed, both nodes generate RERR packets to inform the source, the intermediate nodes along the route and the destination node about the broken link. When the nodes receive RRER packets, they delete the corresponding entries from their routing tables. Then the source node can reinitiate a new RREQ packet containing a new broadcast id and the previous destination sequence number if the route is needed.

2.2 Dynamic Source Routing (DSR)

DSR [8] protocol is characterized based on the concept of source routing rather than relying on the routing table at each intermediate node. In source routing approach, each data packet carries the address of each intermediate node through which the packet pass in order to reach the destination. The key advantage of source routing is that the intermediate nodes do not need to maintain up-to-date routing information in order to route the data packets towards the destination since the packets themselves already contain all the routing information. DSR eliminates the need for periodic route advertisement and neighbor detection packets present in other routing protocols. The routing mechanism of the DSR protocol consists of two basic phases: route discovery and route maintenance.

2.21. Route Discovery

When a node using a DSR routing agent has a data packet to send but does not have any routing information, it initiates a route discovery process. The route discovery of DSR starts by broadcasting an RREQ packet to its neighbors. A neighbor node receiving the RREQ packet broadcasted the routing packet only if all of the following conditions are met: (a) the node is not the intended destination of the Route Request message, (b) the node is not part of source route, (c) the RREQ packet is not a duplicate, and (d) no route information to the destination node is available in its route cache. If all conditions are met, it appends its own address to the route record field of the route request packet and forwards the packet to its neighbors. If condition (b) or (c) is not satisfied, it simply drops the packet. The process continues till the receiving node is the destination of the packet or has a valid route to the destination in its route cache. Finally either the destination or an intermediate node having a fresh route of the destination replies an RREP packet back to the source node. The RREP packet comprises the addresses of nodes that have been traversed by the RREQ. The RREP packet is unicasted back to the source node by using path information carried by the RREP. The route carried by the RREP packet is cached at the source node for future use. Following the route discovery process, each data packet carries the entire path information between source-destination to deliver a data packet to the intended destination.

2.22Route Maintenance

Route maintenance is responsible for detecting link disconnection in the network topology that affects the used routes. DSR monitors the validity of existing routes based on the acknowledgments of data packets transmitted to neighboring nodes. Each host that sends a data packet gets an acknowledgment from the receiving host. When a node fails to receive an acknowledgment, a RERR packet is sent back to the source node to reinitiate a new route discovery phase. Nodes that receive a RERR packet delete all the route entries in the route cache that uses the broken link. The source node must reinitiate the route discovery process, if this route is still needed and no alternate route is found in the cache. Although this routing maintenance procedure reduces control overhead, DSR protocol has two major drawbacks. DSR is not scalable to large networks due to the nature of route discovery (i.e. each data packets carries the list of intermediate nodes along the path). Additionally, DSR requires significantly more processing time and space than most other routing protocols.

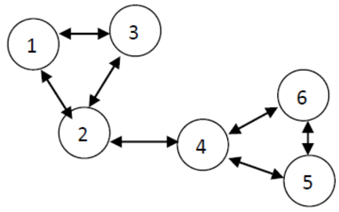
2.3 Destination Sequenced Distance Vector Routing (DSDV)

The Destination Sequenced Distance Vector (DSDV) protocol [9] is a variant of the Distributed Bellman-Ford method, with the improvement of loop free using sequence number. In DSDV, messages are transmitted between nodes based on routing tables which are stored at each node. Each routing table stores all available destinations, the next hop towards a destination, the number of hops to reach them and a destination sequence number that is created by the destination. Sequence numbers are used in DSDV to distinguish obsolete routes from fresh ones and provide loop free routes. DSDV requires that each mobile node broadcasts its own routing table to its adjacent nodes in order to keep an up-to date route to its neighbors. Each broadcasted DSDV packet consists of the following information:

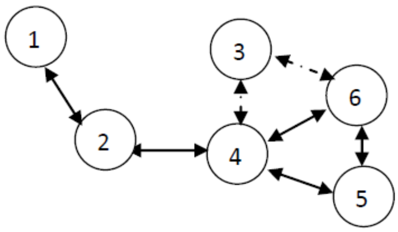
1. The destination address
2. The number of hops reaching to the destination and
3. The latest sequence number known for the destination

DSDV broadcasted routing information periodically however when any new or substantial change occurs in between, this information is transmitted soon to maintain the freshness of the routing table. During table creation the route with the most recent sequence number is always used. For instance, when a node receives a broadcast packet from node i, it updates the sequence number of the entry relative to node i in its routing table, and then rebroadcasts its own routing table. When node j, which is not a neighbor of node i, receives the broadcast from node k, it evaluates its own routing table with the received one, and if the sequence number of the entry relative to node i is newer, then node j updates its entry relative to node i. Hence, node j updates the sequence number for the received one and node k becomes the next hop to reach node i. After updating its routing table, node j rebroadcasts the updated routing table to its neighbors and the retransmission of newly information continues till all nodes of the network notifies the change. Figure 2.2 depicts how the mobility of node 3 affects the routing table of node 2 on a network of six nodes. In DSDV, each node in the network broadcasts the routing information to all other nodes and also establishes its own routing table.

For example, Table 2.1 shows the routing table of node 2. But, when node 3 changes its position as shown in Figure 2.2 the link between node 2 and node 3 and node 1 and node 3 will be broken resulting in the assignment of infinity metric at node 2 for node 3 and the sequence number will be changed to odd number in the routing table at node 2 to indicate infinity metrics. The same is true for node 1 as well. Odd sequence number is used to indicate infinity metrics for unknown number of metrics for a destination node otherwise even sequence number is used. In the next step the change will be re-transmitted to its neighbors' nodes. Since, there is a new neighbor host for node 4 and node 6; they modify their routing table information and rebroadcast it. If node receives fresh routing information from its neighbors with the same sequence number but different metrics, a route having smaller number of hop count will be selected. Table 2.2 shows how DSDV routing table is constructed by a node.



2.2a) Example of DSDV before the movement of node 3



2.2b) Example of DSDV after the movement of node 3
Figure.3. Illustration of routing table maintenance in DSDV routing protocol

Table.1. Construction of routing table of node 2

Destination	Next hop	Metric	Sequence number
1	1	1	SQN402-1
2	2	0	SQN98-2
3	3	1	SQN110-3
4	4	1	SQN546-4
5	4	2	SQN322-5
6	4	2	SQN726-6

Destination	Next hop	Metric	Sequence number
1	1	1	SQN402-1
2	2	0	SQN98-2
3	4	3	SQN118-3
4	4	1	SQN546-4
5	4	2	SQN322-5
6	4	2	SQN726-6

Though each node tries to maintain routing information for every other node in DSDV, DSDV routing protocol has the following shortcomings. One problem is the so called "count-to-infinity" problem. In unfavorable circumstances, it takes up to N iterations to detect the fact that a node is disconnected, where N is the number of nodes in the network [15, 16]. Another problem is that excessive communication overhead is incurred due to periodic and triggered routing updates with mobility. Generally, DSDV routing protocol does not scale well to large networks and mobile environment.

3. SIMULATION ENVIRONMENT

The simulation scenarios consist of 60 to 140 mobile nodes placed on an area of 1500m x 1500m with 9 number of traffic flows (i.e. source-destination connections). The transmission range of each node is 250m and each simulation runs for a period of 1000sec. A Constant Bit Rate (CBR) of 512 bytes data packets with sending rate of 5 packets per second has been used. Identical traffic loads and environmental conditions are used in order to maintain direct and fair comparison among the routing protocols. Each data point for each routing protocols represents an average of twenty randomly generated traffic scenario files. In this study, mobile nodes move according to the widely used random waypoint mobility model [17], where each node at the beginning of the simulation remains stationary for pause time seconds, then chooses a random destination and starts moving towards it with a speed randomly selected from [0, Vmax] . After the node reaches its destination, it again waits for t sec and picks up a new random destination and speed. This cycle continues until the simulation ends. The maximum speed Vmax is 20m/sec and pause times of 20 seconds are considered. The parameters used in this simulation research study have been adopted from existing performance evaluation studies of MANETs [7, 18-20].

4. ANALYSIS OF DSDV, AODV AND DSR MANETS ROUTING PROTOCOLS

The results of a comparison among AODV, DSR and DSDV routing protocols are presented in this section in terms of normalized routing overhead, delivery ratio, network lifetime, energy consumption and normalized energy consumption.

4.1 Normalized routing overhead

Figure 4.1 compared the normalized routing overhead of AODV, DSDV and DSR routing protocols across different number of nodes. Figure 4.1 shows that the normalized routing overhead increases with an increase in number of nodes. Furthermore in each network density, the normalized routing overhead generated by AODV is lower compared with those of the DSDV and DSR routing protocols. The performance advantage of AODV over the DSDV and DSR is further increased in dense networks. This is due to the fact that AODV activate the route discovery process only when a source node needs to communicate data packets with another one unlike DSDV and each data packet does not carry each node's address along the path unlike DSR. As a result, the battery of each node relatively getting depleted at a slower rate compared to DSDV and DSR routing protocols thereby reduces frequency of broken link due to battery exhaustion, leading to minimum routing overhead.

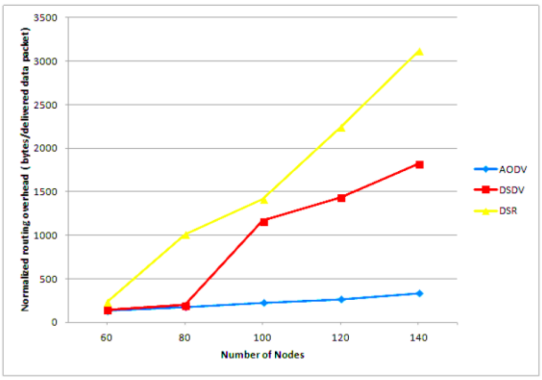


Figure.4.1: Normalized routing overhead with different number of nodes

4.2 .Delivery ratio

Figure 4.2 depicts the delivery ratio against network density of AODV, DSDV and DSR routing protocols. The figure shows that the percentage of packets delivery ratio for each of the considered routing protocols decreases when the network density increases. It could be also noticed that the percentage of packets delivered to the destination nodes is considerably higher in AODV than the others routing protocols. This is due to the fact that DSR and DSDV induced an excessive control packet (e.g. RREQ packets) as shown in figure 4.1 thereby increases channel contention, packet collisions and buffer overflow and hence decreases the bandwidth available for data transmission, leading to more drop data packets. The other reason is that AODV is aggressively maintaining active broken links with minimal overhead unlike DSR and DSDV. Hence, it provides better chances to avoid usage of stale routes for data transmission. DSR has also poor packet delivery ratio compared to DSDV because each DSR data packet carries the address of each intermediate nodes on the route between source and destination and thereby proportionally increases the size of the data packet propagated through the network, leading to packet collision, channel contention, buffer overflow, and exhaustion of node's battery.

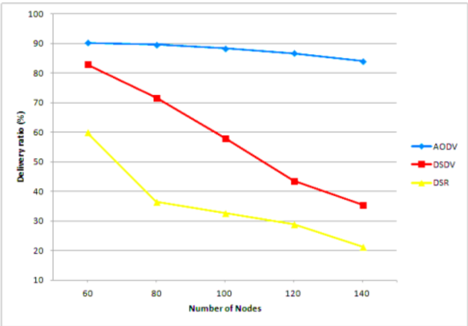


Figure .4.2. Delivery ratio with different number of nodes

4.3. Network Lifetime

Figure 4.3 illustrates the life time of the network versus network density of AODV, DSDV and DSR routing protocols. In the figure when the number of node increases the network lifetime in all the routing schemes decrease. This is because as the number of node increases, the routing packets generated and disseminated through the network increases. As a result, a considerable amount of node's energy is consumed by each node's of the network and hence decreases the network lifetime. As can be seen in Figure 4.3, AODV successfully runs the network for a longer period compared to DSDV and DSR routing protocols. This is because AODV reduces a considerable routing overhead than DSDV and DSR routing protocols as shown in figure 4.1.

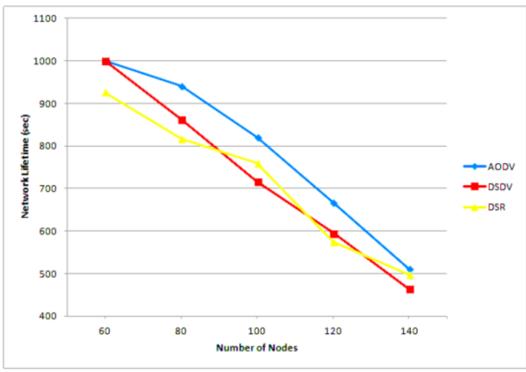


Figure.4.3. Network lifetime with different number of nodes

4.3 Energy Consumption

Figure 4.3 illustrates the energy consumption versus number of nodes of for the considered routing protocols. From the graphs we noticed that as the number of nodes increase the total energy consumption is also increased. This is due to the fact that when the number of nodes increase, a large number of nodes are more likely to participate in forwarding and generating routing packets, thereby increasing total energy consumption. Moreover, the energy consumption of AODV is smaller than both DSR and DSDV routing protocols. Unlike AODV, the packet size in DSR is variable. This is due to the fact that in DSR, routing table is not maintained by each intermediate node, hence each data packets originating from the source appends all the route information on the data packets during transmission which results an increase in energy consumption across all tracing nodes. On the other hand, DSDV has the disadvantage of introducing more control packets that is continuously needed to update stale route entries even if no traffic is affected by the changes, leading to a considerable amount of energy consumption.

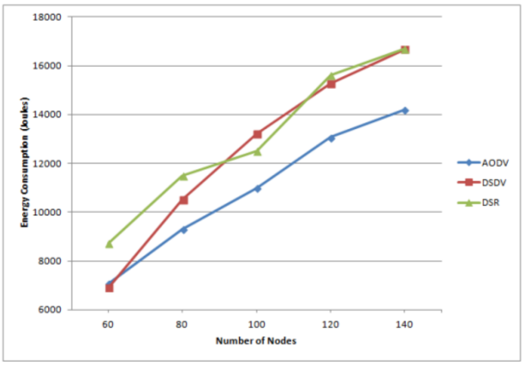


Figure .4.4. Energy consumption with different number of nodes

4.4 Normalized energy consumption

The simulation result of normalized energy consumption as a function of number of nodes for AODV, DSR and DSDV routing protocols is depicted in Figure 4.5. The figure shows that AODV has minimum normalized energy consumption compared to DSR and DSDV routing protocols. This is because AODV increases delivery ratio and decreases energy consumption compared to DSDV and DSR as shown in figure 4.2 and figure 4.4.

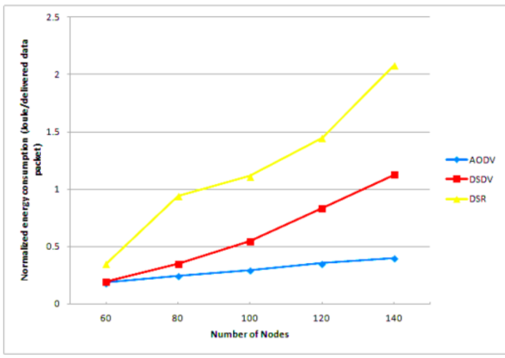


Figure.4.5. Normalized energy consumption with different number of nodes

5. CONCLUSION AND FUTURE WORK

MOBILE *ad hoc* network (MANET) is a self-organizing and self-configuring multihop wireless network, which is composed of a set of mobile hosts (MHs) that can move around freely and cooperate in relaying packets on behalf of one another. MANET supports robust and efficient operations by incorporating the routing functionality into MHs. In MANETs, the unicast routing establishes a multihop forwarding path for two nodes beyond the direct wireless communication range. Routing protocols also maintain connectivity when links on these paths break due to effects such as node movement, battery drainage, radio propagation, and wireless interference. In multihop networks, routing is one of the most important issues that have a significant impact on the performance of networks. This paper has made a simulation comparison among three existing routing protocols and described the performance of each routing protocols by using a number of evaluation metrics. From the comparison of the three routing protocols, it can be seen that AODV routing protocol performs better in all the considered performance metrics. Even though AODV is an efficient MANET routing protocols, AODV and most of the routing protocols have two major drawbacks. The first one is they employ a broadcast scheme referred to as "simple flooding" whereby a route request packet originating from a source node is blindly disseminated to the rest of the network nodes. This leads to excessive redundant re-transmissions, causing high channel contention and packet collisions in the network, a phenomenon called broadcast storm, leading to high power consumption. Reducing the flooding will reduce the protocol overhead and routing load and therefore the power consumption. The second drawback of AODV uses minimum hop count as a cost metric to select a route for data packet transmission. However, shortest hop count technique did not consider energy as a cost metric and hence less energy capable nodes could be part of an established route, leading to frequent broken link. Consequently, most of the mobile nodes could exhaust their energy before attaining the desire objectives. Thus research study concentrated on making AODV more energy efficient routing protocol is to be investigated in the future.

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