Energy Aware Routing in Ad Hoc Networks

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Abstract:

The efficient node-energy utilization in mobile ad-hoc networks is essential as ad-hoc nodes operate with limited battery power. In ad-hoc networks, nodes perform the function of hosts as well as router as there is no existing infrastructure. Thus, failure of node in ad hoc network leads to loss of communication in the network. Maintaining alive node for longer time i.e. increasing network lifetime is one of the important factors in design of ad-hoc networks. The Ad hoc On-Demand Distance Vector (AODV) protocols perform routing based on the metric of least number of hops. To extend the lifetime of the ad-hoc networks, AODV energy aware routing protocol (AODVEA) is used which performs routing based on the metric of minimum remaining energy. In this paper, an efficient modified AODV (AODVM) routing protocol is proposed which performs routing based on the combination of least hops and minimum remaining energy. The performance of the proposed protocol has been examined and evaluated with the NS-2 simulator in terms of network lifetime, end-to-end delay and energy consumption. The proposed protocol gives less delay and energy consumption than AODVEA and improved lifetime than AODV.

Key-words: - MANETS, AODV, Route request, Route reply, AODVEA.

1 Introduction

Next generation of mobile communications will include both prestigious infrastructured wireless networks and novel infrastructure-less Mobile Ad hoc Networks (MANETs). Wireless multi hop ad hoc networks prove to be superior where it is inconvenient or impossible for wired cable networks or services to reach. Wireless network enables users to setup a network quickly, provides advantage in deployment, cost, size and distributed intelligence over wired networks. It remains a challenging task to provide the same type of services at the same quality in wireless mobile environments as in wired environment [1].Typical applications include Military battlefield, emergency/rescue operations for disaster relief effort and telemedicine.

The Power efficient ad hoc mobile networks aim at minimizing the power consumption of entire network, i.e. maximizing the lifetime of ad hoc networks. As wireless services continue to add more capabilities such as multimedia and QoS, low power design remains an important design aspect. However, most of the energy savings at the physical layer have already been achieved [12]. Hence the key to energy conservation in wireless communication lies within the higher levels of protocol stack.

A typical ad hoc network consists of nodes that are usually battery-operated devices that come together and spontaneously form a network. Energy conservation is a critical issue as the lifetime of these nodes depends on the life of the system. A wireless sensor network is densely deployed with a large number of sensor nodes, each of which operates with limited battery power, while working with the self-organizing capability in the multi-hop environment. Since each node in the network works as terminal node as well as routing node, a node cannot participate in the network if its battery power runs out. The increase of such dead nodes generates many network partitions and consequently, normal communication as a sensor network will be impossible. Thus, an important research issue is to develop an algorithm for efficient battery power management to increase the life cycle of the wireless sensor network. New routing algorithms are needed in order to handle the overhead of mobility and topology changes in such energy constrained environment [2].The Ad hoc On-Demand Distance Vector (AODV) routing protocol is intended for use by mobile nodes in an ad hoc network. It offers quick adaptation to dynamic link conditions, low processing and memory overhead, low network utilization, and determines unicast routes to destinations within the ad hoc network [4]. In this paper, an efficient energy aware routing protocol is proposed, which is based upon the on-demand ad hoc routing protocol AODV, and determines a proper path considering node residual battery powers. The proposed protocol aims to extend the lifetime of the overall sensor network by using both, hop count as well as node residual battery power.

2 Literature survey:

In order to reduce energy consumption and increase the lifespan of the network,, Power aware alteration (PAA) was proposed in [7]. The scheme needs a traffic overhead to maintain the network connectivity and to assume data transmission in spite of congestion. Significant reduction in cost (function of remaining battery power) can be obtained by using shortest - cost routing as opposed to shortest hop routing. This power aware routing protocol for mobile ad hoc networks can be easily incorporated in existing routing protocol [8]. In Span: An Energy Efficient Coordination Algorithm, proposed by Chen B, Morris R etc [9], a distributed coordination technique reduces energy consumption without significantly diminishing the capacity or connectivity of network. It adaptively elects coordinators and rotates them in time. In PA-VBS [10], battery capacity is used as a basis for developing a wireless mobile infrastructure, achieving load balancing and fair clustering. In order to make wireless communication energy efficient, a need is felt to propose a scheme to optimize the performance. The performance can be optimized by improving the metrics like maximum end to end throughput, minimum end to end delay, shortest path or minimum hop, minimum total power, load balancing, minimum overhead, adaptability to changing topology, association stability and route relaying load. Energy constrained nodes, low channel bandwidth, node mobility, high channel rates and variability are some of the limitations in ad hoc networks. Hence, ad hoc networks demand specialized routing protocols. The performance of ad hoc routing protocols greatly depends on the mobility model it runs over [5]. Ad hoc routing protocols [2] are classified based on the manner in which route tables are constructed, maintained, and updated. They are classified as Table-driven, Source initiated or demand-driven. In situations where nodes move in groups, source initiated protocol perform better than table driven protocols in terms of energy consumption.

Table driven routing protocols have basic characteristics that they maintain consistent, up-to-date routing information from each node to every other node in the network. Nodes maintain routing tables and respond to the changes in the network topology by propagating updates throughout the network in order to maintain a consistent view of the network. They incur significantly high routing overhead and hence tend to increase the energy consumption compared to the on-demand protocols like Destination Sequenced Distance Vector Protocol (DSDV).

Source Initiated On-Demand Routing creates routes only when desired by the source node. The source node initiates a process called route discovery when it requires a route to the destination. This process is completed when a route is found or when all the possible routes are examined. The process of route maintenance is carried out to maintain the established routes until either the destination becomes unavailable or when the route is no longer required as in AODV and DSR.

The paper is organized as follows. Section 3 gives overview of various Ad Hoc Routing protocols. Section 4 elaborates the two schemes proposed by us. Results are discussed in Section 5.

3 Overview of Ad Hoc Routing protocols

3.1 DSDV

It periodically advertises a node's interconnection topology with the other nodes in the mobile ad hoc network. The mobile nodes maintain an additional table that stores the data sent in the incremental routing information packets. Packets contain the address of the destination, the number of hops to reach the destination, the sequence number of the information received regarding the destination, as well as sequence number unique to the broadcast. The route labeled with the most recent sequence number is used.

3.2 Dynamic Source Routing

DSR allows nodes to dynamically discover a source route across multiple network hops to any destination in the ad hoc network. Each data packet sent carries in its header the complete, ordered list of nodes through which the packet must pass, allowing packet routing

information in the intermediate nodes through which the packet is forwarded. Since the source route is included in the header, other nodes hearing this transmission can cache this information in their routing table for future use.
By studying detailed performance evaluation of three major ad hoc routing protocols: DSR, AODV, and DSDV it can be proposed that max-min energy routing scheme that will not only improve the robustness of the routing protocol but will also help in energy conservation of the mobile nodes[3]. Generally on-demand protocols (DSR and AODV) seemed to perform better than DSDV. Especially when mobility increases. Even with lower mobility and with few moving nodes, DSDV may suffer from quite a big packet loss [6].

3.3 Ad Hoc On-Demand Distance Vector Routing

The AODV protocol is a modified version of DSDV and aims at reducing system-wide broadcasts. Routes are discovered on need basis and are maintained only as long as they are necessary. Each node maintains monotonically increasing sequence numbers and this number increases as it learns about a change in the topology of its neighborhood. This sequence number ensures that the most recent route is selected whenever route discovery is initiated. In addition to this sequence number, each multicast group has its own sequence number, which is maintained by a group leader. This protocol is used for unicast, multicast, and broadcast communication. AODV uses both a unicast routing table and a multi-cast routing table. This route table is used to store the destination and next-hop IP addresses as well as the destination sequence number. Associated with each routing table entry is a lifetime, which is updated whenever a route is used. This route expires if not used within its lifetime value and is declared as invalid. The process of Route Establishment and Route Maintenance is involved for effective routing in AODV. An additional aspect of the protocol is the use of Hello messages which are periodic local broadcasts sent by a node to inform each node of other nodes in its neighborhood. These messages are used to maintain local connectivity of a node. Nodes listen for retransmission of data packets to ensure that the next hop is still within reach. Hello messages also list the other nodes from which a node was heard and this yields a better knowledge of the network connectivity. The Advantages are: loop free routing , optional multicast and reduced control overhead, but it has following disadvantages : delay caused by route discovery process, bi-directional connection needed in order to detect an unidirectional link.

3.3.1 AODV message Format

The AODV routing protocol is designed for mobile ad hoc networks with populations of tens to thousands of mobile nodes. AODV can handle low, moderate, and relatively high mobility rates, as well as a variety of data traffic levels[4]. It has been designed to reduce the dissemination of control traffic and eliminate overhead on data traffic, in order to improve scalability and performance.

<table>
<tr><td>Type</td><td>J</td><td>R</td><td>G</td><td>D</td><td>U</td><td>Reserved</td><td>Hop Count</td></tr>
<tr><td colspan="8">RREQ ID</td></tr>
<tr><td colspan="8">Destination IP Address</td></tr>
<tr><td colspan="8">Destination Sequence Number</td></tr>
<tr><td colspan="8">Originator IP Address</td></tr>
<tr><td colspan="8">Originator Sequence Number</td></tr>
</table>

Fig. 1. AODV Route Request (RREQ) Message Format

Corresponding to RREQ the RREP message format is as shown below:

<table>
<tr><td>Type</td><td>R</td><td>A</td><td>Reserved</td><td>Prefix Sz</td><td>Hop Count</td></tr>
<tr><td colspan="6">Destination IP Address</td></tr>
<tr><td colspan="6">Destination Sequence Number</td></tr>
<tr><td colspan="6">Originator IP Address</td></tr>
<tr><td colspan="6">Life Time</td></tr>
</table>

Fig. 2. AODV Route Reply (RREP) Message Format

3.1.2 Operation of AODV

The protocol can greatly reduce the number of broadcasts requested for routing search processes, when compared to the DSDV routing protocol, which is known to discover the optimum route between source and destination with path information of all nodes. The AODV protocol greatly improves drawbacks of DSR protocol such as the overheads incurred during data transfer. Once a route is discovered in the AODV routing protocol, the route will be maintained in a table until the route is no longer used. The nodes of the DSDV protocol maintain all routing information between source

and destination but the nodes of the AODV protocol have path information in a brief routing table, which stores the destination address, destination sequence number, and next hop address. Each entry of a routing table has a lifetime field, which is set when its routing information is updated and changed. An entry will be removed from the routing table when its lifetime is expired. This protocol reduces the latency time of the routing discovery and determines efficient routes between nodes. The AODV routing protocol determines a least hop-count path between a source and a destination, thus minimizing the end-to-end delay of data transfer. Since the protocol uses the shortest route for end-to-end data delivery, it minimizes the total energy consumption.
Comparison of DSDV, AVODV and DSR protocols is summarized in Table 1.

The comparison of the protocols DSDV, DSR and AODV in regards to various parameters such as protocol type, average end to end delay, routing overhead, power consumption and quality of service above is given.

Table 1: Comparison of Ad hoc routing protocols

Parameters	DSDV	AODV	DSR
Protocol Type	Table-driven	Demand-driven	Demand-driven
Average end to end delay	Less	High	High
Routing overhead	Less	Less	High
Power Consumption	High	Less	Less
Quality of service	Poor	Good	Good

4 Proposed AODVEA and AODVM

In order to extend the lifetime of the network, one possible solution is to make equally balanced power consumption of sensor nodes. Since AODV routing mechanism does not consider the residual energy of nodes at the routing setup, and since it considers only routing hop count as a distance metric, unbalanced node energy consumptions occurs. We propose an efficient routing algorithm, which considers both node hop-count and node energy consumption.

4.1 AODVEA (AODV Energy Aware)

In AODVEA, routing is based on the metric of minimum remaining energy. The node with minimum remaining energy in the route is marked and the route having maximum of minimum remaining energy is selected. For this purpose Minimum Remaining Energy (Min-RE) field is added in RREQ and RREP. Min-RE this field gives the node with minimum remaining energy in the route. Other parameters are as same as AODV route request.

4. 1.1 Operation of AODVEA:

The source node starts communicating as soon as it receives the first valid route reply. However, once the source S receives the next route reply, it runs a algorithm, which is described as follows:

1. Send a ROUTE REQUEST to neighbors.
2. Get various routes available to destination.
3. Compare parameters of routes with respect to remaining energy level and least count.
4. Then the appropriate route for destination is selected.

4.2 AODVM (AODV Modified)

In AODVEA, routing is based on the metric of minimum remaining energy. The node with minimum remaining energy in the route is identified and the route having maximum of minimum remaining energy is selected. In this, Energy by hops field is added to Min – RE field, in both RREQ and RREP message format. Other parameters are as same as AODVEA route request.

4.2.1 Operation of AODVM:

The proposed protocol performs a route discovery process similar to the AODV protocol. The difference is to determine an optimum route by considering the network lifetime and performance; that is, considering residual energy of nodes on the path and hop count. In order to implement such functions, a new field, called Min-RE field, is added to the RREQ message as described above. The Min-RE field is set to a default value of -1 when a source node broadcasts a new RREQ message for a route discovery process.

To find a route to a destination node, a source node floods a RREQ packet to the network. When neighbor nodes receive the RREQ packet, they update the Min-RE value and rebroadcast the packet to the next nodes until the packet arrives at a destination node. If the intermediate node receives a RREQ message, it increases the hop count by one and replaces the value of the Min-RE field with the minimum energy value of the route. In other words, Min-RE is the energy value of the node if Min-RE is greater than its own energy value; otherwise Min-RE is unchanged.

Although intermediate nodes have route information to the destination node, they keep forwarding the RREQ message to the destination because it has no information about residual energy of the other nodes on the route. If the destination node finally receives the first RREQ message, it triggers the data collection timer and receives all RREQ messages forwarded through other routes until time expires. After the destination node completes route information collection, it determines an optimum route and then sends a RREP message to the source node by unicasting. If the source node receives the RREP message, a route is established and data transfer gets started. Such route processes are performed periodically, though node topology does not change to maintain node energy consumption balanced. That is, the periodic route discovery will exclude the nodes having low residual energy from the routing path and greatly reduce network partition. Equation (1) gives Calculation of Routing metric for modified AODV.

α = (Min RE)/ Hop Count --------------------------- (1)

The optimum route is determined by using the value of α described in Equation(1). The destination node calculates the values of α for received all route information and choose a route that has the largest value of α. That is, the proposed protocol collects routes that have the minimum residual energy of nodes relatively large and have the least hop-count and then determines a proper route among them, which consumes the minimum network energy compared to any other routes. Here Min-RE is the minimum residual energy on the route and No-Hops is the hop count of the route between source and destination.

4.2.2 Analysis of Routing Protocols

To understand the operations of the proposed protocol, we consider three different routing protocols for operational comparison:

Case 1: Choose a route with the minimum hop count between source and destination (AODV routing protocol)
Case 2: Choose a route with largest minimum residual energy (AODVEA routing protocol)
Case 3: Choose a route with the large minimum residual energy and less hop count i.e. with the longest network lifetime (AODVM our proposed routing protocol)

The network illustrated in Fig. 3 gives a simple routing example to setup route from source node S to destination node D. The number written on a node represents the value of residual node energy. Consider three different cases of routes. Since the Case 1 considers only the minimum hop count, it selects route <S-B-J-D> which has the hop count of 3. In the Case-2, select route <S-A-K-F-L-H-G-D> which has Min-RE 6 is chosen because the route has the largest minimum residual energy among routes. Proposed model needs to compute the value of Min-Re by Hop count, and selects a route with largest value. Thus Case 3 selects route <S-C-E-I-D> which has largest value of α = (5 / 4)= 1.25.

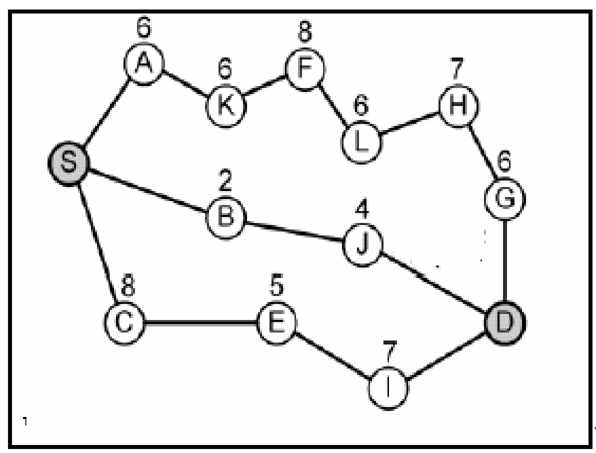

Fig. 3. A sample network for establishment of routing paths

Case 1 selects the shortest path without considering residual energy of nodes, which is the same as the AODV routing algorithm. This case does not sustain a long lifetime in the network as described. Case 2 selects a route with largest minimum residual energy to extend network lifetime but it has serious problem in terms of the hop count. Case-3 improves the drawbacks of Case 1 and Case 2 by considering both residual energy and hop count. It extends network lifetime by arranging almost all nodes to involve in data transfer. The proposed protocol also selects a route with the longest lifetime in the network without performance degradation such as delay time and node energy consumption.

5 Results:

We have Simulated the network using NS2 simulator. Simulations are carried out for various speeds starting from 0 (no mobility) to 80 m/sec.

The network parameters selected for our work are :

Node initial energy	1.000 J
Receive Power	300 mW
Transmit Power	600 mW
Topography	670 x 670
Packet send rate	4
Number of connections	10
Pause time	600
Speed	0 – 80 m/sec
Application	CBR

The sample graphs for a speed of 40 m/sec are shown in Fig. 4.

From Table 2 we can say that, AODVM gives increased network lifetime without greatly affecting average delay and energy consumption. The simulation reveals that the performance of AODVM and AODVEA come out to be superior to AODV as far as the node life time is concerned. As the mobility of the node increases, the life time also improves with marginal increase in delay and energy consumption. The advantage is not obvious beyond a speed of 60m/sec. The proposed algorithm is simple and adds an overhead of a couple of bites to store the hop count and minimum energy.

Table 2: Comparison of modified and existing routing protocols

Parameters	AODV	AODVEA	AODVM
Lifetime	Minimum	Medium	Maximum
Average Delay	Less	High	Medium
Energy consumption	Less	High	Medium

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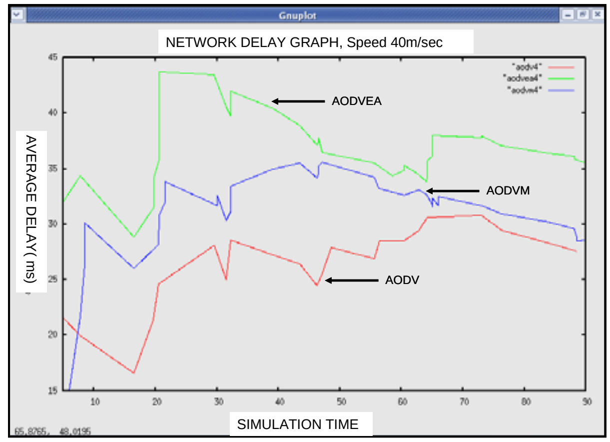
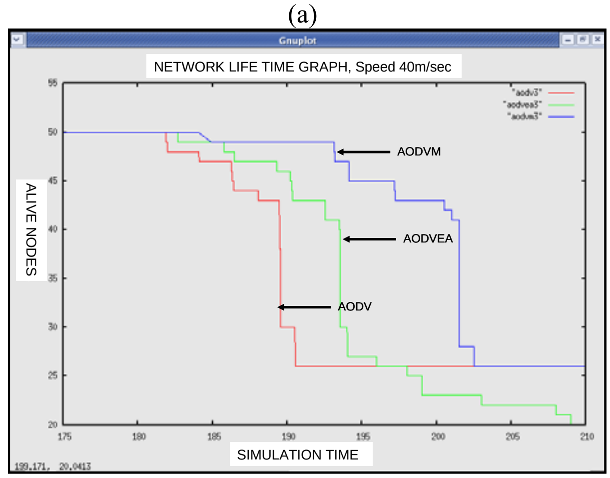
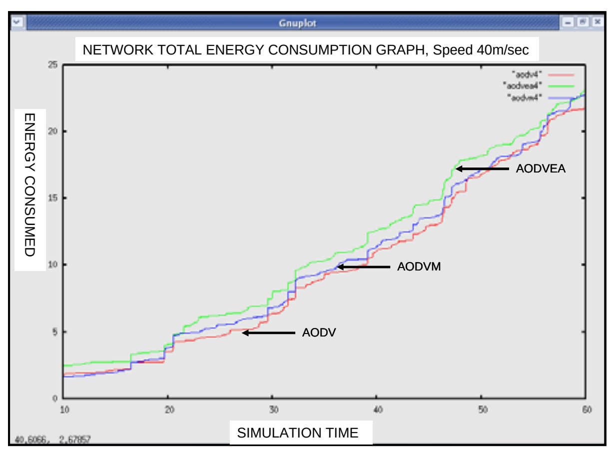


(a)



(b)



(c)

Fig. 4 Comparison of AODV, AOVDVEA and AODVM
(a) Node life time (b) Average delay (c) Energy consumption

6 Conclusion

In this paper, the brief survey of ad-hoc routing protocols is provided. From them AODV is chosen for further enhancement. The importance of energy conservation in ad hoc routing is explained. Then the routing is done based on the metric of the remaining energy in energy aware AODV. The modified AODV performs routing based on both hop count and minimum remaining energy. From the simulation performed for various scenarios, the following conclusions can be made.

Network Lifetime: Modified AODV has the maximum lifetime compared to AODVEA and AODV.

Average Delay: AODVM has average delay less than energy aware AODV but it is more than AODV.

Energy Consumption: AODVM consumes less energy as compared to AODVEA but it is slight more than AODV

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The work can be extended for other parameters such as throughput, packet delivery ratio. This approach of routing using a combination of Hop count and remaining energy will give much better performance for longer simulation period. Simulations are required to be done for other parameters such as link capacity combined with the route selection logic so that overall QoS of wireless network can be improved.

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