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Implementing Energy Efficient Maximum Network Lifetime Ad Hoc Routing in AODV

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Abstract: A Mobile Ad hoc Network (MANET) is a self-configuring infrastructure less network of mobile devices connected by wireless. The most challenge in MANETs is the mobile infrastructure in which nodes can join and leave easily with dynamics requests without a static path of routing. And also energy efficient routing is most important because each node has its own battery power which decides the life time of a node. Failure of one node may affect the entire network. If a node runs out of energy the probability of network partitioning will be increased. Since, every mobile node has limited power supply, energy depletion has become one of the main threats to the lifetime of the ad hoc network. By proposing an energy saving protocol known as Energy Efficient Maximum Lifetime Adhoc Routing in AODV Routing (EEMLAR) which concentrates on increasing network life time by integrating the advantages of transmission power control approach and load sharing approach. This contradicts the 'increment in life time of the network' and also may affect other existing routes. In this study, researchers propose a new route discovery mechanism which considers the presence of the node in other routes and its effect on its lifetime. The proposed protocol ensures route with maximum life time and also maximizes its life span.

Key words: Energy efficient routing, energy consumption, mobile ad hoc networks, network lifetime, optimization

INTRODUCTION

Wireless ad hoc network consist of a collection of mobile nodes, capable of communicating with each other and forming a dynamically changing network with no infrastructure. In order to route packets to a destination node, each node in the wireless ad-hoc network has to use other nodes in the network as relays. It is therefore, essential that the nodes in the network establish routing among themselves. A number of routing protocols have been discussed to enable routing in such an environment (Perkins and Bhagwat, 1994; Garcia-Luna-Aceves and Madruga, 1999).

Many routing protocols have been proposed for ad hoc networks. The mechanisms they adopt are traditionally categorized as table-driven and on demand. On-demand routing protocols query a route when there is a real need (demand) for it. In contrast, table-driven routing protocols maintain routing information for all network destinations independently of the traffic to such destinations. The features of source routing, effective route discovery and route maintenance made reactive (or on-demand) routing protocols attempt to reduce the amount of control overhead disseminated in the network by determining routes to a destination when it is required. Most ad hoc mobile devices today operate on batteries and hence power consumption becomes an important issue. In AODV, there is less consideration of power consumption and network life time.

This reason made the energy efficient routing and energy saving protocols to be proposed and studied extensively in recent years. One of such energy saving protocol is EEMLAR. In EEMLAR, the nodes which has a 'tendency' to 'die out' very soon are avoided during the route discovery phase. The 'tendency' of the node to 'die out' is expressed quantitatively as the ratio of the remaining battery energy and the current transmit power of the node. But there may arise some cases where a node with higher rate of depletion may be selected since this protocol does not consider traffic through the node. This leads to quick die out of the node also affecting other routes through the node. Researchers propose an efficient route discovery mechanism for EEMLAR which helps in selecting a route with maximum life and also maximizes its life span further by reducing the power consumption.

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MANET ROUTING PROTOCOLS

Figure 1 depicts three types of routing protocols in MANET: table driven, on-demand driven and hybrid routing protocol (Perkins and Bhagwat, 1994).

Table driven protocol (proactive): These protocols are also called as proactive protocols since they maintain the routing information even before it is needed. Each and every node in the network maintains routing information to every other node in the network. Routes information is generally kept in the routing tables and is periodically update as the network topology changes.

On demand routing protocols (reactive): In order to overcome limitations of the proactive protocols in mobile environments, reactive protocols such as AODV, TORA, DSR and ABR are used. These protocols are also called reactive protocols since they do not maintain routing information or routing activity at the network nodes if there is no communication. If a node wants to send a packet to another node then this protocol searches for the route in an on-demand manner and establishes the connection in order to transmit and receive the packet. The route discovery usually occurs by flooding the route request packets throughout the network. In on demand protocols, query/response packets are used to discover (possible more than) one route to a given destination. These control packets are usually smaller than the control packets used for routing table updates in proactive schemes thus causing less overhead (Perkins and Bhagwat, 1994).

Hybrid routing protocols: Hybrid routing protocols combine table based routing protocols with on demand routing protocols. They use distance-vectors for more precise metrics to establish the best paths to destination

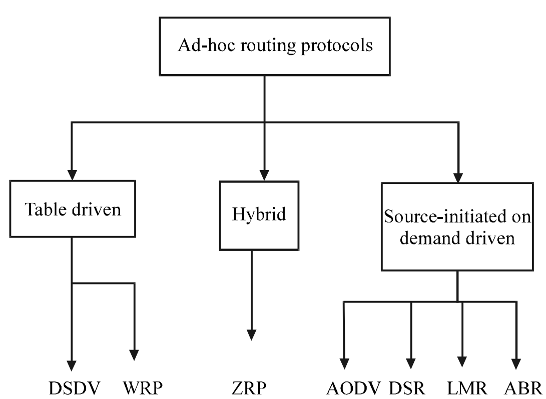

Fig. 1: Classification of routing protocol

networks and report routing information only when there is a change in the topology of the network. Zone Routing Protocol (ZRP) is an example of a hybrid routing protocol (Prakash *et al*., 2010).

These three routing protocols are further divided into several protocols. Among all these protocols, AODV is being considered for energy efficiency. AODV is supposed to be better for this purpose because it is on-demand with route maintenance phase in its process.

LITERATURE REVIEW

AODV based energy efficient routing protocol for maximum lifetime in MANET: The remaining energy of the nodes participating in the path between the source and the destination is accumulated and delivered to RREQ message by adding a new field to the RREQ message (using 11 bits of the reserved filed). In this case, RREP reply message is not given by the destination node immediately to RREQ arrive first but waits for 3* NODE_TRAVERSAL_TIME, receives RREQ destined for the node and adds the energy of nodes participating in the path. By dividing the whole energy calculated into the number of nodes participating in the network which is obtained using the hop counter by this the mean energy of nodes in network on the participation path is calculated (Chang and Tassiulas, 1999).

Energy efficiency of load balancing in MANET routing protocol: The node caching enhancement of AODV is discussed which is presented by Jung *et al.* (2005). The adaptive workload balancing technique applied to MANET routing protocol by Lee and Riley (2005). Finally, they present a new node caching AODV with adaptive workload balancing which combine the protocols from Jung *et al.* (2005) and Lee and Riley (2005). Workload-based asssdaptive load balancing technique is based on the idea that by dropping Route Request packets (RREQ) according to the load status of each nodes, nodes can be excluded from route paths. This algorithm uses the length of the message queue in nodes and the outstanding workload which is defined as the combination of the queue length and residence time of packets in the queue.

Enhancing the performance of MANETs by monitoring the energy consumption and use of mobile relays: The rate of energy consumption with a node having multiple thresholds. So, for heavy load application (high rate of energy consumption like video) the threshold may be set high. On reaching this threshold the node becomes critical. At this point, the service of a mobile relay is required to balance the load (Gui and Mohapatra, 2003).

Remaining-energy based routing protocol for ad hoc network: Remaining-Energy Based Routing (REB-R) protocol leads nodes towards broadcasting their energy level alongside the data to their neighbors and the nodes choose their parents with highest energy level and forward data to it. They proposed A node broadcasts two types of packets. First one is FWD_ROUTE and the other one is DATA. For these two types, researchers use a bit to distinguish packet's type and the mentioned bit is "type" bit. For "energy" part, single precision floating point numbers or number of residual packets could be used (Margi and Obraczka, 2004).

A novel energy-efficient approach to DSR based routing protocol for ad hoc network: An energy efficient routing protocol NCE-DSR (Number of times nodes send Constraint Energy DSR) this protocol is based on DSR and marks related to the number of times of sending message are added to the datagram for routing protocol. The nodes with relatively more number of times of sending message are protected when in use; routing cost function is designed for route choice to prolong the survival time of each node and that of the whole network.

An energy efficient flat routing protocol for wireless adhoc network: A new routing protocol is designed known as Energy Efficient Dynamic Source Routing (E2DSR) that is energy efficient (Talooki *et al*., 2009). Energy efficiency is a critical issue for battery-operated mobile devices in ad hoc networks. As mentioned, unbalanced power consumption may not only result in earlier node failure in overloaded nodes but also lead to network partitioning and a decrease in route reliability (Yu *et al*., 2003). So, there is a need to both improve energy efficiency and balance battery consumption among nodes in MANET to reduce the number of critical nodes in the network.

Conventionally used algorithms such as DSR (Johnson and Maltz, 1996) and AODV (Perkins *et al*., 2003) do not take care of energy in nodes in determining a route that leads to an imbalance of energy level in the network. Some nodes die out soon as they are used in most of the packet transmission paths and on the contrary, there are nodes that are not used even a single time. This energy imbalance affects the reliability of the system. The proposed algorithm involves energy metrics that help in finding out such a routing path that does not leave nodes exhausted and that selects a better energy saving path. The algorithm tries to establish a balance of energy among the nodes. It also provides a mechanism by which an administrator can adjust parameters such as energy and time saving. For example, at the start the administrator may wish to have a routing policy more suitable for time saving and after some duration, she might switch to energy saving.

PROPOSED ALGORITHM

Design criteria considered in the algorithm:

- Keeping track of the residual battery power
- Keeping track of previously used paths
- Keeping back-up paths
- Keeping track of the message overhead
- On-demand calculation/update of routing tables
- Sending data packets at a lower energy compared to the RREP/RREQ
- Moving the nodes to sleep mode when they are not being used
- Requiring a node to send packets with energy
- Proportional to the distance rather than with fixed energy
- Using a hierarchical routing technique
- Using directional antennas
- Transmitting the data packets by taking into
- Consideration the actual amount of energy required to transmit

Need to prolong ad hoc network lifetime: A key challenge in ad hoc wireless network is achieving a long lifetime of nodes that carry limited amount of battery energy. It could be impossible or inconvenient to recharge the battery in the remote location therefore, the crucial requirement is to prolong the network life time.

Energy Efficient Maximum Lifetime Ad hoc Routing (EEMLAR): The power level of each node while calculating the route is in order to increase the network life. Whenever a node is involved in any routing, it loses some amount of energy whose value depends on factors such as the nature of packets, their size and the distance between the nodes. An optimization function considers all these factors and decides which one, amongst all the discovered paths should be selected for an energy-efficient transmission.

In all the earlier algorithms, there is a high probability of repetitively selecting a particular node (the "best node" according to some criterion) which can lead to early exhaustion of the node, thereby affecting the network connectivity. However, by considering individual battery power in considering the path that is if there is a path with a node having very low energy level, then optimization function does not choose that path, irrespective of whether that path is time efficient. Also, the number of hops is an important criterion as the large number of hops will help in reducing the range of power transmission and

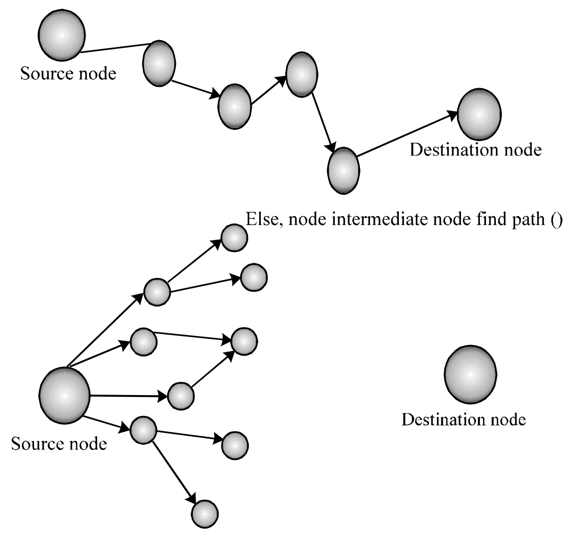

Fig. 2: Data transmission from source to destination node

thus saving energy. Time is also a criterion as the lower the time, the shorter will be the path and the lower will be the total amount of energy consumed. But some nodes might get overused and die out quickly (Fig. 2).

Optimization function: The objective is to find out best energy efficient algorithm that will lead to the maximization of system lifetime. The energy cost function for selecting the energy efficient path is calculated by:

$$\text{Cost} = \text{Time} + \frac{1}{\text{RE}} + \frac{1}{\text{NH}}$$

Where:
RE = Remaining energy of node in route
NH = Number of Hops

Time: It is the simulation time taken by RREQ to reach the destination from the source for a particular route.

Remaining energy of node in route: It is the sum of the remaining energy available at all the nodes in the route under consideration.

Number of hops: It is the total no. of nodes present in the route under consideration. When a source node wants to transmit data to destination, first it looks whether there is any existing valid (whose entry has not expired) path in the routing table. If it exists, the node uses that path. Otherwise, it sends RREQs to its neighbor nodes. When a node (either destination or intermediate) receives RREQ, it ensures that the received RREQ is not a duplicate RREQ, in order to prevent looping paths. If the neighbor node is the destination, it sends RREP.

Otherwise, the neighbor nodes see whether they have any valid path in their tables. If they do, they forward RREQs to that path. Otherwise, they send new RREQ to all their neighbor nodes to find the destination. When the destination gets the first RREQ, it waits for ∂T time and collects all other RREQ coming in this time interval. After time, it calls the optimization function to determine the best path to select and send RREP. It also stores some other relatively inferior paths as backup paths which may be used if there is some network failure, thereby avoiding energy and time wastage in recalculating the path. When the source gets the RREP, it sends the data packets.

The criterion for setting the value of ∂T: ∂T is the time for which the destination node should wait for other RREQ packets after getting the first RREQ. ∂T is determined by the density of the node. If density is high, the value of this parameter should be less, as compared to partially isolated network. The value of this parameter should be optimum for energy saving as it will help in finding more optimum paths and also in preventing the case of waiting in excess or in short time.

SIMULATION ANALYSIS AND RESULTS

Researchers propose a New-AODV protocol which extends the entire network lifetime in an Ad-hoc network environment through NS-2. Each mobile node, by nature has an important role in an Ad-hoc network. Particularly, each node's energy state has a huge influence on the entire network lifetime. Researchers attempted to extend the entire network lifetime by adjusting RREP delay. As a result, researchers know that applying Energy Efficient Maximum Lifetime Ad-Hoc Routing (EEMLAR) to AODV protocol via NS-2 does have a positive result in extending the entire network lifetime. Researchers selected a 2000×2000 m dimension area with 20, 30, 40, 69, 80, 100 nodes. A node's location was set to be random and the nodes have a random speed varying from 0-10 m sec^{-1}.

The main objective of designing EEMLAR was to increase the network life by distributing the network load and selecting paths containing nodes with higher power levels. Figure 3 shows the total energy consumed in different sessions by AODV and EEMLAR.

Energy consumed: EEMLAR does not perform too well in the beginning as compared to AODV but it improves later. Initially, it is not better than AODV because, initially, all the energy of the nodes are equal. So, researchers uselessly wait for δt time as all paths have equal energy

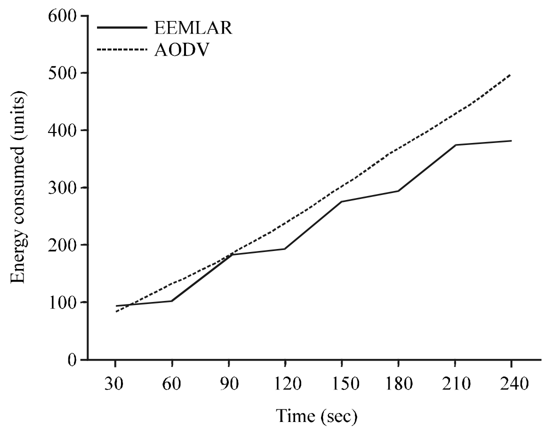

Fig. 3: Energy consumed vs. simulation time in AODV and EEMLAR

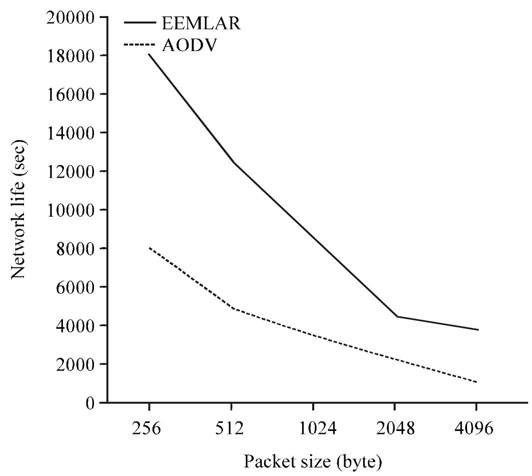

Fig. 4: EEMLAR vs. AODV in increasing network lifetime

in the beginning. AODV does not wait for time and is thus better performing in the beginning. But at a later stage as time increases, there is some imbalance of energy that comes into play and then the algorithm's effect comes into play.

Network lifetime: Researchers can see that energy consumed in EEMLAR is less compared to AODV. Figure 4 shows the trend in the network life. Network life was observed to be proportional to the energy left in the nodes. It was also observed that EEMLAR increases the network life by avoiding the repeated usage of nodes.

Figure 5 shows the available power level of the nodes in the paths selected by EEMLAR and AODV. It was observed that AODV, during the path selection, selects nodes 8, 12, 14 and 18 and it does not choose nodes 10, 13, 15 and 16. Researchers can see there is a great node energy variance in AODV.

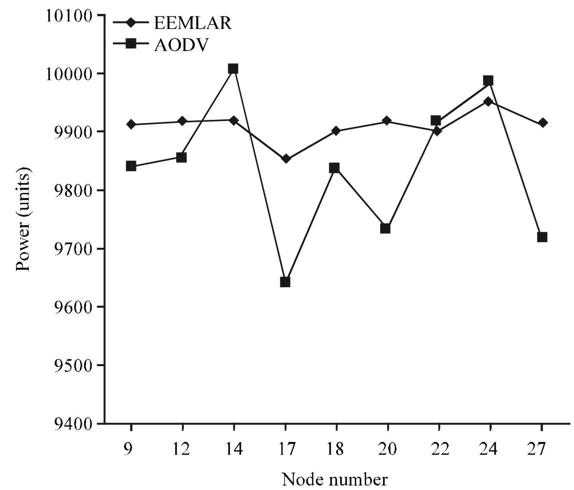

Fig. 5: EEMLAR vs. AODV in available power level of the node in selected path

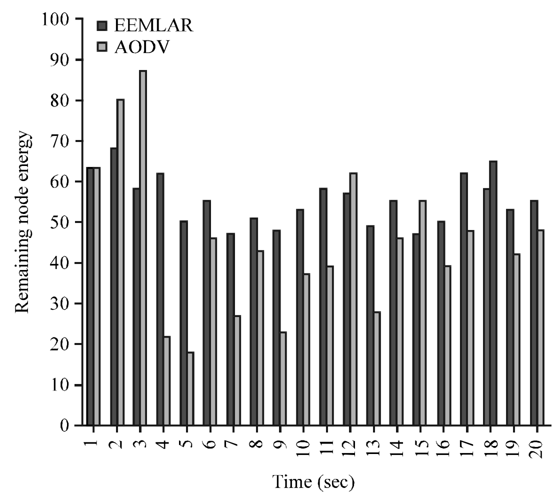

Fig. 6: EEMLAR vs. AODV in remaining energy of all nodes at the end of simulation

When, researchers repeat this experiment with EEMLAR, researchers can see all nodes energy level taken in the path have little variance. Researchers did this experiment with 30 nodes and found that AODV chooses the same nodes every time irrespective of there being a danger of some node getting depleted of energy faster (nodes 8, 12, 14 and 18, in this case). On the other hand, EEMLAR keeps changing path as time goes on and maintains the energy load balance.

Remaining node energy: Figure 6 shows the remaining node energy defines the amount of remaining energy of all nodes at the end of simulation. Simulation results from the graph show that in EEMLAR energy consumed from each node is almost same, whereas in case of AODV, energy consumed at various nodes has very large variations. Some nodes are almost exhausted, whereas some nodes have large amount of energy remained, in case of AODV. This happens because AODV chooses same node every time whereas EEMLAR tries to find optimal energy efficient path every time.

CONCLUSION

The simulation results showed that the algorithm performs better than the popular conventional on demand routing algorithm, AODV, in the following respects:

- Network life increases as researchers save energy in the individual nodes by providing load balancing. Thus, implicitly, the network life increases as well
- Energy consumed: total energy consumed by the algorithm is much less compared to AODV

RECOMMENDATIONS

Future research should also investigate the feasibility of applying different techniques to improve the performance of the proposed approach. Introducing the advantages of clustering and directional antennas in the approach and keeping their harmful effects away should also be studied. The problem of automatically updating the workload and node requirements in the network should also be studied. In this study, energy efficient maximum lifetime ad-hoc routing EEMLAR has been introduced that provide energy efficient path for data transmission and maximize the lifetime of entire network. In simulation scenario, researchers have consider 20-100 nodes that can communicate with in ad-hoc network. For large scale network where more number of nodes can communicate with the creation of an ad hoc network. Then, researchers require an specific problem definition and routing algorithm required.

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