A Reliable Power Aware Routing Scheme for Mobile Ad Hoc Networks

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Abstract - One important characteristic of MANETs is that the nodes are energy-constrained. Since, nodes are battery-operated, recharging frequently or replacing batteries may become undesirable or even impossible. The nodes in Mobile Ad-hoc Networks (MANET) are limited battery-powered. This not only leads to degradation in performance of the network but also reduces the lifetime of the network and in some cases makes the network partitioned. In order to maximize the lifetime of MANETs, routes having nodes with low energy and nodes with more buffered packets should be avoided. So, the energy efficiency is one of the primary metrics of interest. Energy efficient routing in MANETs is considered as a major issue.

In this Paper, a new energy efficient scheme in the routing protocol for mobile ad hoc network has been proposed which will efficiently utilize the battery power of the mobile nodes in such a way that the algorithm improves the network energy consumption and increases the lifetime of the network. The popular on demand routing protocols use shortest path between sources to destination without considering the energy of the intermediate nodes in the path. The proposed algorithm not only considers energy of the node while selecting the route but also takes into account the number of packets buffered in the node. More number of buffered packets means remaining energy will be less and time taken to deliver a packet will be more.

Keywords - Energy Efficient Routing, Packet buffered, Remaining energy, Mobile ad hoc network, Routing Protocol.

I. INTRODUCTION

MANET has emerged as one of the most focused and thrust research areas in the field of wireless networks and mobile computing. In ad hoc mobile networks, routes are mainly multi hop because of the limited radio propagation range and topology changes frequently and unpredictably since each network host moves randomly. Therefore, routing is an integral part of ad hoc communications. Many routing protocols are proposed for MANET. The protocols are mainly classified in to three categories: Proactive, Reactive and Hybrid. Proactive routing protocols attempt to maintain consistent, up-to-date routing information from each node to every other node in the network. Reactive routing protocols create routes only when desired by the source node. Once a route has been established, it is maintained by a route maintenance procedure. Hybrid Routing Protocol which combines the merits of proactive and reactive approach and overcome their demerits.

Nodes in Ad Hoc networks should be enabled to manage efficiently their energy consumption to prolong the network lifetime [1]. The energy consumption of each node varies according to its communication state: transmitting, receiving, listening or sleeping state. Any power failure of a node will affect the overall network lifetime. As a result, energy efficiency should be taken into consideration as it is a critical and extensive research issue. Mobile phones, laptops and PDAs are the devices used as nodes in MANETs, as shown in figure 1. Researchers and industry both are working on the mechanism to prolong the lifetime of these devices. Hardware manufacturers are also coming forward to help in saving the battery power by making energy efficient devices like energy efficient CPUs, low power display units, efficient algorithms for hardware processing and high density batteries.

Fig. 1. Mobile Ad hoc Network

One important characteristic of MANETs is that the nodes are energy-constrained. Since, nodes are battery-operated, recharging frequently or replacing batteries may become undesirable or even impossible. The nodes in Mobile Ad-hoc Networks (MANET) are limited battery-powered. This not only leads to degradation in performance of the network but also reduces the lifetime of the network and in some cases makes the network partitioned. In order to maximize the lifetime of MANETs, routes having nodes with low energy and nodes with more buffered packets should be avoided. so, the energy efficiency is one of the primary metrics of interest. Energy efficient routing in MANETs is considered as a major issue.
Many minimum energy (energy-efficient) routing protocols have been proposed in recent years. However, very limited effort has been made in studying routing overhead, route setup time, and route maintenance issues associated with these protocols. Without a careful design, an energy-efficient routing protocol can perform much worse than a normal routing protocol. These protocols can be generally classified into two categories: Minimum Energy routing protocols [2] and Maximum Network Lifetime routing protocols [3]. Minimum Energy routing protocols search for the most energy-efficient path from the source to the destination, while Maximum Network Lifetime routing protocols attempt to balance the remaining battery-power at each node when searching for the energy-efficient path. Since Minimum Energy routing scheme is also an important part in most recent Maximum Network Lifetime routing protocols such as Conditional Max-Min Battery Capacity Routing (CMMBCR) and Conditional Maximum Residual Packet Capacity (CMRPC) routing [4].

In this paper, a new reliable power aware routing scheme for mobile ad hoc network has been proposed which will efficiently utilize the battery power of the mobile nodes in such a way that the algorithm improves the network energy consumption and increases the lifetime of the network. The popular on demand routing protocols use shortest path between sources to destination without considering the energy of the intermediate nodes in the path. This can lead to path breakage if any node runs out of energy. The proposed algorithm which not only considers energy of the node while selecting the route but also takes into account the number of packets buffered in the node as well as shortest routing path. More number of buffered packets means remaining energy will be less and time taken to deliver a packet will be more. Proposed algorithm more timely path setup and efficient route maintenance, that try to find the optimal route during route discovery phase and maintain the route reactively.

II. ENERGY EFFICIENT ROUTING ALGORITHMS FOR MANET

Energy Efficient Routing Algorithms [10] are not just related to minimize the total energy consumption of the route but also to maximize the lifetime of each node in the network to increase the lifetime of the network. The main purpose of energy efficient algorithm is to maintain the network functioning as long as possible. In MANTEs energy consumption is done in three states of the nodes which are transmitting, receiving and sleeping state. Nodes consume more energy while transmitting than in sleep state. Sleep state means nodes are idle, in which they neither transmit nor receive any signals. More energy can be saved by keeping more nodes in sleep state.

The energy consumption of nodes should be minimized not only during the transmission but also during sleep state to accomplish the network functioning goal. In [11] authors have mentioned some energy related metrics in which the energy efficient routing can be found. The metrics are as following:

- Minimize Energy consumed per packet: the most intuitive metric, however not optimal for maximum lifetime.
- Maximize Time to Network Partition: important for mission critical applications. hard to maintain low delay and high throughput simultaneously.
- Minimize Variance in node power levels: balance the power consumption for all the nodes in the network i.e. all nodes in the network have the same importance.
- Minimize Cost per packets: try to maximize the lifetime of all the nodes.
- Minimize Maximum Node Cost: try to delay the node failures.

There are so many algorithms in which they prolong the lifetime of the network and give the energy efficient routing. These algorithms are classified into two categories which are i) Minimizing Total Transmission power ii) Maximizing Network lifetime. Minimizing Total Transmission power algorithms focuses on minimizing the total transmission power that is used to send packets from source to destination. These algorithms don’t consider the power loss at receiver side and select the route with large number of hops. Maximizing Network lifetime algorithms use average residual battery level of entire network or individual battery power of a node. Algorithms achieve goal of maximizing network life time by distributing the forwarding load over the multiple paths, making some nodes in sleep state and by balancing the traffic load inside the MANET.

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In [15], PEER is a cost-based energy-efficient routing protocol. In a cost-based routing protocol, the total cost of all the links on each available path between the source node and the destination node will be calculated, and a minimum cost path (meeting certain criteria) will be selected. As link cost is very important in the cost-based energy-efficient routing protocols, it is critical to derive an accurate link cost metric to obtain an optimal path. Here derive the link cost and show how to estimate the parameters needed for link cost calculation. Two MAC schemes have been specified in IEEE 802.11 Distributed Coordination Function (DCF) and Point Coordination Function (PCF). As PCF is a centralized protocol, here only consider DCF at MAC layer in this paper as it will be used to work with PEER. For better describing our link cost model, IEEE 802.11 DCF is based on Carrier Sensing Multiple Access with Collision Avoidance (CSMA/CA) mechanism. It consists of two carrier sensing schemes, namely physical carrier sensing and virtual carrier sensing. The virtual carrier sensing scheme is implemented with Network Allocation Vector (NAV). If a node receives a packet (such as RTS, CTS, and DATA packet), it will update NAV with the duration included in the received packet. The NAV value indicates when the on-going transmission session will end. If a node has data packets to send to another node, it first checks its NAV. If its NAV is larger than 0, it has to wait until NAV reaches 0. After that, the sender transmits a RTS packet after the channel is available for a period longer than DCF Inter Frame Space (DIFS) or the back off timer reaches zero. The receiver responds with a CTS packet after receiving the RTS packet. If the sender does not receive the CTS packet within a predetermined time interval, it will retransmit the RTS packet. After receiving the CTS, the sender will send out the data packet and the receiver will reply with an ACK packet after receiving the data packet successfully. If the sender doesn’t receive the ACK packet within a predefined time period, the whole Process will be repeated.

Performance in cooperative ad hoc networks. In [21], introduce a new topology control problem: energy-efficient topology control problem with cooperative communication, and topology control algorithm to build cooperative energy spanners in which the energy efficiency of individual paths are guaranteed. The algorithm can be performed in distributed and localized fashion while maintaining the globally efficient paths. In [23], the authors introduce an energy-efficient cross-layer design for the network layer and medium access control (MAC) layer that reduces energy consumption and prolongs network lifetime.

In the network layer, minimum transmission energy consumption (MTEC) routing protocol is used for selecting the MTEC path for data transmission, based on the proportion of successful data transmissions, the number of channel events, the remaining node energy of nodes and the traffic load of nodes. The authors design an adaptive contention window (ACW) for the MAC layer that provides nodes with high successful transmission rates with greater opportunity for contending for a channel to save energy.

III. POWER AWARE MULTICAST ALGORITHM FOR MANET

The power-efficient-multicast algorithms are tree-based and cluster-based. In tree-based algorithm, it uses pruning rules to construct a power-efficient-multicast tree. Based on the number of sources, the tree-based-multicast algorithm is further divided into single-source and multicast-source algorithms. The single-source-multicast algorithms are Multicast Incremental Power (MIP), S-REMIT, and RBIP reviewed in [11]. The MIP and S-REMIT algorithms used pruning rules to construct a power-efficient-multicast tree. The RBIP algorithm considers a reliable multicast tree and takes re-transmission cost (energy consumption). G-REMIT is also reviewed in the Tree-based multicast. It is mainly designed for multiple source energy efficient multicast trees [12]. The REMiT Algorithm is minimizing the energy-consumption and maximizes the network lifetime. In G-REMIT model, it minimizes the energy-consumption for group-shared trees. L-REMIT model maximizes the network lifetime for source-based trees. [13] Presented a power-aware-multicast reactive algorithm for MANETs. It uses the power-aware metrics to extend the lifetime of node and network. In [14], it proposed a Maximum Lifetime and Minimum Hop-Count (MLMH) algorithm for maximizing lifetime of source-based multicast tree. The MLMH model defines a new metric called Energy Efficiency Metric (EEM). The EEM model is summation of relative increment of lifetime and hop-count values.

Lifet ime-Aware- Multicast-Tree (LAM) algorithm maximizes a multicast lifetime by finding a route that minimizes variance of the remaining energies of the nodes in the network [15]. Prioritized-overlay-multicast algorithm aims to improve the efficiency and robustness of the overlay multicast in the MANET by building multiple role-based- prioritized trees [16]. Usually, it takes the benefit of location information. Multicast Ad hoc On-demand Distance Vector protocol (MAODV) [17] and it is an extension of multicast AODV.
In MAODV, all members of multicast group are formed into a tree and the root of the tree is group leader. The multicast data packets are propagated among the tree. The core of MAODV protocol is used to form the tree, repair the tree when a link is broken and how to merge two previously disconnected trees into a new tree. Multiple Path Multicast Ad hoc On demand Vector (MP-MAODV) [18] is a multipath routing protocol extension based on MAODV. It is based on multipath selection and establishment, multipath route maintenance and load distribution for distributing traffic among node-disjoint paths. It is create bi-directional-shared multicast tree, which connecting multiple sources and receivers. The MAODV is a shortest routing, that is, the least hops routing, whereas MP-MAODV is creating multiple routes from the source to the destination used to provide a backup route.

IV. PROPOSED RELIABLE POWER AWARE ROUTING SCHEME

A RPAR finds the most stable path out of the entire existing paths from source to destination using on-demand routing. The popular on demand routing protocols use shortest path between sources to destination without considering the energy of the intermediate nodes in the path. This can lead to path breakage if any node runs out of energy. The algorithm which does not always choose only the shortest path between source and destination but choose such routing path that nodes have the maximum residual energy as well as shortest path and algorithm which not only considers energy of the node while selecting the route but also takes into account the number of packets buffered in the node. More number of buffered packets means remaining energy will be less and time taken to deliver a packet will be more.

A. Algorithm for Route Discovery process in RPAR

- When any node has data to send, it generates route request packet (RREQ) and floods it on the network with a common transmission range.
- The route request packet should carry two pieces of information: hop count and energy consumption.
- Search for all shortest (Minimum hops) routes.
- Among the shortest paths pick the route on which nodes have the maximum residual energy as well as minimum number of packets buffered in the node.
- Destination node sends the route reply packet (RREP) on selected route.
- The proposed scheme adds the following parameters in the header of route reply packet.
  1. Residual Energy Status (RES): the residual energy of the node.
  2. Buffered Packets (BP): the number of packets buffered in the node.

The algorithm does not always choose the shortest path between source and destination but chooses such routing path that has nodes with maximum residual energy as well as minimum number of packets buffered in the node among the shortest paths. In figure 3, nodes with blue color have more than 50% of remaining energy and nodes with light blue color (2 & 6) have less than 50% of remaining energy. The small circle with the nodes gives the number of buffered packets. As shown in figure 3, the shortest path from source node 1 to destination node 9 chosen by AODV is 1-2-3-9 (shortest hop), but due to low residual energy of node 2, it is not chosen. Node 5 and 6 also lie in the transmission range of source node 1. Out of the two, node 5 is chosen as it has the maximum residual energy, minimum packets in buffer and also it is nearest to source node 1. Thus the route 1-5-7-8-9 will be selected on the basis of above mentioned algorithm, which is more reliable and number of packets can be transferred before any node dies.

Fig. 2. Reliable Power Aware Routing Scheme

B. Residual Energy Model

The energy consumed \( e_c(T) \) by a node after time \( T \) is calculated as

\[
e_c(T) = n_i \times a + n_i \times b \hspace{1cm} \text{(1)}
\]

Where, \( n_i \) and \( n_i \) are number of packets transmitted and received by a node after time \( T \) respectively, \( a \) and \( b \) are constants with value between 0 and 1.

The residual energy \( e_r(T) \) of a node at time \( T \), is calculated as

\[
e_r(T) = e_i - e_c(T) \hspace{1cm} \text{(2)}
\]

Where, \( e_i \) is the initial energy of a node [19].

The residual energy of the node is calculated using equation (2).

Residual Energy Status (RES) is found as
If (Residual energy) < 50%
Then set RES = 0
If Residual energy > 50%
Then set RES = 1
In this section, it discusses some of the simulation parameters to measure the network performance.

A. Simulation Environment

The proposed model has considered an area of 1,000 mts x 1,000 mts with a set of nodes placed randomly. It simulated by using Network Simulator (NS-2.33). Here, each node is initially placed at a random position within the defined area. As it progresses, each node pauses current location for 2 sec and then randomly chooses new location. Each node maintains its behavior, alternately pausing and moving to a new location during the simulation time. The simulation parameters are shown in table I.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topology area</td>
<td>1,000 x 1,000 mts</td>
</tr>
<tr>
<td>Simulation time</td>
<td>2,000 sec</td>
</tr>
<tr>
<td>Traffic type</td>
<td>CBR</td>
</tr>
<tr>
<td>CBR packet size</td>
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</tr>
<tr>
<td>Node mobility</td>
<td>0 to 20 mts/sec</td>
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<tr>
<td>Frequency</td>
<td>2.4 GHz</td>
</tr>
<tr>
<td>Channel capacity</td>
<td>2 Mbps</td>
</tr>
<tr>
<td>Transmission range</td>
<td>150 mts</td>
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<tr>
<td>Transmission power</td>
<td>1.400 mW</td>
</tr>
<tr>
<td>Receiving power</td>
<td>1.000 mW</td>
</tr>
<tr>
<td>Idle power</td>
<td>830 mW</td>
</tr>
<tr>
<td>Mobility model</td>
<td>Random waypoint</td>
</tr>
<tr>
<td>Voltage</td>
<td>5 V</td>
</tr>
<tr>
<td>Pause time</td>
<td>1 sec</td>
</tr>
</tbody>
</table>

VI. RESULTS AND DISCUSSION

In order to evaluate the network performance, it uses the metrics such as network lifetime & energy consumption.

A. Network Lifetime

In this experimental setup, it considered 25 nodes, which are deployed within the defined area. Number of packets sent between 5–20 packets/sec and each node moved 2 mts/sec. Group size versus the network lifetime as shown in Fig. 1. From the results, it concludes that the proposed model is always kept maximum number of nodes alive for longer period of time as compared to others. If the group size is 12, then the proposed model has kept the nodes alive for 8,150 sec, whereas the MIP model and LAM model have kept the nodes at 7,450 sec and 6,455 sec, respectively.

B. Energy Consumption

Fig. 2 shows the evaluation of Erms for different time instances. Initially, it assumed that all nodes consumed zero Fig. 2. Erms for different time instances. From the results, it concludes that the MIP model has reached at the top position as compared to both the proposed model and LAM model in terms of Erms. As on time increases the energy consumption of all nodes will increase due to mobility. Then it system requires more number of route discoveries to perform well. Consequently, it takes high energy consumption over the network.

VII. CONCLUSION

The algorithm efficiently utilizes the battery power of the mobile nodes in such a way that it will improve the network energy consumption and increase the lifetime of the network and This algorithm does not always choose only the shortest path between source and destination but choose such routing path that nodes have the maximum residual energy as well as shortest path.

This algorithm not only considers energy of the node while selecting the route but also takes into account the number of packets buffered in the node. More number of buffered packets means remaining energy will be less and time taken to deliver a packet will be more. This proposed algorithm is differed from existing algorithms.

The simulation results reported in this paper demonstrate that the proposed model improved the network lifetime by 20% on average. Extending network lifetime is accomplished by finding multicast that tends to minimize the variation of remaining energy of all the nodes.
REFERENCES


