EESRBM: Energy Efficient Stateless Receiver Based Multicast Protocol for Ad Hoc Networks

N.Muthuvairavan Pillai, J.George Chellin Chandran

Abstract- Multicast routing is used to send the information or message to a group of destination nodes simultaneously in a single transmission from the source. Multicast routing protocols typically rely on the priori creation of a multicast tree (or mesh), which requires the individual nodes to maintain state information. This multicast state maintenance adds a large amount of communication, processing and memory overhead for no benefit to the application. Hence a stateless receiver-based multicast (RBMuticast) protocol was developed that simply uses a list of the multicast member's addresses, embedded in packet headers to enable receivers to decide the best way to forward the multicast traffic. Nodes in Mobile Ad-hoc Networks (MANETs) are battery powered and hence have limited life time. This RBMuticast does not consider the energy of the nodes and hence a node may die due to its excessive utilization which can result in energy depletion problem and thereby affect overall network performance. This also makes the communication living time to decrease and communication cost to increase. Thus I have developed a stateless multicast protocol called "Energy Efficient Stateless RBMuticast protocol for Ad Hoc Networks". This protocol called EESRBM considers a hop with energy saving such that it holds low transmitting receiving costs and thereby selecting a long-lived path from source to destination. This protocol is more efficient than any of the existing multicast protocols.

Keywords- Mobile ad hoc networks, multicast routing, stateless, receiver-based communication, energy-efficiency.

I. INTRODUCTION

In our daily life, several applications require data delivery to multiple destination nodes, where the use of multicast routing is an ideal approach to manage and reduce network traffic. In order to support any type of multicast service to particular devices, the source nodes must know the locations of the multicast destination nodes. This can be provided by a service discovery protocol that sits outside the routing protocol, updating the source(s) with the current location of the sink nodes. With a service discovery protocol providing updates on the sinks' locations, the routing protocol can assume knowledge of the sinks' locations. This knowledge can be exploited to design a stateless multicast routing protocol.

In this paper, I have proposed a new stateless multicast protocol for ad hoc networks called EESBM: Energy Efficient Stateless Receiver Based Multicast Protocol for Ad Hoc Networks. It is a stateless protocol that considers the battery power of each node as important criteria while determining the route for data packet transmission.

It uses geographic location information to route multicast packets, where nodes divide the network into geographic "multicast regions" and split off the packets depending on the location of the multicast members.

Manuscript received on June, 2013.

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This protocol is called a receiver-based protocol since the relay node of a packet transmission is decided by the potential receivers of the packet in a distributed manner. The EESRBM protocol is an energy-efficient protocol since it considers a hop with energy saving. The nodes in Mobile Ad-hoc Networks (MANETs) are battery powered and hence have limited life time. Due to excessive utilization a node may die which can result in energy depletion problem and thereby affect overall network performance. To avoid this energy depletion problem due to excessive energy consumption at a higher rate and t increase the network performance this protocol considers an energy-efficient hop, i.e. a hop with low transmitting and receiving costs. This makes a long-lived path to be selected from source to destination and thereby making the communication living time to increase and communication cost to decrease.

In this, the multicast routing uses the concepts of "virtual node" and "multicast region" for forwarding packets closer to the destination multicast members and determining when packets should be split into separate routes to finally reach the multicast members. For energy efficient routing in stateless multicast, an algorithm called "Residua Energy Increasing Algorithm" is used. This algorithm calculates the remaining energy of each node and selects the node with high residua energy. If a node in the network has heavily depleted its battery power, then an alternative node would be selected for routing so that not only the power of each node is used optimally but there is an automatic load sharing or balancing among the nodes in the network. This protocol thereby helps to reduce the maintenance overhead as it is stateless and also helps to reduce the power depletion of nodes thereby making it an energy efficient stateless protocol for multicasting in ad hoc networks. This protocol is we suited for multicast applications in ad hoc networks such as Wireless sensor Networks (WSNs) and mobile ad hoc networks (MANETs).

II. RELATED WORK

Existing multicast protocols for WSNs and MANETs generally use a tree to connect the multicast members. ODMRP [1] is a mesh-based rather than a conventional tree-based and uses a forwarding group concept. Additionally, multicast algorithms rely on routing tables maintained at intermediate nodes for building and maintaining the multicast tree [2], [3]. The CAMP [4] maintains a multicast mesh instead of tree and the packets are forwarded along the shortest path from source to destination. But it creates overhead in building and maintaining multicast mesh at intermediate nodes.

The existing protocols designed for configuring energy power of each node focuses on such stateful (tree or mesh based) protocols. That is, given the geometric positions of a set of nodes in a plane, to find the transmitting power of each node, such that the energy cost of the multicast/ broadcast tree is minimized. For example, NJT and TJL [5] find a multicast tree such that the total energy cost of the multicast tree is minimized.

RBMuticast [6] is a stateless protocol that needs no costly state maintenance. Only the nodes own location and the location of the multicast members are needed for multicast packet routing. But it is no energy-efficient protocol since it does not consider the energy efficiency of the nodes.

Receiver-based communication is an opportunistic way of thinking about protocol design in that decisions are not required to be made at the sender side but instead are made at the receiver side. In receiver-based routing, decision making is deferred to the possible receivers, who make decisions in a distributed manner.

EESRBM protocol is completely different from previous protocols in that it provides the energy efficient routing in a completely stateless multicasting. It considers a hop with energy saving such that the one that o low transmitting and receiving costs. It selects the hop based on the residua energy of each hops. This makes a long-lived path o be selected from source to destination. This energy efficient protocol decreases the communication cost involved and increases the communication living time. Since it is an energy efficient routing, it reduces the energy- depletion problem and prevents the node from dying and thereby increasing the overall network performance.

III. EESRBM PROTOCOL DESCRIPTION

EESRBM is a stateless receiver based multicast protocol that uses geographic location information to route multicast packets. There are some assumptions made for this protocol. First, it is assumed that a receiver-based MAC protocol exists and the next hop of a route should be decided among potential receivers. Next, it is assumed that the receiver-based stateless multicast needs the sender node's location and the destination node's location to decide the next hop route, and that both are provided in the MAC packet.

Throughout this paper, it is assumed that the multicast members are stationary, such as multiple stationary sinks in WSNs or stationary roadside access points in vehicular ad hoc networks. The intermediate nodes can be either static or mobile. Although mobile intermediate nodes result in route breaks in conventional multicast protocols, since no multicast tree or mesh is used in this protocol, mobile intermediate nodes are supported at no additional cost in EESRBM. Mobile destinations (multicast members) create a challenging problem for multicast protocols, and its solution is out of the scope of this paper.

A. Eesrbm overview

Nodes in EESRBM create "multicast regions" centered around themselves. There are many ways to create these regions (see Section 3.3). However, a quadrants approach is used in this paper due to its simplicity and good performance, where each multicast region corresponds to one quadrant of the network, for a grid centered at the node, as shown in Figure 1. When a user initiates a request to send (RTS) a packet to a multicast group, data are passed down to the EESRBM module in the protocol stack. Once the EESRBM module gets this packet, it retrieves the group list from its group table, compares the group node's location to the multicast regions, assigns the group nodes to the multicast regions based on their locations, and using these locations, calculates a "virtual node" location for each multicast region. EESRBM replicates the packet for each multicast region that contains one or more multicast members and appends a header to each of these replicated packets. The packet header consists of a list of destination nodes (multicast members) in that region, Time to Live (TTL) value, and a checksum value.

The destination of a packet is a "virtual node" for that multicast region, which can be determined in several ways (see Section 3.4), but for simplicity it can be assumed to be the geometric mean of the locations of all the multicast members in that multicast region. At the end, all packets for all multicast regions are inserted in the MAC queue, and finally broadcasted. The nodes for forwarding the packets are selected based on the energy efficiency of the nodes (see Section 3.5). The procedure for transmitting packets is summarized in pseudo code in Algorithm 1.

Algorithm 1. EESRBM Send

Require: Packet output from upper layer

```
Get group list N from group table
for node n in group list N do
   for multicast region r in 4 quadrants
    regions R do
       if n ε r then
          Add n into r. list
      end if
   end for
end for
for r ε R do
  if r. list is non-empty then
    Duplicate a new packet p
  Add EESRBM header (TTL, checksum,
    r. list) to p
  Insert p to MAC queue
  E= Tc + Rc
  Forward packet node to node with low transmitting
and receiving cost
  end if
end for
```

When a node receives a packet, the packet is passed up to the EESRBM protocol. The EESRBM first checks the checksum value in the packet header. If there is any corruption in the packet, then it drops the packet. It also drops the packet if it is not in the forwarding zone. The forwarding zone is the area within the radio range of the sender that has a smaller distance to the destination than the sender-destination distance.

After a node receives a multicast packet, it then retrieves the destination node list from the EESRBM packet header. It then checks if it is inside the destination list. If this node is inside the destination list, it removes itself from the list and passes a copy of the packet to the upper layers in the protocol stack. The EESRBM then checks the TTL value and if the TT value is lower than 0, then it drops the packet. Finally, if there still remain nodes in the destination list, multicast regions and virtual nodes are recalculated, and new packets are generated if required. The packets (one per multicast region that contains multicast members) are then inserted in the MAC queue for transmission. The procedure executed after receiving packets is summarized in pseudo code in Algorithm 2.

Algorithm 2.EESRBM Receive

Require: Packet input from lower layer

```
Calculate checksum. Drop packet if error
  detected
Drop packet if not in forwarding zone
Get destination list D from packet header
for node d in destination list D do
```

```
if I am d then
Duplicate the packet and input to  upper layer
  Remove d from list D
   end if
end for
if TTL in header ¼ 0 then
 Drop the packet
   return
end if
for d ε D do
 for multicast region r in 4 quadrants regions R do
   if d ε r then
   Add d into r. list
   end if
 end for
    end for
    for r ε R do
    if r. list is non-empty then
    Duplicate a new packet p
    Add EESRBM header (TTL _ 1,
     checksum; r. list) to p
     Insert p to MAC queue
     E=Tc+Rc
    Forward packet node to node with low  transmitting
and receiving cost
    end if
    end for
```

An example of how EESRBM is employed is shown in Figure1.

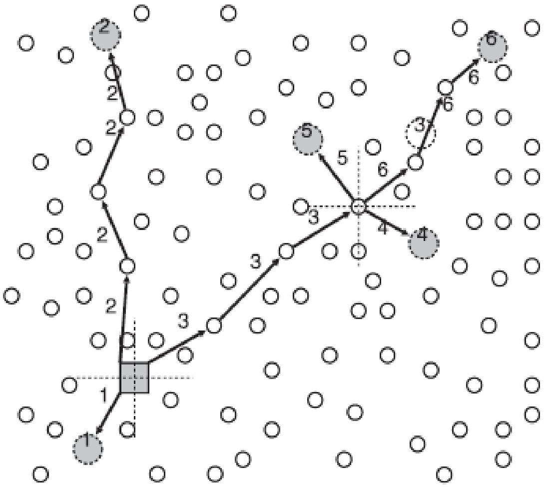

Fig. 1. Example showing how EESRBM delivers multicast packets. The source node is the square node. Multicast members are shaded circles, and virtual nodes are dotted circles. Because every destination node will become a virtual node at the end, they are all shown with dotted circles. The number on the side of the lines indicates the destination of that packet.

There are four multicast regions: southwest, northwest, southeast and northeast multicast regions. The first two multicast regions, the southwest and northwest quadrants, contain only one multicast member each, and thus a packet is sent directly to these multicast destinations. The third multicast region northeast has three multicast members and hence virtual node is calculated based on the geometric mean of the locations of the multicast members (dotted circle with label 3 in the figure) and a single packet is sent to this virtual node. The fourth multicast region southeast has no multicast members, and hence no packet is transmitted into this region. Once the packet sent towards virtual node 3 reaches an intermediate node for which the multicast members are no longer in the same multicast region, the node will split off packets to each of the multicast regions, using either virtual nodes if there are two or more multicast members in the multicast region or sending the packet directly to the multicast member if it is the only one in the multicast region.

A. Route request

The user initiates a request a to send (RTS) a packet to a multicast group. This multicast group consists of the list of multicast members where the packet has to be reached. This group is managed by group heads.

B. Region splitting

Once a node receives a multicast packet (from the application layer or from a previous hop node), it divides the network into multicast regions, and it will split off a copy of the packet to each region that contains one or more multicast members. Since it spits the network into multicast regions, hence finding the destination becomes more correct. The two possible divisions of the network into multicast regions are shown in Figures 2a and 2b.

There is no method that is clearly best. Influencing factors include the sink node locations and how the relay nodes are distributed. Dividing space into three 120 degree pieces is a straightforward approach because it resembles a Steiner tree in that every node has three branches. To separate space into 120 degree regions, we must calculate the angle to each destination node. Calculating this angle relies on trigonometric calculations and hence requires floating point operations.

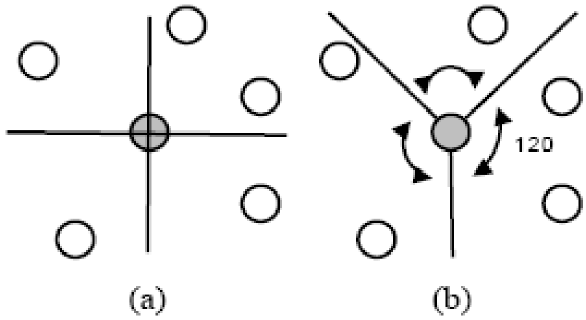

Fig. 2. Two possible ways to divide a space into multicast regions: (a) dividing the space into four quadrants and (b) dividing the space into three 120-degree regions.

Most CPUs in MANETs do not support floating point operation due to the demand for low power and low cost, and hence floating point operations must be simulated by integer operations and are thus expensive. For the quadrants approach, the multicast region decision only needs two comparisons (X and Y axes) for each multicast member and is extremely fast. Hence it is considered as preferable and this 4 quadrants approach is applied in the implementation of EESRBM protocol.

C. Virtual node assignment

The possible ways to adapt the need for multiple multicast destinations to a MAC layer that can only handle a single destination are choosing a node near the geographic mean of the multicast members, or choosing a node near the nearest multicast node, as shown in Figure 3. The geographic mean approach has fewer hops in general.

In EESRBM since there is no knowledge of neighbor nodes and no routing tables, hence a "virtual node" is assigned which is located at the geographic mean of the multicast members for each multicast region.

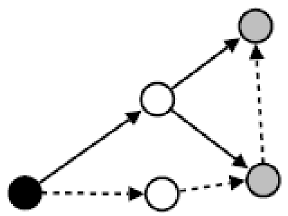

Fig 3. Demonstrates how to choose a next hop node. The solid node is the source node, and the gray nodes are the multicast members. The solid line is the route when choosing a target node near the geographic mean of the multicast members, and the dotted line is the route when choosing a target node close to the nearest multicast member. It can be seen that the longest distance is two hops distance in the first case, and it is three hops distance in the second case.

This virtual node is used as an imaginary destination for the multicast packet in that region. The virtual nodes (as shown in Figure 1) are not necessarily reachable or even physically exist. The idea behind this is that even if a virtual node does not exist, it is still possible to find a route using the assumed receiver-based MAC protocol to get the packet closer to the location of the virtual node.

On the other hand, when using the nearest multicast node as the destination, all node addresses physically exist and virtual nodes are not necessary. However, with this approach we lose the advantage of shorter routes as shown in Figure 3.

A. *Energy calculation*

Energy is calculated for each of the nodes. Residual Energy increasing algorithm is used to calculate the residua energy of each node. Local rate of energy consumption based on application (e.g.: audio, video, word, etc) can be monitored. The remaining battery life (residual energy in a node) can be estimated based on the application (rate of consumption). Thus early detection and avoidance of energy depletion problem is possible based on monitoring of power (rate of energy consumption) and remaining battery life (residual energy in a node). The energy for a node is calculated by:

$E=Tc+Rc$

Where Tc and Rc are the transmission and receiving costs of a node respectively. The node with low transmitting and receiving costs is considered for further forwarding of the packets. Figure 4 and 5 shows the battery power of a node without considering energy efficiency and with considering the energy efficiency of nodes respectively.

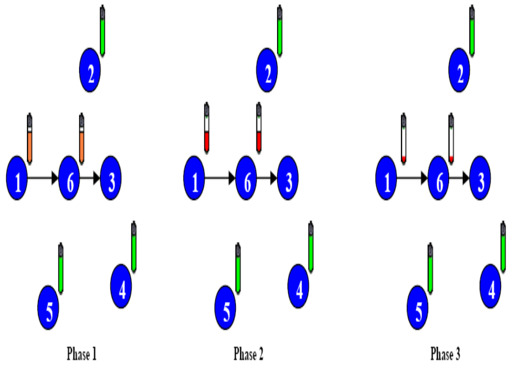

Fig 4. Battery status without EESRBM

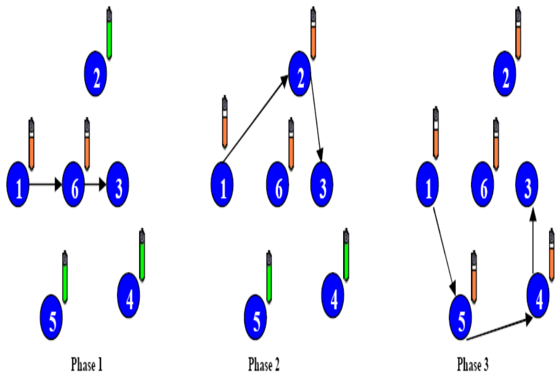

Fig 5.Battery status with EESRBM

In Figure 4, packets are to be sent from node 1 to node 3. Let us assume that the shortest path algorithm selects 1 -> 6 -> 3 as the best path. Disregarding the source node 1 and destination node 3 (which are fixed in this case), it will be observed that the intermediate node 6 will suffer heavy depletion in its battery power because only node 6 is selected repeatedly as intermediate node by the shortest path algorithm.

Now consider the proposed algorithm Residua Energy Increasing for route section. Figure 5 represents the case where data packets are forwarded using this strategy from the same source to destination. After phase 1, the battery of intermediate node 6 has depleted by 10 % (say) and so in phase 2, node 6 will not be considered. An alternate path 1 -> 2 > 3 will be selected, since node 6 has less battery power than that of node 2. Now consider phase 3 in figure 5. Both node 2 and 6 have depleted their power by 10% (say). For transmission of next set of data packets, both the intermediate nodes would be rejected and intermediate nodes 5 and 4 will be selected (1 -> 5 -> 4 -> 3), since they have their battery power much higher than node 3 and 6. Hence it provides a long lived communication path to be established between source and destination.

B. *Destination list*

The goal of this approach is to keep intermediate sensor nodes from having to store any multicast routing state. This is possible only if all required information to multicast a packet is carried along with the packet. The question is how much information the multicast packet needs to carry for successful delivery to all multicast members.

Since it is assumed as a receiver based MAC layer, hence the next hop is determined by a joint decision among potential receivers. The EESRBM header does not need to carry any state for routing the packet.

However, it is still needed to decide when the packet must be split off to different destinations. This is usually implied by tree branches in tree-based multicast approaches. But because of the location information assumption, here multicast regions are used to decide when packets must be split off without any tree structure. A packet will be split off to each multicast region if multicast members exist in that region. Therefore, a destination list is the only requirement for multicast packet delivery and must be carried inside the packet header.

C. *Eesrbm header*

Figure 3 shows the structure of an EESRBM header. The first byte Protocol ID provides the identity of the protocol in the stack. TTL provides a maximum time, in hop number, that a packet should last in the network. Type of Service (TOS) indicates four kinds of packets in EESRBM, which are “data,” “join,” “leave,” and “update” packets. The update packets are used in group management and periodic group list updates. Destination List Length (DLL) indicates how many nodes are in the node list, and thus will determine the length of the header. The EESRBM header size is not fixed since the destination list length is variable. Source Address stores the EESRBM group address of this packet and Destination List Address stores the addresses of the *DLL* destination nodes.

Any multicast protocol that uses a destination list, the packet header length will increase linearly with the number of destination nodes. The maximum number of multicast members allowed in a group is restricted by the packet size. For packets in the IEEE 802.15.4 standard, the maximum packet size is 128 bytes, and hence the maximum number of nodes in the destination list is around 50, which is sufficient for practical purposes.

D. Group management

ESRBM supports multicast group management where nodes can join or leave any multicast group. Some nodes manage the multicast groups and act as the group heads. Nodes join and leave a group by sending “join” and “leave” packets to the group head. Join and leave packets are multicast packets with destination lists that contain only the group head address.

EESRBM supports Many-to-Many multicast mode, and thus every node in a multicast group can multicast packets to all other nodes in the same group. The extra burden is that the node must maintain group node lists for groups it has joined. In the case of nodes joining or leaving, the group head must send “update” packets including a list of its updated multicast group members to all group nodes. Nodes send “join” packets periodically to the group head, and nodes that die without sending “leave” packets are removed from the list after a time-out period.

E. Route Reply

After the packet is reached to destination, the destination acknowledges the sender (or) source about the receipt of the packet. This makes EESRBM a reliable protocol.

IV. CONCLUSION

Current multicast protocols generally rely on various tree structures and hence intermediate nodes need to maintain tree states or routing states for packet delivery. The protocols designed for configuring energy-power of each node focuses on such stateful protocols. In this paper, we have presented a new stateless multicast protocol for ad hoc networks called EESRBM: Energy Efficient Stateless Receiver- Based Multicast protocol. It provides energy efficient routing in a completely stateless multicasting. It considers a hop with energy saving such that the one that o low transmitting and receiving costs. It calculates the remaining energy of each node and selects the node with high residua energy. This makes a long-lived path to be selected from source to destination. This protocol decreases the communication cost and increases the communication living time. Thus, EESRBM helps to reduce the maintenance overhead as it is stateless and also helps to reduce the power depletion of nodes thereby making it an energy efficient stateless protocol for multicasting in ad hoc networks. It increases the overall network performance. EESRBM is we suited for multicast applications in ad hoc networks such as Wireless sensor Networks (WSNs) and MANETs.

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