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A Power Efficient Cluster Head Based Routing Protocol for Mobile Adhoc Network

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Abstract

Wireless adhoc networks are potential area of research in telecommunication wherein most of devices connected over an infrastructure less network are power operated. Since power is an important but scares resource in mobile environment, it necessitates a design of a protocol that not only saves the battery life but also maximizes the life time of participating network nodes .In this paper a power efficient cluster head based routing protocol is being proposed that maximizes the power saving by selecting the best node for sending the data packet across the network.

Keywords: Wireless Ad Hoc Networks, MANET, Power Consumption, Power Aware Routing Protocols

1.Introduction

MANET is a group of multihop nodes that do not require a predefined infrastructure to form a wireless network. Such a network can be quickly formed, as the nodes are mobile in nature. MANET[1] are often partitioned into separate networks and again merged into one network on need felt basis. .The various nodes[10] can directly communicate only when participating nodes are located within each other's radio range. If the destination node is outside the radio range of the sender node, then the message is sent through a hop node. In fact, the hop node is a mobile node that falls into the overlapping radio range of both the sender and destination nodes. It may be noted that due to the limited transmission range of wireless network interfaces, multiple network hops may be needed for one node to exchange data with another across the networks. The various nodes of MANET are connected dynamically in an arbitrary manner wherein each node acts as a router so that it can take part in discovery and maintenance of routes across the network. Some examples of usage of adhoc network are situation like disaster management, information exchange among the soldiers of battle field or participation of business associates for the purpose of information sharing. The mobile nodes frequently change their positions leading to change in topology. Therefore, there is need to developed a routing protocol of adaptive nature capable of handling fast moving mobile nodes within the network.
The protocols for mobile adhoc network can be principally divided into two types: proactive and reactive protocols where proactive protocol is a table driven routing protocol and reactive protocol is a demand driven routing protocol.

1.1 Table-Driven Routing Protocols: These protocols adapt an eager strategy wherein each node collects up-to-date routing information from every other node in the network and maintains the collected information in the form of tables. The changes in network topology are dynamically updated into the tables to maintain a consistent view of the network. The example of Table Driven Routing protocols are- 'Destination Sequence Distance Vector(DSDV)','Cluster Head Gateway Routing Protocol(CGRP)','Wireless Routing Protocol(WRP)' and Global State Routing Protocol(GSR).

1.2 Demand Driven Routing Protocols: These protocols adapt a lazy strategy wherein the routes are created between source and destination node on demand. The source node initiates the route discovery activity within the network. It sends the request to other nodes which respond by supplying the information about the possible routes. The route is selected by considering all route permutations. The route is maintain by a 'route maintenance procedure' until the route is required by source node or route becomes invalid because of movement of the destination node or some intermediate node. The examples of Demand -Driven Routing protocols are- 'Adhoc On Demand Distance Vector Routing (AODV)','Dynamic Source Routing(DSR)','Temporally Ordered Routing Protocol(TORA)',Associatively Based Routing (ABR)', and Signal Stability Routing(SSR).

2. Related Work:

The Mobile devices [8,9] by nature employ batteries for their power requirements. Whereas battery power is inherently limited by its construction. This limitation on battery life coupled with the additional energy requirements for supporting network operations such as routing renders energy conservation one of the main concern in MANET. Therefore efficient power utilization [13] becomes a potential area of research for designing a routing protocol that consumes minimum power preferably with no impact on the performance of applications. In Literature there exist many power saving routing protocols such as discussed below:

Power Aware Localized Routing Protocol (PLR): This protocol [7, 11] is a localized, fully distributed energy aware routing algorithm. It works with the assumption that a source node has a location information of its neighbors and the destination. Therefore it knows the link costs from the source node to its neighbors, all the way to the destination. Though based on this information, the source node cannot find the optimal path but can select the next hop through which the transmission of packet can be made with comparatively power consumption.

Minimum Total Power Routing Protocol (MTPR): This protocol [3]sets up the route that needs the lowest transmission power among possible routes. This scheme can be applied in the environment where transmission power adjustment is available. Because the required transmission power is proportional to the n-th power of distance between nodes, this scheme prefers shorter links and has the tendency to select the route with more hops. However, MTPR always select its nearest neighboring node as a next node for packet transmission therefore number of nodes participate in forming a routing path.

Minimum Battery Cost Routing (MBCR): This protocol [4] uses the inverse of the remaining battery capacity as the cost function. It uses the sum of cost for all intermediate nodes as the metric for route selection. However MBCR protocol uses the remaining battery of nodes as the means for selecting the route but in this method some nodes get overused leading to a situation when the path in becomes is congested in the network while others path to the same destination remain free.

Power Aware Source Routing(PSR): This protocol [2,5]is based on dynamic source routing .It balances the traffic load inside the network so as to increase the battery lifetime of the nodes and hence the overall useful life of the adhoc network.

A critical look at available literature indicates that the following issue needs to be addressed while designing a power aware routing protocol such as:

1. The existing Power Aware Routing Protocols use large number of hop nodes for packet transmission from source node to destination node.
2. The number of packets exchanged is very large.
3. The existing power aware routing protocols broadcast packets.
4. The overall power consumption is very high.

In this work, a routing protocol has been proposed named as '**a power efficient cluster head routing protocol'** whose work is to not only save the battery life but also to maximize the life time of all the network nodes who participated in the communication. The proposed protocol is able to achieve the maximum power saving by selecting the best gateway node for sending the data packet across the network**.**

3. The Proposed Routing Protocol:

The proposed routing protocol selects a path that shall incur least power consumption for packet transmission from source node to destination node. The nodes belonging to the same cells are so organized that they form a cluster and one of them is designated as a cluster head, The various nodes of the cell can directly communicate with the cluster head (CH).Thus, in a cluster, nodes are classified into three categories-normal node (NN), gateway node (GN) and cluster head(CH)(see Fig 1). NN is the node that belongs to the same cluster. A GN is also the node that belongs to the same cluster but is also member of adjacent cells/clusters. This node is called a gateway node because through this node data packets can be sent to other nodes outside the current cell as shown in Fig1. Each node contains a tag called node type i.e equal to 0,1and 2 indicating the node being normal, cluster and gateway node respectively.

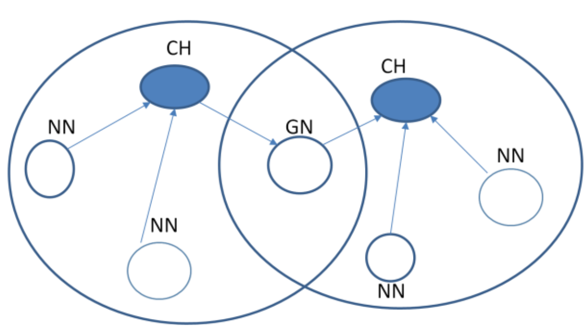

Fig 1. Adhoc Network

3.1 Selection of Cluster Head(CH):

The proposed algorithm takes three parameters for selecting CH namely : 'Remaining Battery Power', ' Token Number' and 'Idle Time'.

Where

1. Remaining Battery Power(RBP) : Defines the remaining battery power of a node.
2. Token Number(TN): Every node is assigned a token at the time of its joining the cluster. The token number represent as to for how long a node has been present in the cell.
3. Idle Time (IT): This parameter represent the time for which the node has remained idle and node which has been idle for the longest time shall be selected as least active participating node. The idle time of node is calculated as:
   Idle Time (IT)= Current Time- Last time of packet transmission by node i.

The above parameters are used for computed a term called ' selweight' for each node as given below.

Selweight= 2*RBP+100/TN+IT

It may be noted that from above expression, a node is selected as a cluster head (CH) when

1. It has a sufficiently large remaining battery power
2. The nodes having small token numbers have been given weightage to become clusterhead because their probability of staying with in the cluster is more as they have been in the cluster for a long.
3. The least active participating node shall be given the charge of cluster headship in order to evenly distribution the load within the cluster.

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As and when, the need arises to select the next cluster head, the node with maximum 'selweight'is selected for this purpose. The need to select a new cluster head may arise because of the following reasons:-

1. First node in the cell would on its own become the cluster head.
2. At the time of network partition or merging a new cluster head may be selected.
3. If the current cluster head finds that its remaining battery power has fallen below a threshold value it may hand over its responsibility to next cluster head.

3.2 Neighbor Awareness Table (NAT): The cluster node maintains a table called Neighbor Awareness Table (NAT) with the format is given in Table 1.

Table 1: Neighbor Awareness Table(NAT)

Neighbor	Remaining Battery Power(RBP)	Node Types	Remote Neighbor	Idle Time	Token Number

Where :

Neighbor : contains the list of neighbor nodes within the cell of the cluster head.

Remaining Battery Power : Value of battery power assumed to vary between 0-100

Node Type : 0 , 1,2 indicating the normal node ,cluster node and gateway node respectively

Remote Neighbor: is the list of neighbors of the gateway node which fall in adjacent (cells)

Idle Time **:** Idle time of a node

Token Number **:** Value of token number assumed to vary between 0-200.

3.3 Neighbor Awareness List (NAL): Each NN maintains a table called ‘Neighbor Awareness List (NAL)’ for storing the information about its immediate neighboring nodes present within the cell. The Neighbor Awareness List contains the IP-Address of the neighboring node in the increasing order of power signal of the corresponding nodes as shown in Table 2.

Table 2: Neighbor Awareness List(NAL)

Node -Id	IP-Address	Remaining Battery Power (RBP)	Node Types	Idle Time	Token Number

Where:

Node-Id : A Unique number assigned to the nodes

IP-Address : contains the IP address of the existing node of a cell

Node Type : 0 , 1 indicating the normal node ,cluster node respectively

Remaining Battery Power : value of battery power assumed to vary between 0-100.

Idle Time **:** Idle time of a node

Token Number **:** value of token number assumed to vary between 0-200.

3.4 Arrive/Depart packet: When a node arrives at or departs from a cell, it broadcasts a packet called Arrive/Depart packet. The format of packet is given as:

Table 3: Arrive/Depart Packet

Packet Type	Source Address	Cell _Id

Where:

Packet Type **:** Identifies the packet either as Arrive /Depart packet

Source Address **:** Contain IP address of sender node.

Cell_Id : Contains the unique identification in the form of an IP address of the cell.

As and when a node enters a cell, it broadcasts the arrive packet conveying its arrival to other nodes. On receiving the packet broadcasted by new entrant, if the new entrant node belongs to different cell to which the recipient node belongs to, then the details about new entrant are loaded into the NAL and NAT .

As and when a node leave from a cell, it broadcasts the depart packet conveying its depart to other cell. On receiving the depart packet from the leaving node ,all the recipient nodes updated its NAL and NAT.

3.5 Beacon Request Packet (BR): After sending the arrive packet, the new entrant node becomes the member of the cell and then it broadcast a Beacon Request Packet (BR) to all its neighboring nodes . The format of BR is given in Table 4.

Table 4: Beacon Request Packet (BR)

Packet Types 0	Remaining Battery Power(RBP)	Source Address	Destination Address

Where:

Packet Type : 0 is indicating that it is a request packet

Source Address : Contain the IP address of the sender node

Destination Node : Contain the broadcast IP address

Remaining Battery Power : Value of battery power assumed to vary between 0-100.

For example in Fig 2, the node with Node-Id '5' has entered into the cell .It has dispatched BRs to nodes 1, 2,3 and 4. Where node1 is the cluster head (CH), node 3 is the gateway node and nodes 2 ,4 are normal nodes.

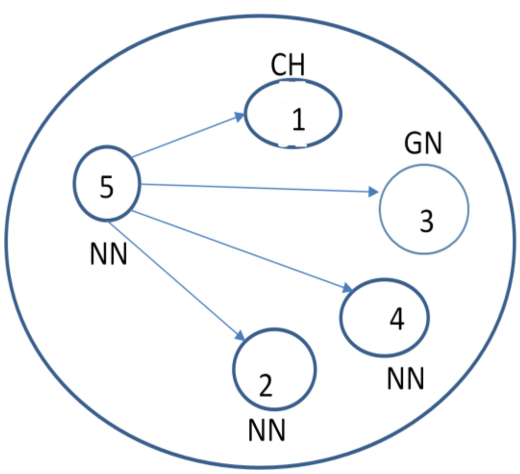

Fig 2. Node 5 Broadcast the Request Packet

When a node receives a Beacon Request (with packet type zero) from a new entrant (node5), it extracts the information about the new node and updates this information into its Neighbor Awareness List through the algorithm called updateNAL( ).

The detailed algorithm is given in fig.

```
Algorithm: updateNAL( )
Input: Beacon Request Packet(BR)
Output: updates its own NAL
batPow=br.bp
{
    i=0;
   while(NAL[i].bp>batPow)
    i++;
    insert(BR.Node_id,BR.Source
     address,BR.bp,0)
  }
```

3.6 Beacon Reply Packet(BP): Thereafter the recipient node acknowledges the receipt of the BR by sending a Beacon Reply Packet(BP) with packet type equal to 1 . The format of BP as shown in Table 5 .

Table 5: Beacon Reply Packet-(BP)

Packet Type	Source Address	Destination Address	Node Type	Idle Time	Token Number

Where :

Packet Type :1 is indicating that it is a reply packet

Source Address: Contain the IP address of receiver node

Destination Node: Contain the IP address of the node that has sent a BR Packets

Node Type: 0,1,2 indicating the normal node ,cluster node and gateway node respectively

Idle Time: Idle time of a node

Token Number : Value of token number assumed to vary between 0-200.

For example (see in Fig 3), the nodes 1,2,3 and 4 have responded back by sending BPs to nodes 5.

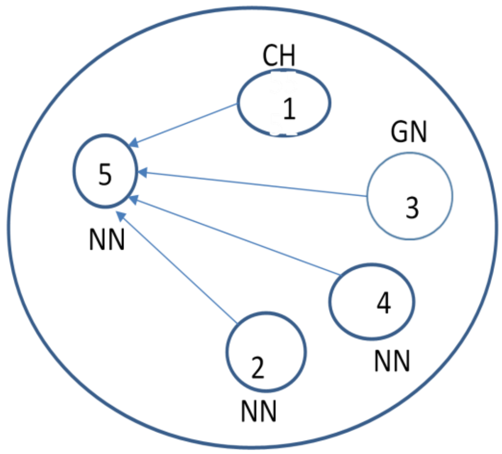

Fig 3: The nodes reply back by send BP

On receiving the BP from neighboring nodes of the cell, Thereafter new node updates its NAL with the IP address of the neighboring nodes using updateNAL( ). It assigns itself the token number which is one more than the maximum token number allotted to any of its neighboring node. However, when it receives a BP from the cluster Head (with packet type =1), it sends its own NAL to the cluster head along with its own Node_id .

Infact every new entrant into the cell shares its NAL with the cluster head. The cluster head merges the Neighbor awareness list of new entrant with its own neighbor awareness Table using mergeNAL() algorithm. The detailed algorithm is given below:

```
Algorithm: mergeNAL
Input: NAL of new entrant
Output: merged NAT with NAL
i=0;
while (NAT[i].Node-id!=shareNAL.NAL)
i++;
}
 Algorithm : insert node(i,NAL)
{
      j=0;K=0;
      while(NAL[i].Node-id1!=NULL)
        {
          (NAT[i].remoteneighbor[k]=
               NAL[j].Node.id)
            j++;
            k++;
```

    }
}

If the node falls into the same cell and it is also member of an adjacent cells then it is designated as a gateway node(i.e. node type =2) because through this node, packets can be sent to other nodes present outside the current cell. However, if a node is not a gateway node then it is considered as a normal node. It may be noted that for packet transmission to destination node ,the source node unicasts the packet either to a node in its own cell or to its cluster head. The cluster head unicasts the packet to a gateway node. Therefore thus scheme not only reduce the number of intermediate hops but also reduce the power consumption and network traffic.

The working of the proposed protocol is illustrated in the example given in following section.

4. Working of Proposed Routing Protocol:

Consider the cells given in Fig 4(a) and Fig 4(b) wherein cell1 contains the nodes 1,2,4 and cell2 contains the nodes 3,6,7,8 and 9 .

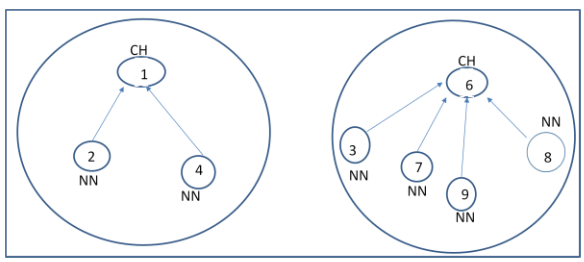

Fig 4: An Adhoc Network of two cells 4(a) and 4(b)

It may be noted that node 1 i.e. cluster head of cell1.The contents of NAT of cluster head of cell 1 are given in Table 6 .

Table 6. Neighbor Awareness Table (NAT)

Neighbor	Remaining Battery Power(RBP)	Node Types	Remote Neighbor	Idle Time	Token Number
2	85	0	Nil	15	10
4	80	0	Nil	14	11

Similarly, the contents of NAT of cluster head of cell 2 are given in Table 7, where node 6 is CH.

Table 7. Neighbor Awareness Table (NAT)

Neighbor	Remaining	Node	Remote	Idle Time	Token

	Battery Power(RBP)	Types	Neighbor		Number
3	75	0	Nil	13	12
7	70	0	Nil	10	13
8	68	0	Nil	8	14
9	64	0	Nil	7	15

Let us assume that node 3 moves in such a manner that it becomes member of cell1 while remaining in cell2 (see Fig5).

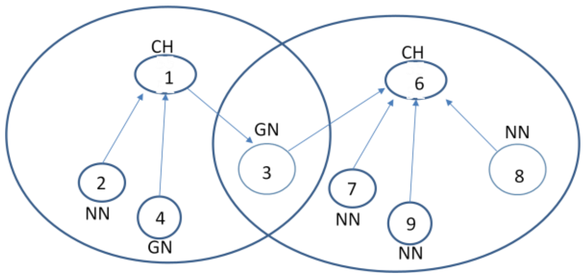

Fig 5. Show node 3 as a gate node

After exchange of BR and BP, it share its NAL with cluster head of cell 1 i.e node1. The cluster head(CH) of cell1 updates its NAT .The updated NAT of CH of cell 1 is shown in Table 8.

Table 8. Neighbor Awareness Table(NAT)

Neighbor	Remaining Battery Power(RBP)	Node Types	Remote Neighbor	Idle Time	Token Number
2	85	0	Nil	15	10
4	80	0	Nil	14	11
3	75	1	6,7,8,9	13	12

It may be noted that Node3 has been designated as gateway node between cell1 and cell2 for packet transmission.

Let us assume that node 5 enters in cell 1(see Fig 6) and it broadcasts (BR) to all its neighboring node numbered 1,2,3 and 4 .

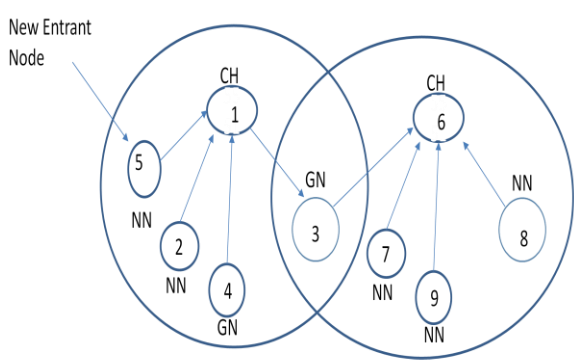

Fig 6. Node5 act as a new entrant node

After receiving broadcast reply packet(BP) from neighboring nodes ,it updates its own

Neighbor Awareness List (NAL) given in Table 9.

Table 9: Neighbor Awareness List(NAL) of Node5

Node -Id	IP-Address	Remaining Battery Power(RBP)	Node Types	Idle Time	Token Number
1	202.31.12.9	90	1	10	05
2	202.31.12.10	75	0	15	12
3	202.31.12.11	58	0	13	12

As soon as new entrant node receives a packet type equal to 1 from node1 then it send its own Neighbor Awareness List to node 1. Thereafter cluster head i.e. node 1 merges the Neighbor awareness list of node 5 with its own Neighbor awareness Table. The updated NAT of cluster head 1 is given in Table 10.

Table10. Neighbor Awareness Table(NAT)

Neighbor	Remaining Battery Power(RBP)	Node Types	Remote Neighbor	Idle Time	Token Number
2	75	0	Nil	15	10
4	80	0	Nil	14	11
5	70	0	Nil	10	16
3	58	1	6,7,8,9	13	12

Now consider the scenario given in Fig7.

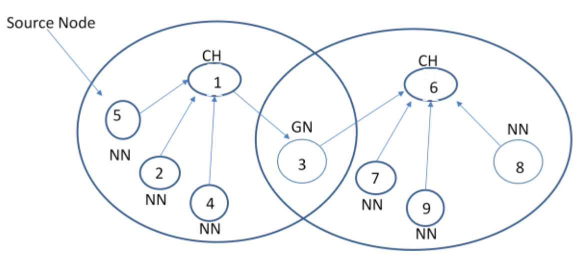

Fig 7. Adhoc Network

Let us assume that node5 desires to communicate with node 8, i.e. node5 and node 8, become source and destination node respectively.

Having decided to communicate with node8, node5 searches for destination node in its own NAL, if the destination node is found then it sends packet to same, otherwise it sends the packet to CH of the cell i.e. node 1. Now CH searches the destination node in the NAT, it finds that node 8 is the remote neighbor of node3,which is a gateway node.

Consequently CH sends the packet to gateway node3. On its turn node3 send the packet to its neighbor node 8 which is the destination node as shown in Fig 8.

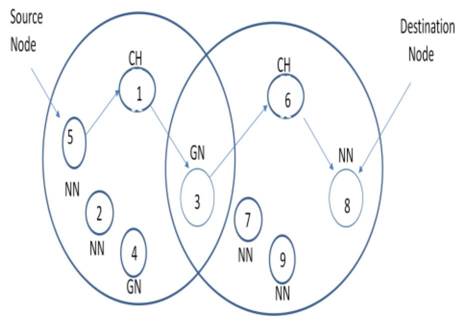

Fig 8: Packet transfer from source node to destination

It may be noted that CH is so chosen that it has maximizing power back up. The sender node sends the packet to cluster head only when the destination node is not present in the cell.

Moreover CH send the packets to destination through gateway node. Normally CH is able to unicast the packet to gateway node in whose cell the destination node is not present otherwise CH broadcasts the packet to all the gateway nodes.

5. Conclusion :

The proposed power aware routing protocol reduces the number of hop nodes for packet transmission from source node to destination node. The proposed routing protocol unicast scheme instead of broadcasting for the packet transmission, resulting in reduction of power consumption and network traffic.

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