SPC: The Selective Prioritized Clustering Algorithm for MANETs

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***Abstract*—Energy conservation is the major issue of concern for MANETs [1], [2] as terminals are battery operated. We propose an algorithm called selective prioritized clustering (SPC), to reduce power consumption at network level. It uses topology control and hierarchical clustering based approach, and is applicable to an environment where the complete network is divided into a specific number of clusters which includes sub-cluster. Each sub-cluster has two cluster heads. The algorithm produces a global path. During formation of global path all cluster heads are participating but when data transmission takes place only few clusters those are part of the global path participates. Local path method concurrently runs in the sub-cluster through which a global path passes. Local path formed in the sub-cluster further improves energy in that sub-cluster. The final path is the combined path of both.**

***Keywords*-Energy consumption, clustering, global and local path, topology control, Ad hoc network.**

I. Introduction

Mobile ad hoc networks (MANET) [1] have been a topic of great interest in the last couple of years due to its wide range of application in different environments. One of the major characteristics of a MANET is, nodes can join or leave the network at any time in a dynamic fashion causing instability of topology thus consumes more energy due to change of routing information in the network. In ad hoc network, communication cost in term of energy is much more as compared to computation cost. So efforts are made to reduce the communication overhead. Many researchers tries to reduce energy consumption in different ways, it also found in the literatures that energy can be conserved at any layer of the protocol stack. Power management, power control and topology control [3] are some of the techniques used for efficient use of limited battery power. Power management based techniques like IEEE 802.11 IBSS PS [4] mode reduces power consumptions by putting some nodes in the sleep state when they are not receiving or sending the data packets. But its performance of energy saving in multi-hop network is still a major challenge for the researchers. The objective of power control based techniques is to reduce the transmission power. Topology control method focused on reduction of energy consumption at node level as well as network level. It also decreases the interference in the network to increase throughput and network life.

The proposed SPC algorithm uses hierarchical clustering approach to keep away some cluster or sub-cluster from participating in data transmission. Those cluster or sub-cluster participate actively in the data transmission are remain active and others goes to sleep mode. The algorithm applies power management techniques to put some node in the sleep state and uses topology control techniques for finding the global and local path.

The rest of the paper is organized as follows. Some of the works related to the proposed area are described briefly in section 2. Descriptions of proposed algorithm discussed in section 3. Section 4 illustrates results and discussions and concluding remarks given in section 5.

II. Related Work

Topology control technique[5], [6] can be defined as the technique to achieve one or more objectives by satisfying some constraints (like connectivity, biconnectivity, k-neighbor set etc). The basic objectives of topology control are to minimize the maximum power used by any node in the network, and/or to minimize the total power consumed by all the nodes in the network. The common assumption of topology control is that, all the nodes in the network are transmitting with common maximum power via omni directional antenna. In other way we can say that the network topology can be expressed as a graph G(V,E), where V represents set of nodes and E represents set of links. By applying topology control we have to get sub graph G'= (V, E') of G, in G' the node has shorter and fewer numbers of edges as compare to G. Depending upon the functionality topology control approach can be categorized to power control based and power management based approach. Further it can be classified as homogeneous and non-homogeneous type. Further the algorithm used in topology control approach can be defined as centralized or distributed approach.

SPAN[7] is a distributed power saving protocol based on power management approach, which adaptively elects coordinator from all nodes in the network and perform multi-hop packet routing. Other nodes remain in power save mode to conserve energy. SPAN gives guarantee of network connectivity by ensuring that every node has at least one active node in its radio range. Fairness among the nodes is based on the amount of residual energy and the additional neighbor pairs that a node can connect. It balances both fairness and network connectivity. The entire active node form a connected backbone, each node periodically broadcast hello message which includes different information. When any inactive node found that its two of the neighbors cannot reach directly or through one or two active node then that node became an active node. On other hand any coordinator node can step down, if every pair of its neighbors can reach each other either directly or via other coordinators.

Ramanathan et al. proposes two centralized topology control algorithm[8] for ad hoc network. They have proposed two centralized algorithms called CONNECT and BICONN-AUGMENT for use in static network. Algorithm CONNECT is a greedy algorithm similar to minimum spanning tree (MST). The BICONN-AUGMENT is also a greedy based algorithm whose objective is to identify the biconnected components in the network. For mobile network they have proposed two distributed heuristic, namely local information no topology (LINT) and local information link-state topology (LILT).

Sheu et al. proposes a location free topology control algorithm(LFTC) [9] for faster access. The algorithm has two phases, link determination phase to determine the power required to send data packet while interference announcement phase properly handle the hidden terminal problem.

Sahoo et al. [10] propose a distributed transmission power control protocol for wireless network to achieve energy conservation in the node level. The protocol uses distributed algorithm to build the power saving tree topologies without taking the local information of the nodes and provide a simple way to maintain network by changing the transmission power. The Cone Based Topology Control(CBTC)[11] uses direction information to form a good topology and is based on angel of arrival (AoA) information.

This section discussed some of the work in topology control approach. The next section will discuss our proposed SPC algorithm.

III. Proposed Algorithm

A. System Model

In this model nodes are randomly deployed in a geographical area. It is assumed that nodes are stationary, homogeneous and use Omni directional antenna for transmission. The total network is divided into non overlapped clusters with central node with high transmission power called initiator. Initiator divides the cluster into four quarters. The nodes within each quarter are grouped together as sub cluster. Each sub cluster has exactly two head nodes of which one is near to initiator and other is away from the initiator and requires maximum power to reach. Initially all the local nodes (nodes other than head nodes and initiator) remain in sleep state and they become active only on demand with the help of cluster head.

B. Algorithms

The proposed Selective Prioritized Clustering (SPC) algorithm achieves multi objectives. The objective here is to decrease power consumption and increase network capacity. The algorithm invokes global path and local path methods. Global path method selects and deselects cluster and/or sub clusters depending upon requirement. Local path method achieves energy efficiency within sub-clusters by executing concurrently in the sub-cluster to reduce the network delay. It bypass the route with those node which has battery level less than the threshold value. The algorithm SPC is given below.

Gloabal Parameters:

Tstatus:Begin,End,Error
Status :TREQ,TEND,Error
Pmode:Active,Sleep

Algorithm III.1: SPC(Sid, Did)

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comment: Find optimal final path
for each $node \in network$
  do { **if** $node = "Localnode"$
      then $Pmode = Sleep$
      else $Pmode = Active$
$G \leftarrow \{headnodes \& clusternodes\}$
$Tstatus \leftarrow "begin"$
repeat
  $Gp \leftarrow Globalpath(G, Sid, Tstatus)$
  for each $Cid \in GP$
    do { $LP \leftarrow Localpath(Cid, src, status)$
  $Finalpath \leftarrow mergeof(GP, LP)$
until no more data transmission needed

Initially all the nodes except head nodes and initiator nodes are in sleep state. The algorithm SPC finds an optimal final path which is a merged path of global and local path and reduces the overall energy consumption by efficient selection of sub clusters. The algorithm uses three global parameters such as Tstatus, Status and Pmode. Tstatus indicates the current state of data transmission such as Begin, End and error. The second parameter Status shows any one of the event such as arrival of TREQ packet, TEND packet, or Error packet. The global parameter Pmode can be active or sleep. Whenever a new data transmission required from original source to destination, the algorithm SPC invokes the method Global path with parameters G(set of head nodes and initiators), Sid(Source id), and Tstatus. The global path returns the set GP of Cluster Ids (Cids) for which local path is to be finding out. Algorithm invokes the method Local path with parameters Cid and Sid (original source id), concurrently for each sub-clusters in the set

GP. The method Local path returns set LP of local node ids. The final path is merged path of these two sets. Data transmission is carried over this final path. The method Global and Local repeats depending on event such as new data transmission, end of data transmission, Error in data transmission etc. The algorithm for finding global path is shown below.

Algorithm III.2: GLOBAL PATH($G, Sid, Tstatus$)

comment: Find Global path

if $Tstatus = "Begin"$

then {
Find a shortest Global path from G
Send TREQpacket along the global path.
return (sub-cluster ids)
}

else if $Tstatus = "End"$

then {
Send TENDpacket along the Global path .
Delete the Global path
reinit Global parameters and return null
}

else (Tstatus ="Error")

then {
send resign packet to initiator
comment: to select a cluster head to play its role
wait for arrival of agree packet
Pmode(nodei)=Sleep
}

Global path method finds a shortest path between source and destination cluster head. Source cluster head is the cluster head which is near to source node in the sub-cluster and same for destination cluster head. Global path method is invoked whenever transmission status is changed. Although global path does not provide an energy efficient path but it helps to reduce the overall energy consumption by efficient selection of sub clusters. If the transmission status is begin, it sends a TREQ packet along the global path to inform those sub-cluster which are to be participated in the data transmission where method Local path can be run. At the end of data transmission, it sends a TEND packet along the global path for Local path method to deactivate the local nodes within the participated sub clusters. Sometimes sub cluster may contain both source and destination, In such case global path will have least length joining two head nodes and will not be part of final path. Some nodes along global path may get depleted during transmission, in such case Tstatus become "Error" and node send a resign packet to initiator to select another head to play its role.
The algorithm for finding local path is shown below

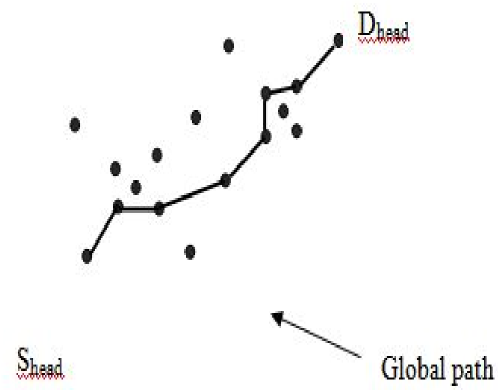

Figure 1. Finding Global Path among the Cluster heads and Initiators.

Algorithm III.3: LOCAL PATH(Cid, Sid, Did)

comment: Find Local path

if $status = "TREQ"$

then {
for each $node \in Cid$
do
{ **if** $node = "Localnode"$
then $Pmode \leftarrow Active$ }
if $node.id = Sid$
$soure \leftarrow Sid$
else if $node.id = Did$
$destination \leftarrow Did$
}

else if $status = "TEnd"$

then {
for each $Local - node \in Cid$
do $Pmode \leftarrow Sleep$
delete path
}

else ($status = "Error"$)

then {
if $BATTpower \leq BATTthreshold$
send resign packet to neighbors
}

Local path find energy efficient path within the sub cluster. The local path is invoked each time status of global path is changed such as arrival of TREQ packet, arrival of TEND packet, or Error during transmission...Etc. On receiving TREQ packet each sub cluster in the set GP activate the local nodes and find energy efficient path within the sub cluster. If the sub cluster contain the original source, then source equal original source else one of the cluster head and so as so for destination. At the end of data transmission

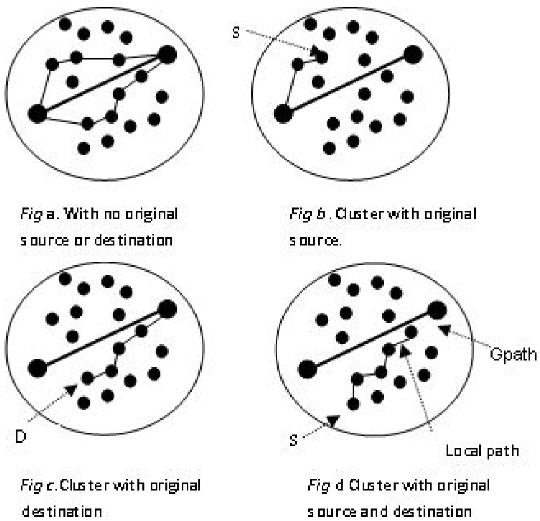

Figure 2. Local Path with different options

(on receiving TEND packet), it delete the local path and deactivate the local nodes within the sub cluster in which local path method is running. Some nodes may get depleted while data transmission, in such case node send a resign packet to the neighbors and it goes to sleep state after getting reply from the neighbors. If the status is error, it means the depleted node is part of the local path within the final path and it need to find an alternate for local path within sub cluster.

Final path: The final optimal path can be obtained by merging the global path and local path .

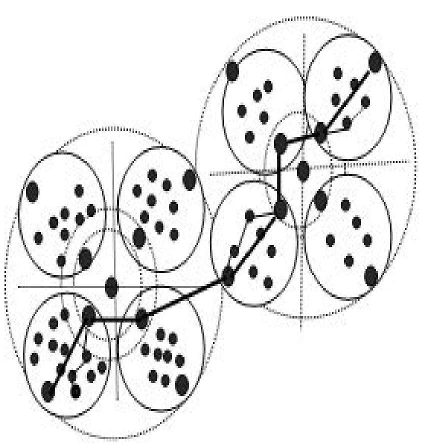

Figure 3. Fig local path and globalpath

The path with thick line shows [1]the global path and thin line show s the local path.

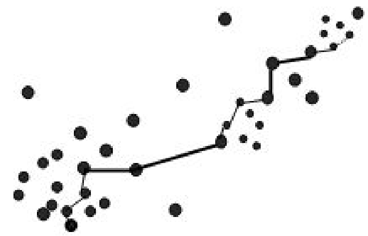

Figure 4. final optimal path merge of global and local path

IV. Simulation result and analysis

We implemented our algorithm on Qualnet 4.5 network simulator [12] with AODV as routing protocol and IEEE 802.11 as MAC protocol. Nodes are randomly deployed in a geographical area of 1500 x1500 meters and CBR (constant Bit rate) traffic with data packet of size 512 bytes are transmitted. The Antenna model used is Omni directional and Energy model is MICA2.

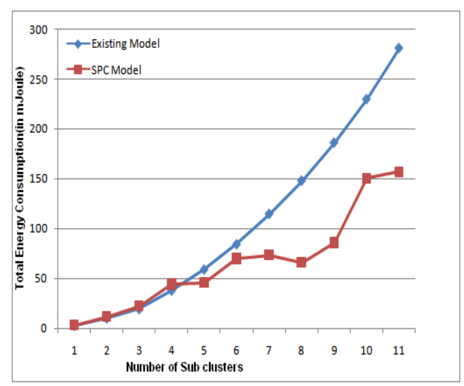

Figure 5. Total power consumption

Figure depicts the total power consumption obtained by SPC is more energy efficient than existing one. Initially the power consumption is high due to the overhead of finding global path but as the number of clusters increases the overall energy consumption of network reduces substancially. The energy consumption on SPC depends on the position of source and destination, so the energy consumption is not gradual. If the source and destination present in same sub cluster it provides its best result.

V. Conclusion

In this work, we presented a topology control algorithm based on clustering to acheive energy efficiency both at network and node level. This algorithm considered both power management based and topology control based approach to achieve the goal. It reduces high idle state energy consumption by making most of the local nodes, which are not likely to be participated in data transmission, in to sleep state. We implemented the Proposed Algorithm SPC on qualnet 4.5 Network Simulator with AODV as routing protocol The results obtained are significantly depending on the configuration parameters and energy model used for simulation. We executed series of experiments as batch processing with different number of clusters and different source and destination. We found a substantial decrease in energy consumption as the number of clusters increases. The best result obtained when source and destination lies in same sub cluster while number of sub clusters are high.The experimental result obtained shows the modified AODV with SPC concept takes less energy consumption.

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