Connectivity Based Equivalence Partitioning of Nodes to Conserve Energy in Mobile Ad Hoc Networks

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ABSTRACT
The nodes in Mobile Ad Hoc Networks (MANETs) work on low power batteries. So, reducing energy consumption has been the recent focus of wireless adhoc network research. The power in the nodes dissipates even when the network interface is idle. In this paper, we present a topology maintenance algorithm, *Equivalence Partitioning method* which is based on the connectivity among the nodes in the network. This algorithm partitions the network into equivalence sets in which one of the nodes in the set is active and the other nodes in the set turn off their radio. This algorithm takes care that the capacity or connectivity of the network does not diminish significantly. This is a simple, distributed, randomized algorithm where nodes make local decisions to form the equivalence partitions and go to on or off state. In addition, this topology maintenance algorithm can be made to work along with the 802.11 power saving mode to improve communication latency and system lifetime.

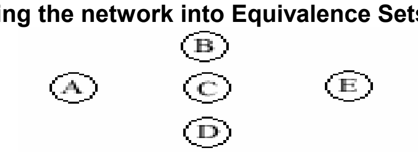
Keywords
Equivalence partitioning, on state, off state, active node

INTRODUCTION
Wireless multi-hop adhoc networking has been the focus of many recent research and development efforts for its applications in military, commerce and educational environments. Most of the protocols that have been proposed to provide multi-hop communication in wireless adhoc networks [2, 3] are evaluated in terms of route length [4], routing overhead, and packet loss rate. But minimizing the energy consumption is an important challenge in mobile networking. Since the network interface may be often idle, power could be saved by turning off the radio when not in use. But the coordination of power saving with routing in adhoc wireless networks is not straight forward. The subject of this paper is to present a topology maintenance algorithm which partitions the network in such a way that one on the nodes in each partition must be active so that the connectivity of the network does not diminish and the other nodes can turn off their radio. The responsibility of the active node is randomly changed so that every node is treated equally and the life time of the over all network is increased.

RELATED WORKS
Reducing energy consumption has been the recent focus of wireless adhoc network research. The Geographic Adaptive Fidelity (GAF) [5] scheme of Xu et al. self configures redundant nodes into small groups based on their geographic locations and uses a localized, distributed algorithm to control node duty cycle to extend network operational lifetime. But in many settings, such as indoors or under trees where GPS does not work, location information is not available. The dependency on global location limits GAF's usefulness. In addition, geographic proximity does not always leads to network connectivity. The SPAN [1] scheme of Chen and Jamieson proposes a distributed algorithm for approximating connected dominating sets in an adhoc network that also appears to preserve connectivity. SPAN elects coordinators by actively preventing redundant nodes by using randomized slotting and damping. Equivalence partitioning differs from GAF as it constructs the partitions based on the connectivity information rather than the geographic location of the nodes. Also unlike SPAN, it constructs equivalence partitions and randomly rotates the active nodes within the partition.

EQUIVALENCE PARTITIONING DESIGN
In Equivalence Partitioning technique, we divide the network into different sets of equivalent nodes, so that one of the nodes in the partition can be active in order to maintain the connectivity and the rest can remain in their power saving mode. The role of the active node is randomly chosen so that the burden of forwarding, sending and receiving data is distributed evenly to all nodes.

Partitioning the network into Equivalence Sets



Figures 1: A network with five nodes

This is a distributed randomized algorithm for connecting equivalence partitioning among the nodes in the network. Consider the network shown in Figure 1. The nodes B, C, D are in the path between the nodes A and E. In this case all the three nodes need not be awake to forward the packets from node A to E. We treat that the nodes B, C, D form an equivalent partition it is sufficient that one of the nodes to be awake to maintain the connectivity. This Equivalence Partitioning algorithm is as follows.

- The node N_i constructs its neighbor set by sending HELLO packets to its one hop neighbors. The nodes hearing this packet respond with a HELLO reply so that the node Ni constructs its neighbor set. Let NH_i be the neighbor set of node N_i
- Now, N_i advertises its neighbor set to its one hop neighbors so that it can find out the number of pairs of its neighboring nodes connected via this node.
- Find the intersection between the neighbor sets of the adjacent nodes. Let C be the cardinality of the intersection set with the first neighbor.
- If the cardinality is equal to or more than two, then form an equivalence partition and assign a unique partition id to the nodes.
- Consider the next neighbor. Let C' be the cardinality of the intersection set between the node Ni and its neighbor currently considered. If $C' > C$, a new group is formed between the node Ni and this neighbor, destroying the previous partition.
- If $C' = C$ with same elements then add the new neighbor to the same partition and assign the partition id.
- Repeat the above process until each node receives the neighbor set from all its one hop neighbors.

Each and every node is exactly in one of the partitions.

Active Node Announcement

Once the Equivalence partitions have been constructed and the nodes have their partition id, the active node in the partition must be elected. The following strategies can be used to elect the active node.

- When we start with a new network all the node will have the same power. In this case, the node with the least id in the partition can be chosen to become the active node.
- When the power among the nodes in the partition is not equal, then the node with the maximum power or the maximum estimated lifetime can be chosen to be active.

The nodes remain active for a time T seconds which is dependent on the application. The active nodes can be randomly rotated in round robin fashion or based on heuristics which take the expected life time of the node into consideration.

Compatibility with 802.11 Power saving mode

This topology maintenance algorithm can be used along with the 802.11 power saving mode to improve the system lifetime. An interesting question is how a node in the *off state* handles traffic originating from it or destined to it. In the former case, if the node has data to send it can simply power on its radio and send out data. In the later case, the 802.11 power saving mode can be used in which the active nodes can temporarily buffer data for the nodes in the *off state* and send data later.

RESEARCH CHALLENGES AND FUTURE WORK

The simplicity and the fast convergence of the Equivalence partitioning algorithm would further lot of research challenges. We are currently working on in finding the optimal way of choosing the active node in a partition and the random rotation policy. Different heuristics related to the rotation of the active nodes are being analyzed so that all the nodes in the network are treated evenly and the overall network lifetime increases. More evaluation of the partitioning algorithm should be performed, to determine convergence time and the adaptability to network mobility. The cases in which the active node moves far from the remaining nodes and the value of the optimal time after which the partitioning algorithm must be undertaken should be analyzed. We have presented a topology maintenance algorithm, and have shown its benefits. It is our belief that this approach opens up new areas of research in energy conservation in mobile adhoc networks. We have provided a basis for discussion of a number of research issues that need to be addressed to improve the performance of the overall network.

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