

Quantitative Analysis of An Adhoc Wireless Network - Proposed Topology

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Abstract: Wireless technology has advanced tremendously over the past decade, introducing a wide array of devices with networking abilities. Adhoc networks are dynamically created and maintained by a group of wireless enabled devices (gargets) with out the assistance of pre-existing infrastructure like Base Station (BS) for communication purposes. The intrinsic attributes of adhoc networks, such as dynamic network topology, constraint battery power and quality, limited battery power andlarge number of heterogeneous nodes, make very network management significantly more challenging than stationary and connected networks. In this paper, we proposed a dynamic topology management scheme, in which we consider the issue of performance enhancement of wireless networks in terms of 'Power consumption of node as well as system, node density in the backbone routing and delay and node life time'. Minimizing power consumption is an important challenge in mobile networks. Wireless network interface is often a device's single largest consumer of power. To fulfill the above requirements, We have designed to topology management scheme, which allows as many nodes of the adhoc network as possible to be in the power sleep mode and most of the time they should be path between any source and destination to route the packets with minimal delay. In our topology management sheme, MARI (Mobile Agents with Routing Intelligence) nodes are selected in such a way that, the MARI nodes have maximum power level among their one hop neighbors and all non-MARI nodes have the routing intelligence i.e. they make all decisions relating to routing. The gateway nodes having sufficient power level are selected to that they can forward packets between MARI nodes. Gateway nodes do not have routing intelligence. These MARI and gateway nodes stay continuously awake to route the packets of other member nodes.

Key words: Wireless adhoc networks, power consumption, MARI nodes, gateway nodes, nodeoverhead

INTRODUCTION

Several problems will occur in managing of wireless adhoc networks ^[1], because of the domain in which such networks are used. The sample of adhoc network is shown in Fig 1. Some of the properties of Ad Hoc networks ^[2] that make them difficult to manage well are

Complexity of nodes: The nodes used in the Ad hoc network can range from simple sensors located in the field to fully functional computers (laptops). An implication of this diversity is that not all nodes will be able to contribute equally to the management task.

Message over head: In wireless networks, very frequently changes in the topology (i.e., new nodes gets added, failure of node, addition or deletion of sub network etc) will occur. Thus management station needs to collect

connectivity information from nodes periodically, which indicates an increased message over head for collecting topology information.

Power consumption: Almost all the nodes in the adhoc network run on batteries. Thus we need to ensure that the networks management overhead is kept to a minimum so that the power is conceived.



Fig.1: Ad Hoc wireless network

Mobility: The node may power them selves off to conceive energy resulting in partitions or a node may move out of transmitting range of other nodes. Similarly, a node may die when its battery run out of power. In all these cases, the partitioned sub networks need to continue running independently and management protocol must be robust enough to adapt.

MATERIALS AND METHODS

Minimizing of power consumption is an important challenge in mobile networking. Wireless networks interface is often a device's single largest consumer of power^[3] Since the network interface may often be idle, this power could be saved by turning the radio off when not in use. The requirement of co-operation between power saving and routing protocols is particularly acute in the case of multi-hop adhoc wireless networks^[4,5] where nodes must forward packets for each other.

The objective of this paper is to design a topology management scheme for adhoc networks for power saving. The characteristics of it are:

It should allow as many nodes as possible to turn their radio receivers.

It should forward packets between any source and destination with minimally more delay than if all nodes were awake.

The picking of backbone should be distributed, so that each node should make a local decision.

To fulfill the above requirements, each node in the network makes periodic, local decisions on whether to sleep or stay awake and as a MARI node, participate in the forwarding backbone topology. The MARI nodes have the maximum power level among their one hop neighbors and all non-MARI nodes are within the transmission range of MARI nodes. These MARI nodes have the routing intelligence i.e., they make all decisions related to routing. The gateway nodes are selected which are having power so that they can forward packets between MARI nodes and they don't have routing intelligence. Here both MARI nodes and Gateway nodes are continuously awake to route the packets to the other member nodes with in the transmission range. All the member nodes will go to sleep mode, if they do not have to transmit or receive data and they wake up a 'n' number of times in a beacon period 'T'. The wake up time for each node is calculated from a pseudo-random manner, such that the MARI node and neighbor nodes know the wake up of that node time. Thus the member node can remain in power saving sleep mode most of the time^[6,7] if it is not actively sending or receiving packets. The packets are routed over the backbone consisting of MARI nodes and

gateway nodes. The routers are found with the help of mobile agents^[8].

TOPOLOGY MANAGEMENT IN ADHOC WIRELESS NETWORKS

The topology management in adhoc wireless networks is decided at every node

Which node to turn on

When the node to be turn on

What should be the transmit power

So that network connectivity is maintained under the conditions of mobility.

Most of the algorithms proposed for Topology Management which are based on the first two points or the third point i.e., switching between active (transmit, receive or idle) to the transmission power. They are:

Power On-off scheduling algorithms

Power scheduling algorithms.

In on-off management scheme, few nodes are having more power, which are called as cluster heads and gateways. These are selected distributively in such a way that each node in the adhoc wireless network is either cluster head or connected to cluster head. The gate way nodes are selected such that they forward packets between cluster heads. Here any node can send packets to any other node in the network through cluster heads and gateways. Thus the cluster heads and gateways form a virtual backbone to the rest of nodes. The packets destined to the nodes in the sleep mode can be buffered at its cluster head. When the node wakes up cluster head can deliver the packets to the node. The cluster node and gateway nodes are always in awake mode. Some proposed on-off scheduling topology management schemes are Span^[9] and TMPO (Topology Management by Priority Ordering)^[10].

In the power scheduling topology management schemes, each node adjusts its transmission power in such a way that it has few neighbors. In this topology management scheme all nodes take part in the routing, it is called as 'flat topology management scheme'. Few power scheduling topology management schemes are CBTM (Cone Based distributed Topology Management)^[11] and K-Neigh Protocol for symmetric topology control^[12].

The proposed topology management is power on-off scheduling scheme.

MARI TOPOLOGY MANAGEMENT SCHEME

This topology management scheme runs above the MAC layer and interacts with the routing protocol. If a

node has been asleep for a while, the packets destined for it are not lost but are buffered at a neighboring MIRA node. When the node awakens, it can retrieve these packets from the buffering MIRA node. This scheme makes the routing simple, with minimum number of entries as only those entries in a node's routing Table that correspond to currently active MIRA nodes can be used as valid next-hops.

Definition1: MARI nodes are the nodes such that all non-MARI nodes are connected to any one of the MIRA node and route packets for any other nodes with the help of Mobile Agents. The route consists of Source node, Corresponding MARI node, Gate way nodes and intermediate MARI and Gateway nodes and destination node.

Definition 2: Sleep cycle period is the time period during which member nodes remain in the power efficient sleep mode and wake up once in fixed time duration in one beacon period.^[4,5]

We assume that each node periodically broadcasts a small packet "HELLO" message, which contains:

Node id, Status (whether the node is MARI node, gateway, member or undecided), its current power level, its current MARI node, a wakeup counter etc.,

Based on the HELLO message received from the neighbors, each node constructs a Table which contains the list of its neighbors, their MARI nodes, power level, wakeup counter and the information about their neighbors. A node switches form time to time between being a MARI node and being a member. A node becomes a gateway, if its MARI node chooses it as a gateway to route the packets between MARI nodes. A node is said to be kept in the undecided state, if it loses the connectivity with its MARI nodes due to mobility.

MARI Placement: MARI nodes along with gateways confirm a path in the virtual backbone, which is used for routing and there is demands for additional power for transmission, reception and processing of packets. Thus the MARI nodes should be selected in such a way that they have enough/higher power level.

Algorithm for MARI node placement is given in Algorithm1.

Algorithm-1: MARI node placement (this algorithm is executed by all undecided nodes)

- MAXPOWER = P(node power)
- for each one hop neighbor node N_i (undecided node)do
- if status of node N_i is MARI then

- Mystatus = member node
- My NARI node = N_i
- else
- if power of $N_i > \text{MAXPOWER}$ then
- MAXPOWER = power of N_i
- end if
- end if
- end for
- if Mystatus = undecided AND
- if Mypower = MAXPOWER then
- Mystatus = MARI node
- send HELLO packet.
- end if

Undecided nodes periodically checks if it has a maximum power level among its node hop neighbors which have not joined to any MARI node (i.e., undecided neighbors). If a node has a maximum power level among such one hop neighbors, it becomes a MARI node and declares itself as a MARI node in the status field of next HELLO message and communicate to all its neighbors.

In the undecided node knows that its neighbor node has become MARI node from received HELLO message, it changes its status as a member. It declares its status as a member and current MARI node in its next HELLO packet.

If more than one neighbor of the undecided node becomes MARI nodes, then the undecided node select its MARI node from which it has receives HELLO packet first.

There may be undecided nodes whose one hop neighbors with power level more than the undecided node chose to join MARI nodes, as the MARI nodes have more power level than its one hop neighbors. Such undecided nodes with maximum power level among one hop undecided neighbors declares themselves as MARI nodes in the next HELLO message.

A MARI node prepares a list of its member nodes, which are joined to the MARI node, form the broadcast of HELLO messages received from one hop neighbors.

This information in the Table is periodically changes as a new HELLO packet is received.

MARI NODE WITHDRAWAL

The MARI node will drain its energy more rapidly, as compared to member nodes. Before the MARI node loses its major part of its power, the responsibilities of the MARI node should be transferred to other node with sufficient power level. The concept is:

When a MARI node observe that its power is gone below a threshold, it will withdraw its status of MARI

node. The withdrawal of MARI node is declared to its all member nodes in the next HELLO message as an undecided node. Generally the threshold will be set to 80% of power level when the node decided to become a MARI node.

When a gate way or member node comes to know that it can not contact its MARI node, it changes its status to undecided and starts MARI node placement procedure.

The Fig .2 shows an example of a Topology formed with MARI nodes, gateway nodes and member nodes are indicated by O, Δ and * respectively.

Gateway node selection: The maximum number of hops between any two close MARI nodes is two; hence gateways are required and are used to forward the packets between the MARI nodes. The gateway nodes must have sufficient amount of power, to transmit and receive the packets to and from the MARI nodes. The algorithm for selection of gateway nodes is given Algorithm-2.

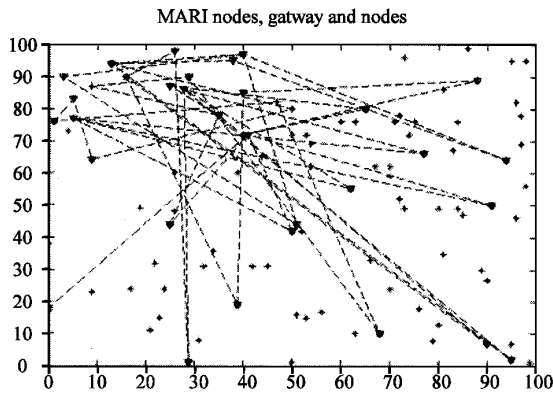


Fig. 2: Sample of 100 nodes with MARI, Gateways and member nodes (shown with O, Δ and * symbols, respectively)

Algorithm-2: Gateway selection algorithm (executed by MARI nodes periodically)

- Transmit broadcast packet STAY-AWAKE
- Wait for one beacon period
- for each MARI node M_i within two hops do
- if M_i has not decided gateway for this MARI node then
- if M_i is not neighbor of my existing gateways then
- M_i gateway = mymember which has maximum power among neighbors of M_i
- else
- M_i gateway = myexisting gateway
- end if

- else
- M_i gateway = gateway of M_i for this node
- end if.
- end for.

To determine the gateways, MARI nodes need information in its two hop neighborhood. This information is obtained from the HELLO packets; it has received from its one hop neighbor. But as the members of different MARI nodes are not synchronized, they may miss the HELLO packets from members of different MARI nodes.

MARI node periodically sends broadcast request packet STAY_AWAKE to its members to put them in awake mode for at least one beacon period.

MARI node finds out all the MARI nodes within two hops and MARI node selects its member as a gateway which has maximum power level, for each MARI node within two hops. Generally the gateway is taken such that it has more number of neighbors to ensure less number of gateways.

The MARI node determines the validity of the gateway node i.e., power level periodically, if the power level is below the threshold level the MARI node starts the selection procedure for new gateway.

Routing over the virtual backbone: For simplification, in this study we have not given the Scheduling of the sleepy cycle. We have designed a mobile agent based routing protocol to measure the effectiveness of the topology management scheme. It is an on demand routing protocol. This routing protocol is executed only on MARI nodes. The gateway forwards the packets by using NEXT-HOP-DESTINATION fields.

The routing algorithm is given in Algorithm-3

Algorithm-3: Sleep cycle scheduling (executed by all member nodes for each beacon period):

- Transmit HELLO packet at appropriate time in (T, T_1)
- for each sleep cycle period (T_m, T_{m+1}) , $m=1 \dots n$ do
- if there are no packets to transmit then
- Go to sleep mode until time t_{im} .
- Remain in wake until time $t_{im} + \hat{\delta}$
- if packet received at time in $(t_{im}, t_{im} + \hat{\delta})$ then
- Remain in wake up mode until time $t_{im} + \hat{\delta}$
- end if
- if $time < T_{m+1} - \hat{\delta}$ then
- go to sleep mode until time T_{m+1}
- end if
- else
- Transmit the packet(s) at appropriate time(s)
- if $t_{im} - \hat{\delta} < time < t_{im}$ then
- Remain in wake up mode until time $t_{im} + \hat{\delta}$
- end if

- if time < $t_{m+} + \delta$ then
- Remain in wake up mode until time $t_{m+} + \delta$
- end if
- end if
- if time < $T_{m+} - \delta$ then
- go to sleep mode until time T_{m+}
- end if
- end if
- end for

Each member or gateway node S , which needs route to destination D , sends a request for route to its MARI node M_s .

The MARI node M_s checks, if the destination D is its neighbor, if not, then it sends Mobile agent to another MARI nodes with in two hops through gateways. This will forward by all the MARI nodes until the destination node will be the neighbor of the any one MARI node M_d

If the destination D accepts the route request, it acknowledges to MARI node M_d . The MARI node M_d waits for time T_w for mobile agents coming from various paths. After time T_w , MARI node M_d selects the path over which accumulated congestion matrix and the path information is received from forward mobile agents. The congestion matrix is :

$$f_m = \alpha f_m T + (1-\alpha) f_m \tag{1}$$

Where f_m is fraction time channel is free during past T seconds and α is weighing factor in (0,1).

Reverse mobile agent follows the path which was followed by the forward mobile agents.

The reverse mobile agent updates the routing Table of the MARI node along the path. When reverse mobile agent reaches the MARI node M_s , it updates the routing Table and informs node S about path establishment. Now node S can send packets over the established path.

SIMULATION MODEL

To evaluate the topology management scheme, we simulate 100-node network in a square region. Each node use a band width of 2Mbps and each time twenty nodes send and receive traffic. Each of these nodes sends CBR traffic to another node.

RESULTS AND DISCUSSIONS

To measure the effectiveness of the topology management scheme, we simulated with on demand Fig. 3: Average delay for CBR traffic routing, several static and mobile topologies.

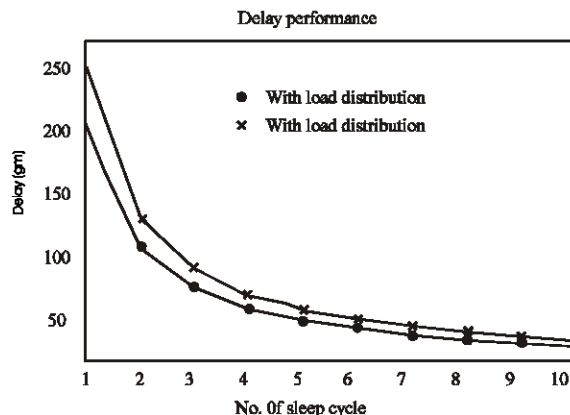


Fig 3: Average delay for CBR traffic

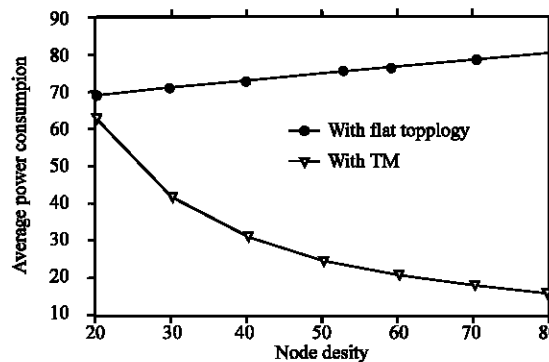


Fig. 4: Average power consumption with respect to increase in node density

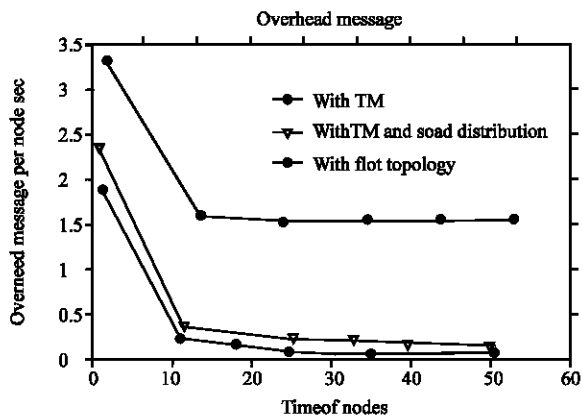


Fig. 5: Overhead messages per node

Delay performance: The Fig. 3 shows the average delay as the number of sleep cycles in a beacon period are increased. This delay was observed for packets of constant bit rate.

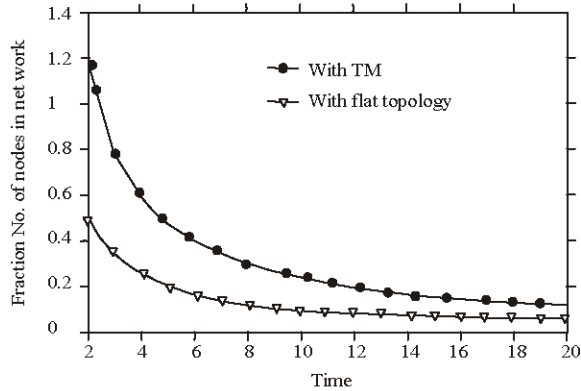


Fig. 6: Node lifetime

Power consumption: The Fig. 4 shows the average power consumption as node density increases. It can be noticed that, as node density increases, average power consumption per node is much less in topology management scheme as compared to flat topology network.

Over head: The Fig. 5 shows the comparison over head messages of MARI scheme with and out load distribution and flat topology. The amount of overhead messages per node per second decreases as the No. of nodes increased. It can also observe that the overhead message is less in the proposed topology as compared to the flat topology.

Node Life Time: The Fig.6 shows the fraction of nodes remaining in the network as a function of simulation time. Initially we have considered a random amount of power of 100 mW to 200 mW. If the power of a node is below 25mW we marked as dead. From Fig. it is clear that the life time of node is increased nearly by a factor of 2 as compared with the flat topology.

CONCLUSION

The proposed topology management scheme is applied to the limited number of nodes and we extend to any number also. In this method we have obtained improved QOS of an adhoc network in terms of Power consumption, Average delay, node overhead and node life time etc.. The future extension work on this can be done by considering shortest path routing in metric of power and also consider the grudge nodes in routing.

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