Published in the Proceedings of the Twelfth International Conference on Information Technology, December 21-24, 2009, Pages 223-226

# Energy efficiency in Wireless Ad Hoc Network using Clustering

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**ABSTRACT**

Wireless networking has witnessed an explosion of interest from consumers in recent years for its applications in mobile and personal communication. Energy efficiency is also an important design consideration due to the limited battery life of wireless node. In order to maximize the network life time and to minimize energy consumption, instead of routing through shortest path we propose routing through alternate paths. Along with that when traversing in one path, other nodes of network will be switched off in order to reduce energy consumption. For efficient sleep and active node mechanism we divide the entire network into clusters. In this paper we propose the method of using clustering along with that the probabilistic approach to find the number of active and sleep nodes at a particular time. We consider the network in terms of queuing network and consider the packets arrival rate in terms of poisson distribution.

## Keywords

Queuing theory, poisson distribution, probability, clustering, wireless ad hoc network

## 1. INTRODUCTION

Wireless networks are based on the IEEE 802.11 standards and become increasingly popular in the computing industry. Ad hoc networks are dynamically formed, infrastructure-less, wireless multi-hop networks. They can be deployed anywhere without the need for any fixed infrastructure like base stations. The node configures them to form a network. A group of nodes are deployed where fast network establishment is needed. The nodes configure themselves dynamically to establish network connectivity. The packet is transferred from source to destination in multi-hops through intermediate nodes. Intermediate node act as host and router and take part in route establishment. These networks are typically deployed where there is no infrastructure available or reliable, and fast network establishment and self-reconfiguration are required. The nodes can be deployed in a large scale to establish network dynamically. These networks can withstand harsh environmental condition [1]. For example, soldiers in a battlefield can have handsets to communicate with each other, or in emergency situations like earthquakes where the existing infrastructure has been destroyed, an ad hoc network can instantly be deployed to aid in disaster recovery, meetings or conventions in which persons wish to quickly share information, and data acquisition operations in inhospitable terrains. In order to facilitate communication within the network a routing protocol is used to discover routes between nodes. The primary goal of such ad hoc network routing protocol is correct and efficient route establishment between a pair of nodes so that packets can be delivered in a timely manner [2]. Along with that energy efficiency is a critical issue in ad hoc network for longer network connectivity.

Energy conservation is an important issue in ad hoc network as each node is battery operated. Since battery power is limited and the progress of battery technology is very slow with capacity expected to make little improvement in the near future. Therefore energy is a critical issue in wireless ad hoc network. It also effects the network lifetime. In ad hoc network each node acts as a host and/or router. The energy is consumed in two phase as shown in equation (1), the energy used in path discovery and amount of energy used in packet transmission.

$$E_{total} = E_{path\text{-}discovery} + E_{packet\text{-}transmission} \quad (1)$$

$$E_{path\text{-}discovery} \propto control\text{-}packets$$

During packet transmission procedure a typical mobile node may exist in 4 modes: (a) idle, (b) active, (c) sleep, and (d) transient.

$$E_{packet\text{-}transmission} = E_{idle} + E_{active} + E_{sleep} + E_{transient} \quad (2)$$

$$E_{active} = E_{recv} + E_{transmit} \;\&\; E_{sleep} \simeq 0 \quad (3)$$

In transmit mode a mobile unit uses its maximum power level to transfer packet to another node, wherever in idle mode a node has nothing to do. Still least amount of energy is consumed as it is in idle mode. The sources of power consumption, with regard to network operations, can be classified into two types: (a) communication related, and (b) computation related. Communication involves the cost of sending data along with control packet from source, routed through intermediate node and cost at receiving at destination end. It mainly deals with the cost of routing in network or in path establishment. Whereas computation mainly involves the cost of using CPU and main memory, disk drives and other components of computer for calculating computation related cost [2].

If we take the shortest route to deliver the message it is not the good way of energy conservation in network. As a group of node coming under the shortest path is used rapidly as compared to other nodes, so their power decreases rapidly and may a situation come that they are having no power. In that situation we refer the alternate path routing [3]. By taking alternate paths energy of a group of nodes is using at a particular instant in a respective way. By this all nodes of a network take active participation in route selection; overall energy expenditure of a network is minimized, causing maximization of network life.

The remainder of this paper is organized as follows. The basic concept of queuing theory and ad hoc networks is explained in section 2. Section 3 gives the algorithm for finding alternate path and clustering concept in our network. The probabilistic approach for finding number of sleep nodes and active nodes is given in section 4. Finally we conclude our paper in section 5.

## 2. QUEUING THEORY AND AD HOC NETWORKS

We consider our network structure as Markovian system. A Markov process, named after the Russian mathematician Andrey Markov, is a mathematical model for the random evolution of a memory less system, the property of Markov process says that future believes on present not on past. It believes in latest information.

In our network we consider the distribution of inter arrival times and the distribution of the service times are exponential distribution and thus exhibit Markov (memory less) property. In our network the packet is always transferred from source to destination, we consider our source as a server. We refer M/m/1/k queuing system.

Where M= specifies the arrival distribution, it is Markovian

m= it specifies the service time distribution, it is Markovian

The number of server is 1

k= number of packets, Packets are served in FIFO order.

Considering queue limit of node, if more number of packets passed through queue it is lost, here queue limit is k. It drops from the system and never comes back, it is called blocking. Since the number of packet in the system is limited, the arrival process is state dependent. If the number of packets < k, then the arrival rate is λ, else if number of packets > k, arrival rate is zero. Then the steady state probabilities

$$P_0 = \frac{1\text{-}\rho}{1\text{-}\rho^2} \quad (4)$$

$$P_k = P_0 \rho^k \quad (5)$$

Where $\rho = \frac{\lambda}{\mu}$ =traffic intensity and $1 \leq k \leq K$. It is interesting to note that the system is stable even for ρ > 1.

If $\rho > 1$, then $\frac{\lambda}{\mu} > 1 \Rightarrow \lambda > \mu$, queue length increases

Mean number of the packet in the system is given by

$$\bar{N} = E[N] = \sum_{k=0}^{K} kP_k = \cdots$$

$$= \begin{cases} \frac{\rho}{1-\rho} - \frac{K+1}{1-\rho^{K+1}}\rho^{K+1} & : \rho \neq 1 \\ \frac{K}{2} & : \rho = 1 \end{cases} \quad (6)$$

Mean response time is the mean time a packet spends in network, i.e. waiting time in queue and being serviced. By putting little's formula

$$\bar{T} = \frac{\bar{N}}{\lambda}$$

The loss probability is simply the probability that an arriving packet finds the system is full, i.e. the loss probability is given as $P_k$ with

$$P_{Loss} = P_K = \begin{cases} \frac{\rho^k - \rho^{K+1}}{1-\rho^{K+1}} & : \rho \neq 1 \\ \frac{1}{K+1} & : \rho = 1 \end{cases} \quad (7)$$

So if the packets number will be greater than the limit of the queue it will be dropped from the node. For efficient routing in order to lessen the number of packets loss we suggest that the packet to be delivered in alternate paths instead of shortest path. So initially the numbers of all possible alternate paths are to be calculated. Then while packets travelling through a particular path the nodes of other paths to be switched off if they are not doing any useful work in order to minimize energy consumption. The algorithm describing this alternate path finding procedure is given in section 3.

## 3. ALGORITHM FOR FINDING ALTERNATE PATH AND CLUSTERING

In this section we propose our algorithm to find out alternate paths in a network to maximize network life if direct path between source and destination does not exist [4] [5]. Initially the nodes are deployed in an area to establish network connectivity. Then we go for alternate path finding procedure, by running this algorithm in a network we keep track of all alternative paths which does not contain any duplicate nodes. By taking the alternate paths traffic load is shared and congested paths are avoided which may cause in retransmission due to collision. Since no node is duplicated, all nodes take in active participation in route selection. No node is penalized more as compare to other nodes in network. So there is no network partition which causes maximization of network life [6] [7]. Before going to the algorithm find out list of neighbor's of all nodes. For evaluation of algorithm a priority queue is considered. Considering that the front node of a queue has to be processed first as it has highest priority than other.

Algorithm for alternate path ():

1. Initialize all nodes of network to ready state from switch off state at time of deployment of network.
2. Put the source node in queue.
3. Repeat step 4 until queue is empty.
4. Process front nodes of queue by adding its neighbor's to queue along with that keep track of their parent node. Don't add repeated nodes to queue.
5. End of step 3.
6. As destination is reached stop and find the path traversing from destination in a reverse order by tracking the origin till source node at origin is reached. Then switch off all nodes coming in the path for finding another path without any duplicate node.
7. Go to step 4 and process to front node.
8. Exit.

After we get a list of alternate routes in network, we go for clustering the network [8]. We divide the network level wise. Each level is forming a cluster. Each cluster is assigned with a cluster head. A node is selected as a cluster head having more battery energy which can communicate to its neighbor in one hop distance [9] [10]. The lower level of network which is nearer to the source node keeps track of all alternate paths. All the cluster heads which are formed in a network can exchange their messages in between them at any point of time by broadcasting messages in between the cluster heads. The cluster head in each cluster broadcasts the control message to all its nodes. This control message contains the information about node ID, and residual energy. When packet starts transferring in one path, the cluster head of initial level make the node taking part in route selection as active and make other nodes to be in sleep mode. It broadcasts the message to all the cluster heads. All the cluster head make the node in that path active and other to be in sleep mode. When the next packet starts traversing it transfer through another path. Then the cluster head positively play their role to make the node falling in that path to active and other nodes of the cluster to be sleep mode. Using this when packets transferring in a particular path, the nodes of that path are in active state where all other nodes of a network are in sleep mode. So by this overall energy consumption of whole network is lessening. At any point of time if cluster head is not having required amount of energy it can elect the node with huge resource as cluster head and same with the other nodes of the network in order to maintain network connectivity. Section 4 gives the probabilistic approach of finding the number of sleep node and active node.

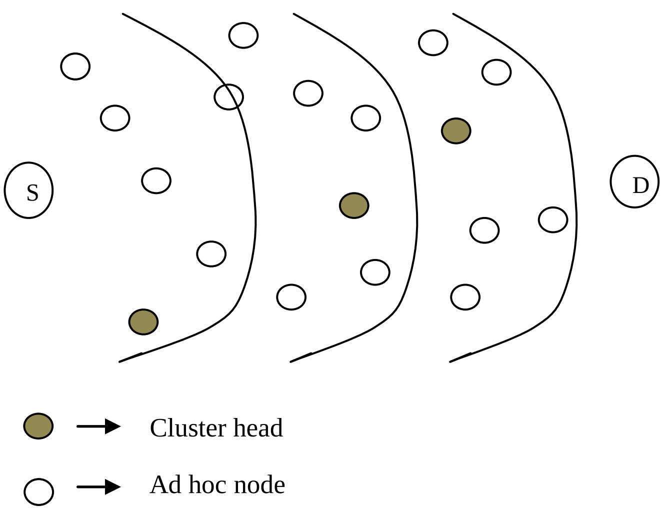


**Figure 1**: Clusters in wireless ad hoc network

## 4. THE PROBABILISTIC APPROACH

To find out the number of nodes to be active and the number of nodes to be in sleep node, we take the following probabilistic approach.

Let N= total number of nodes

X= number of active nodes

Y= number of nodes in sleep mode

Now the joint probability of ‘x’ nodes among the total nodes active and ‘y’ nodes among total nodes in sleep mode.

The packet arrival distribution rate with Poisson’s distribution= λ

Probability of a node being active= P

Probability of a node being in sleep mode= 1-P

For the discrete random variable, the joint probability mass function

$$P\{X = x \text{ and } Y = y\} = P\{Y = y|X = x\} * P\{X = x\} = P\{X = x|Y = y\} * P\{Y = y\} \quad (8)$$

Since these are probabilities we have

$$\sum_x \sum_y P\{X = x \text{ and } Y = y\} = 1$$

For discrete random variable since X and Y are independent

$$P\{X = x \text{ and } Y = y\} = P\{X = x\} * \{Y = y\} \quad \forall\, x, y \quad (9)$$

For finding the value of P$\{X = x\}$ and P{Y=y} first consider from calculus $\lim_{n\to\infty}\left(1 - \frac{\lambda}{n}\right) = e^{-\lambda}$

From the definition of Binomial distribution

$$P\{X = x\} = \binom{n}{x} p^k 1 - p^{n-x} \quad (10)$$

If the binomial probability is defined as follows p $= \frac{\lambda}{n}$, we evaluate the limits of p as n goes larger.

$$\lim_{n\to\infty} P\{X = x\} = \lim_{n\to\infty} \binom{n}{x} p^x 1 - p^{n-x}$$

$$= \lim_{n\to\infty} \frac{n!}{(n-x)!*x!}\left(\frac{\lambda}{n}\right)^x \left(1 - \frac{\lambda}{n}\right)^{n-x}$$

$$= \lim_{n\to\infty} \frac{n!}{(n-x)!*n^x}\left(\frac{\lambda^x}{x!}\right)\left(1 - \frac{\lambda}{n}\right)^x \left(1 - \frac{\lambda}{n}\right)^{-x}$$

$$= \text{F}\,\frac{\lambda^k}{k!} e^{-\lambda} \quad (11)$$

The F term can be written as

$$\text{F}=\frac{n\,(n-1)\ldots(n-x+1)}{n^x}$$

Since x is fixed, this is a rational function of n with limit 1. So the limit of the distribution becomes

$$P\{X = x\} = \frac{\lambda^x e^{-\lambda}}{x!} \quad (12)$$

which assumes Poisson’s distribution.

More generally, whenever a sequence of independent binomial random variables with parameters n and $P_n$ is such that $\lim_{n\to\infty} n\, P_n$=λ, the sequence converges in distribution to a Poission random variable with mean λ.

So now equation (9) becomes

$$P\{X = x \text{ and } Y = y\} = P\{X = x\} * \{Y = y\} = \frac{\lambda^x e^{-\lambda}}{x!}\ \frac{\lambda^y e^{-\lambda}}{y!} \quad (13)$$

It shows the probability of x number of nodes in active state and y number of nodes in sleep state. By putting the value of probability to 1 and specifying the rate of arrival λ we find the ratio of number of active nodes and sleep nodes, which effectively measure the energy consumption rate. As by the node going into sleep state it consume less energy, therefore as the number of nodes not doing any useful work in the system going into sleep state, then the energy conservation will increase, which enhance our system performance. It will help to maximize network lifetime.

## 5. CONCLUSIONS

In this paper we give a very brief study about queuing theory. By using the alternate path and clustering technique we try minimize energy consumption of overall network. As all nodes are battery operated, and battery power is finite we go for efficient use of this in order to minimize energy consumption and maximize network life. By making some of nodes to sleep mode we try to minimize energy consumption in network. To calculate the number of active nodes and sleep nodes in network we are using the probabilistic approach. Our future work includes to make an energy efficient protocol for wireless ad hoc network and to study its simulated behavior using Qualnet simulator.

## 6. ACKNOWLEDGMENT

This research is supported by project grant Vide No: 13(1)2008-CC&BT of Ministry of Communication & Information Technology, Dept of IT, Government of India, titled " Energy Aware Protocol for Wireless Networks" and being carried out at department of Computer Science and Engineering, NIT Rourkela

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